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Fukushima and the Lessons of History: Remarks on the Past and Future of Nuclear Power

> *Hegel remarks somewhere that all facts and personages of great importance in world history occur, as it were, twice. He forgot to add: the first time as tragedy, the second time as farce.*
>
> Karl Marx, *The 18th Brumaire of Louis Bonaparte*[1]

In this essay, I rush in where angels fear to tread, into the business of "history in the making." It has become common sport to underscore the importance of current events by labeling them "historic," and Japan's nuclear disaster was no exception. Within hours of the first explosion at the Fukushima Daiichi nuclear complex, the German weekly *Der Spiegel* proclaimed "the end of the nuclear age" on its front page.[2] As it happened, the magazine was on the mark for Germany, where Fukushima became the nail in the coffin of nuclear power: the governing center-right coalition abandoned a decades-old pro-nuclear stance, even rescinding a controversial law that was only a few months old. Other European countries are tilting in that direction. In a referendum, Italy reaffirmed a previous decision to abstain from nuclear power, while Belgium and Switzerland are considering exit plans. However, most countries in the world remain indecisive; one year after Fukushima, the meaning of Japan's nuclear disaster is still open and contested. Even in the German context, the importance of Fukushima is more complicated than one might think.

Nonetheless, this essay aims for more than an exercise in speculation. It consists of two parts. The first gives a brief summary of the development of nuclear power in Germany, arguing that the decision of 2011 was the final step in a long farewell. This part also offers some perspectives on other countries, as Germany's trajectory is in many respects typical of developments elsewhere in the West. The second part builds on this discus-

I wish to thank the Hiroshima Peace Institute for inviting me to its conference in November, 2011, where an earlier version of this paper was presented. That version is due to be published in Japanese. I also thank the Carson Center fellows who attended the work-in-progress session on 5 October 2011, and particularly Bao Maohong, who translated the article into Chinese.

1 Karl Marx, *The Eighteenth Brumaire of Louis Bonaparte*, Original (1852; repr., New York: International Publishers, 2008).
2 Cover, *Der Spiegel* 11 (2011).

sion, assessing the methodological arsenal of the historical profession in order to shed light on future developments. Approaches from the history of science and technology play a prominent role in this endeavor, making it something of an empirical response to Markus Vogt's ethical account, also appearing in this issue. After all, nuclear power is one of those large technological systems that scholars have long recognized as a crucial feature of modern history. What can we learn when we conceive nuclear energy as a piece of technology rather than an ethical challenge?

One should stress from the outset that a technological system as defined in this essay is more than an artifact. It is now common within the history of technology to see technological systems as characterized by a complex interaction of human beings and technological artifacts. In the case of nuclear energy, the technological system includes not only reactors and other complex machines but also the scientists and engineers who design and operate them, the managers who build them, and the politicians who support them. In fact, one could go even further to include consumers as well, since assumptions about future consumption played a key role in nuclear development. At any rate, technological systems are more than cold steel and wires, a fact that highlights the importance of merging ethical and historical perspectives. Reactors do not have morals. But technological systems do.

I. Towards a Mythology of Nuclear Power

On 30 June 2011, the German parliament voted to close the last reactor within the country by 2022. Of the 600 votes cast, 513 were in favor, with most of the negative votes coming from the Leftist Party (*Linkspartei*); the Green Party delivered 61 votes in favor with six abstentions.[3] With that, the law became the first nuclear policy statement in a generation to win support across the political spectrum. The preceding months had seen a dramatic conversion within the governing coalition, which had reaffirmed its stance in favor of nuclear power only a few months earlier. In spite of vigorous protests, the government had extended the operating life of existing reactors in the fall of 2010, thus revising the previous phaseout decision of 2000. As German chancellor Angela Merkel declared in a speech in parliament, "The dramatic events in

3 "Gesetzentwurf CDU/CSU, FDP auf Drucksache 17/6070," Deutsche Bundestag [German Federal Parliament] *www.bundestag.de* (Berlin: 30 June 2011), http://www.bundestag.de/bundestag/plenum/abstimmung/20110630_17_6070.pdf.

Japan are a watershed for the world, and a watershed for me personally."[4] For a generation used to seeing the political right as pro-nuclear and the left as anti-nuclear, it was as if the pope had turned Muslim.

Dramatic conversions have a tendency to turn into myths. Counting on the amnesia of the general public, some spin doctors suggested that Christian Democrats, despite their extension of reactor licenses the year before, were merely closing loopholes in the 2000 phaseout agreement. A more noteworthy reading stressed the role of Angela Merkel, who reacted with a firmness that she has frequently shunned on other issues. At any rate, the stories told after Fukushima were notably short on context, and that makes it all the more important to recount the history of nuclear power in Germany and beyond. Nuclear technology is arguably complicated and difficult to understand, but its history, if told in an adequate fashion, is anything but a dry topic. It is a history of unexpected results; one might even call it ironic if the outcome had not been so tragic. Most crucially in the present context, it is a history that dispels the notion that Fukushima put an end to nuclear energy in Germany. As we shall see, the nuclear complex had been in decline for more than three decades.

However, myth production is also underway in the anti-nuclear camp. Fukushima underscored the movement's contention about the inherent risks of nuclear power. For those who have read Charles Perrow's discussion of "normal accidents," Japan's nuclear disaster unfolded in an unsettlingly familiar fashion.[5] And yet it would be shortsighted to attribute the demise of nuclear power simply to its inherent risks and a persistent civic movement that highlighted them. For all the importance of civic protests, they might have been futile if they had not joined doubts within the nuclear community, where the case for nuclear power became weaker and weaker until it was essentially a problem in search of a solution. The key to success was a combination of external pressure and internal doubt that made abandoning nuclear power the path of least resistance.

What all this comes down to is that the German decision of 2011 was not simply due to a sudden shock. To be sure, the weeks after 11 March were terrifying indeed, and not only for those who were living in northern Japan. It is also quite clear that Merkel would not

4 "Die Atomkanzlerin erklärt ihren Ausstieg," *Süddeutsche.de*, 9 June 2011, http://www.sueddeutsche.de/politik/regierungserklaerung-zur-energiewende-merkel-erklaert-den-atomausstieg-zur-herkulesaufgabe-1.1106773.

5 Perrow's approach to technological accidents is discussed more extensively toward the end of this article.

have reversed her pro-nuclear stance without Fukushima. Yet the disaster was ultimately more of an accelerator: at its core, the phaseout decision of 2011 was due to a coming-together of long-range trends and the wisdom of the moment. Fukushima may be slowly disappearing from the news but its significance endures and may actually grow over time. After all, there has been talk about a "renaissance" of nuclear power for several years now, propelled by the threat of global warning. Finland is building the first new reactor in a generation, and some countries are drafting plans for new building programs.

To the historian, all this sounds quite familiar. After all, that is how the first atomic age got started: high hopes based on very limited construction programs. However, even before Fukushima, the second atomic age looked timid in comparison to the first—a farce on the heels of a tragedy. Now that the presumably improbable disaster has happened, the case for nuclear power looks more dismal than ever. With that, the German decision has by no means the hallmarks of a unique path. Quite the contrary, it may be merely the prelude to what historians may one day see as a crucial turning point.

II. A Tale About Energy Planning: Nuclear Power in Germany

Like most countries, Germany built its current reactors between the late 1960s and the early 1980s. After a number of experimental projects, construction of the first commercial reactors started in 1967. The construction of commercial-scale reactors was initially not a divisive political issue, as it seemed like common sense. Since the 1950s, the government had invested a lot of money into nuclear development, most notably into two new research centers in Karlsruhe and Jülich. Like many Western countries, Germany saw nuclear technology as a key area of science-based progress—a modern, world-class nation just had to master the peaceful atom. In the German context, embracing nuclear power seemed even more important as it provided an opportunity to regain world-class status in science after the terrible demise of academic prestige due to the reign of the Nazis. In any case, politicians from the left and the right were unanimous that West Germany needed nuclear reactors. When the oil crisis of 1973 made energy a hot topic all over the West, political and business leaders felt that they were on the right course.[6]

6 Even after more than three decades, the defining study on German nuclear development remains Joachim Radkau, *Aufstieg und Krise der deutschen Atomwirtschaft 1945-1975: Verdrängte Alternativen in der Kerntechnik und der Ursprung der nuklearen Kontroverse* (Reinbek bei Hamburg: Rowohlt, 1983).

It is important to recognize that when research began in the 1950s, it was by no means clear what type of technology would emerge. Nuclear energy was supposed to have many different uses: nuclear ships, locomotives, even airplanes were on the drawing board. The large power stations of today were essentially the result of a long process of narrowing down the range of technological options; even with nuclear power stations, the original idea was notably different from the ultimate outcome. In the 1950s and 1960s, nuclear experts conceived reactors for electric power generation as merely one component of a nuclear system that also included breeder reactors and reprocessing plants. Since breeder reactors were supposed to produce more fissile material than they use, experts were aiming for a technological system that could sustain itself indefinitely. It is hard to understand the allure of nuclear energy without the endless fuel cycle, as it promised a permanent solution to energy woes—a technological utopia tantamount to perpetual motion.

Nuclear technology was new, but that did not mean that there were no pre-existing traditions. In the field of nuclear technology, military use preceded civil use, and that framed the choice of reactor types to an extent that one might speak of predetermination. Since 1955, the submarine USS *Nautilus* was underway with nuclear power, giving a head start to light water reactors. Even France decided to abandon its own gas-graphite program in 1969 and bought American light water technology.[7] However, submarines had peculiar technological requirements, most prominently a preference for compact designs that led to the use of enriched fuels. That also met with another military interest, as fuel enrichment was an existing technology: it was needed for building bombs, and that meant that civil use of enriched fuels was a great way to write down the costs of the nuclear arms race. The drawback was that reactors contained far more fissile material than necessary. That was great for submarines, which were supposed to stay ashore for months, but it implied a dangerous concentration of hazardous material in large power stations.

With that, nuclear reactors became a showcase for the difference between military and civilian technology. As a military technology, light water reactors were not built according to a "safety first" principle, and it is not at all certain that this reactor type would have been chosen if safety had been the overriding concern. Unlike other reactor types,

7 Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity after World War II* (Cambridge, MA: MIT Press, 1998), 297.

water-moderated reactors need emergency cooling systems to forestall a meltdown. At Fukushima, it was the failure of cooling systems in the wake of the 11 March earthquake that was the decisive reason for the disaster. Other reactor types would have shut down automatically.

However, the inherent risks of light water reactors were not plain from the outset. David Okrent, a member of the US Advisory Committee on Reactor Safeguards, noted that "a revolution in LWR [light water reactor] safety occurred in 1966," when the threat of nuclear meltdown with subsequent damage to containment, later known as the "China Syndrome," became recognized.[8] However, the timing could not have been worse: as building programs were gathering momentum, there was no opportunity to pause for a moment and consider alternatives to light water reactors. The best option was to add safety measures, but multiple emergency cooling systems did not assuage the fears of more conservative experts. After all, emergency cooling systems were tricky devices: they were on stand-by most of the time, but they had to operate perfectly in case of an incident. In short, the risks of light water reactors were a contested topic within expert circles long before they were making headlines in the mass media.

Nuclear reactors were also controversial for other reasons. Initially, the greatest resistance came from electric power companies who were supposed to build and operate them. From their point of view, it was good business to proceed cautiously: reactors were expensive, the technology was complicated, and the overall economics was by no means certain. Furthermore, utilities had other sources of electricity that had their own lobbies. Within the utility giant RWE, for example, a powerful lobby was plotting against nuclear power because it competed with the company's brown coal branch.[9] It took massive pressure from the government to strong-arm utilities into the new technology.

Opposition also came from the communities where reactors were supposed to be built. Wherever plans were drafted, planners had to cope with skepticism and open protest. Protest was first and foremost local: people were skeptical of the changes that a nuclear power plant would bring to their hometowns. Most reactors were planned for sparsely populated rural areas, where they appeared as harbingers of industrial transformation.

8 David Okrent, *Nuclear Reactor Safety: On the History of the Regulatory Process* (Madison: University of Wisconsin Press, 1981), 296.

9 Joachim Radkau, "Das RWE zwischen Braunkohle und Atomeuphorie 1945–1968", in *RWE—ein Konzern wird transparent "der gläserne Riese"*, ed. Dieter Schweer (Wiesbaden: Gabler, 1998), 173–96.

In other words, people were skeptical even before they learned about the dangers of nuclear power: they realized without knowing too much about nuclear technology that these power plants would change their way of life. In the southwest German town of Wyhl, winegrowers feared that the steam from the large cooling towers would change the local climate.

Of course, nuclear power plants also implied the promise of jobs. However, local people were realistic: they realized that most of these jobs would go to people from outside—locals simply did not have the necessary skills. The one important attraction was money, as German companies pay a hefty tax to the municipality where they are situated. As a result, towns and villages with a nuclear power plant were usually flush with money, but even that attraction has lost much of its charm nowadays. The tax shrinks dramatically when a reactor goes out of service. Therefore, nuclear municipalities have learned, at times painfully, that the expansion of the tax base is temporary.

Thus, the movement against nuclear power was initially a local movement, borne out of a wide array of concerns. Nuclear hazards emerged as the key issue as locals became educated about the risks of nuclear technology. The anti-nuclear movement developed a tremendous expertise of its own, with numerous people willing to understand the complex technology and its inherent dangers. As the movement grew, protesters learned more and more about technological hazards, licensing systems, political connections, and effective modes of protest. But important as knowledge was and is for effective protest, it was crucial that this knowledge did not remain aloof. The movement remained rooted in regional campaigns, each of which would deserve a discussion of its own: Wyhl, Brokdorf, Gorleben, Kalkar, Wackersdorf.[10]

Over time, local protests won powerful allies within the political system, bringing permanence to a movement that was, like all social movements, inherently unstable. After all, nuclear power is not a very interesting topic by itself: it is complicated and brings dissenters up against powerful and well-funded opponents. Therefore, it was very important that the German anti-nuclear movement found friends in politics. Most crucially, nuclear energy has been a defining issue of the Green Party since its foundation in 1980.

10 Scholarly treatment of these regional campaigns is notoriously uneven. The lion's share of attention went to one of them, Wyhl, which even became an entry in the popular anthology of German *lieux de mémoire*. See Bernd-A. Rusinek, "Wyhl", in *Deutsche Erinnerungsorte*: II, ed. Étienne François and Hagen Schulze (Munich: C.H. Beck, 2001), 652–66. See also chapter II.1 of this essay.

The issue also received support within the Social Democratic Party (SPD), one of the two large parties in the Federal Republic of Germany. After the Chernobyl disaster of 1986, the Social Democrats voted to abandon nuclear power. On the other side of the political spectrum, the conservative Christian Democratic Party (CDU/CSU) and the Liberal Party (FDP) maintained their pro-nuclear stance.

As a result, the nuclear issue became entrenched in the political system: the political left was against nuclear power, and the right was in favor. That kept the issue alive politically, as nuclear power often featured prominently in election campaigns. It also meant that government policy remained staunchly pro-nuclear, as the Christian Democrats and the Liberal Party ruled the Federal Republic in a coalition government from 1982 to 1998. The protest movement nonetheless achieved some remarkable successes. Vigorous and well-informed opposition prevented the construction of a large reactor complex in Wyhl and a reprocessing plant in Gorleben. Furthermore, protest made construction of new power plants much more difficult: new reactors had to undergo complicated licensing procedures, where protesters monitored and contested each and every step. As a result, the nuclear construction program slowed down notably.

Interestingly, this was not only a victory for the protesters. The utilities also profited in an indirect way. In the 1980s, it gradually dawned on energy managers that their earlier plans had been overblown. In the early 1970s, blueprints had called for a massive expansion of generating capacity, mostly through nuclear power. A decade later, it turned out that there would not have been any need for so many reactors. The Federal Republic of Germany could easily provide enough electricity with existing power plants and did not need more of them. In short, the nuclear protesters had saved the German utilities a huge amount of money.

This was more than an irony of history. It was an important lesson in the economics of nuclear energy. Nuclear reactors are expensive to build and cheap to run. For power plants running on gas or coal, it is the other way round. In other words, building a reactor means hedging a bet on energy demands several decades into the future—a gamble with all sorts of unknowns. Energy managers thus learned that reactors could land you in economic trouble even when they operated perfectly, and the current stance of Germany's utilities looks notably cautious as a result. While they are presently grumbling about the government's change of mind, utilities have shown little interest in new reactor programs. After having the luck to come out of the first nuclear age with a profit, another gamble simply looks like bad business.

The German nuclear community had also learned something else by the 1980s: nuclear energy would not supersede conventional utilities but rather co-exist with them. That is important because the original assumption of the atomic age was that nuclear energy would make coal and other fossil fuels for electricity production obsolete. In reality, nuclear power never supplied more than 30 percent of electricity in Germany, which means that coal was always more important for German utilities than nuclear power. While power companies looked like staunch believers in nuclear energy from the viewpoint of the anti-nuclear movement, they never committed themselves unconditionally. One can only hope for the day when company archives are open to reveal internal debates.

Nuclear dreams took another blow in the late 1980s when the Kalkar breeder project and the Wackersdorf reprocessing plant project were abandoned. Despite consuming enormous amounts of money, both financially and politically, they did not become unstoppable, unlike the power plants in Brokdorf and Grohnde, which became operational in spite of heavy protest. However, nuclear planners had envisioned Kalkar and Wackersdorf as indispensable pillars for the endless fuel cycle, which meant that the decisions of the late 1980s changed the general character of the nuclear project. In short, nuclear power became simply another method of heating water.

The German decision was typical of nuclear development worldwide. Breeder projects failed miserably wherever they were started; most recently, the Japanese government slashed the budget for the Monju fast breeder reactor, which had been under repair since a major accident in 1995.[11] No country came close to maintaining an endless fuel cycle, and with that defeat went the aura that had once sustained nuclear euphoria. Gone are the dreams of atomic energy as the technology of the future, or the belief that every self-respecting modern nation should use this super-modern technology. Compared with computer technology and the life sciences, nuclear power emerged as a technology with an exceedingly narrow range of uses: it was about electricity, pure and simple. From a historical perspective, the reality of nuclear power appears a far cry from the original fantasies. By the late 1980s, West Germany had essentially

11 David Cyranoski, "Japan Freezes Fast Breeders Plan," *newsblog, nature*, 28 September 2011, http://blogs.nature.com/news/2011/09/japan_fast_breeder_freeze.html.

abandoned nuclear utopias. It was now clear that German nuclear energy would mean water-moderated reactors and nothing more.

The next step came with German reunification. The German Democratic Republic (GDR) had its own nuclear program. It maintained a large nuclear complex on the Baltic Sea near Greifswald and was building another one near Stendal. Therefore, the West German nuclear lobby saw reunification initially as an opportunity: faced with stiff local opposition in the West, it dreamed about new reactor projects in the former GDR. However, the GDR reactors were shut down during reunification, and no new reactor project ever got anywhere.[12] This outcome begged an important question: if you could not build a new nuclear reactor in East Germany, where state governments were otherwise eager to promote industrial enterprises, was there any place in Germany where one could build another reactor? Revealingly, there has been no serious proposal for a new reactor anywhere in Germany since reunification, which implies a tacit admission that the nuclear age would end in Germany. Few people dared to spell it out, as neither pro- nor anti-nuclear activists had an interest in doing so, but since the 1990s, the consensus has been that, unless something dramatic happened, Germany would become nuclear-free once the last of the existing reactors shut down.

Reunification was also important in a second respect. In September 1990, Germany signed the Two Plus Four Treaty with the United States, Great Britain, France, and the Soviet Union to clear the path for the merger of the two German states. In this treaty, Germany pledged to refrain from the manufacture of nuclear, biological, and chemical weapons. That was the endpoint of a long flirtation with the nuclear option. Of course, West Germany had never actually built a nuclear bomb, and never maintained an active weapons program. Still, there were a number of politicians who had considered nuclear bombs an option. All that ended in 1990, due both to the Two Plus Four agreement and the end of the Cold War in Europe, which rendered all ideas about a German bomb pointless. It is one of the mysteries of nuclear policy that it took until 2005 to empty the federal plutonium storage in Hanau—a leftover from the breeder project that could have provided the raw material for a bomb.[13]

12 On the GDR's nuclear history, see Mike Reichert, *Kernenergiewirtschaft in der DDR*: *Entwicklungsbedingungen, konzeptioneller Anspruch und Realisierungsgrad*, 1955–1990 (St. Katharinen: Scripta Mercaturae, 1999), and Wolfgang D. Müller, *Geschichte der Kernenergie in der DDR: Kernforschung und Kerntechnik im Schatten des Sozialismus* (Stuttgart: Schäffer-Poeschel, 2001).

13 Bundesumweltministerium [Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety], "Hanau vor dem Ende seiner Atomgeschicte," *BMU-Pressedienst* 173/04 (2004).

After 1990, protest movements shifted attention to the issue of nuclear waste. In 1995, the nuclear industry started to use a storage facility in the northern German community of Gorleben. Every single shipment of waste became subject to a huge demonstration of several thousand protesters, kept at bay by an equally large army of policemen. In contrast, demonstrations against nuclear reactors became rare, not least because many of them were operating smoothly. Concern about reactors shifted eastwards, as anti-nuclear protest focused on reactors that were remnants from Soviet times, such as Temelín in the Czech Republic, Kozloduy in Bulgaria, or Chernobyl in the Ukraine, where the last reactor was only shut down in December 2000. The disaster at Fukushima Daiichi came as a surprise to anti-nuclear protesters, too.

In 1998, a general election brought a coalition of SPD and Green Party members to power. Both parties once more made election-campaign pledges to abandon nuclear power and, after long and tense negotiations, they sealed an agreement with the nuclear lobby in 2000. The deal limited the lifespan of existing reactors to 32 years, thus fixing a date for shutdown. It attests to the vigor of anti-nuclear sentiments in Germany that this deal met with protest from anti-nuclear activists who pushed for more drastic timetables. On the other side, the nuclear lobby tried to profit from the growing debate over global warming by praising nuclear power as carbon-neutral. Before the federal election of 2009, the German Atomic Forum (*Deutsches Atomforum*) launched a media offensive to suggest that the nuclear question was still open.[14] In any case, the issue remained a political hotbed, and nuclear power played a prominent role in the federal election of 2009.

This election brought into power a new center-right government under chancellor Angela Merkel. In the fall of 2010, her coalition government enacted a new law that extended the lifespan of existing reactors by twelve years on average. Inevitably, this law met with vigorous protest. However, it was remarkable how the government sold the revision. It neither made a case for new reactors nor praised nuclear power unduly. Instead, it argued that nuclear energy was a "bridging technology"—a technology needed to bridge the time until renewable energy sources were available. That was a far cry from the utopias of the 1950s; enthusiasm for nuclear power had truly come a long way. In fact, it was hard to imagine a less enthusiastic stance from a proponent of nuclear energy. This is important for a proper understanding of the shift in government policy after Fukushima.

14 S. Heiser and M Kaul, "Die Geheimpapiere der Atomlobby," taz.de, 28 October 2011, http://www.taz.de/taz-enthuellt/!80743/.

Needless to say, the nuclear lobby was jubilant after the decision of 2010, but their victory proved to be a Pyrrhic one when this law was quashed after Fukushima. The outcome matched the long-term trajectory of the nuclear lobby; since the late 1970s, it had suffered many defeats and few gains, and the latter had a tendency to turn into strategic blunders. The Gorleben shipments provide a case in point: from a technical standpoint, the costly transfers of spent fuel into the storage facility were successful, but they ultimately did more for anti-nuclear protests than for the proper disposal of nuclear wastes. Even the debate over climate change did not bring a significant shift in public opinion. Whatever it tried, the nuclear lobby remained on the defensive. Nuclear power was a solution in search of a problem.

In sum, the decision to abandon nuclear power in Germany was not as sudden as it might appear at first glance. For several decades, the pro-nuclear camp had failed to find a convincing rationale for its cause and momentum was clearly with the opposition. Recent nuclear accidents in Forsmark (2006) and Krümel (2007) received widespread media coverage, though the most frightening incident—the 2002 reactor head hole at Davis-Besse—somehow escaped public scrutiny. Characteristically, the *Spiegel* cover of March 2011 was not the journal's first farewell to nuclear power; in 1995, an issue had announced "the atomic age is ending."[15] While Merkel's recent decision was obviously tied to an unforeseeable event in Japan, the end of nuclear power really came about gradually over many years—the final step in a long decline. In a way, Merkel chose the path of least resistance after Fukushima. Why spend much political capital to defend a technology that was bound to expire anyway?

If we look at the path of nuclear power in Germany since the 1950s, one big lesson emerges: prepare for the unexpected. No group succeeded in realizing its original intention. Engineers and physicists thought they were engineering a new human era—and they ended up building power plants with dubious profit margins. The social democrats were initially enthusiastic—and ended up as an anti-nuclear party. The center-right coalition supported nuclear power, but they drew no benefits from that stance, and actually had to revise it after Fukushima in a way that conservatives found humiliating. Plans for an energy future are obviously tricky, and the best advice that history has to offer is to allow for as much flexibility as possible.

15 Cover, *Der Spiegel* 7 (1995).

However, Germany remains in the center of Europe. In a dozen years, Germany may be nuclear-free, but it will most likely be surrounded by reactors in Great Britain, France, Belgium, Switzerland, Sweden, and the Czech Republic. The German anti-nuclear movement has been very hesitant to grapple with this fact, to a point that borders on willful denial. After the events of last year, that stance looks more dubious than ever. If things turn out badly, Germany will become a major importer of nuclear electricity from abroad. After all, nuclear power supplied 22 percent of all electricity in Germany in 2010—a significant share that will not be easy to replace.

Of course, Germany may emerge as a pioneer of renewable energy, and international attention on German energy policy is virtually guaranteed for the next few years. We already see an emerging discussion over the price of renewable energy—for instance, in conflicts over new power lines and hydroelectric projects, where the lack of proper standards for balanced decisions is painfully clear. However, one of the less obvious challenges is whether Germany can stay within the nuclear community after the decisions of last year, as the nuclear expert system is dearly in need of critical input. After all, the lifespan of existing reactors is the key issue when it comes to nuclear safety in upcoming years. Old reactors are much more prone to problems and accidents, and it is a pity that the German path now carries the air of a political decision. The technological case for a time limit on nuclear reactors was and remains strong.

What all this comes down to is that a lot hinges on how the German path will be received internationally in upcoming years. Will it come across as a political ploy or a hallmark of nuclear safety that may serve as a yardstick for other nations? The latter is more likely than one might think. After all, when we look across Europe, the prospects of nuclear power seem dim. Compared with the frenzy of the 1960s and 1970s, existing construction programs are lukewarm and timid; even the World Nuclear Association concedes that Europe is becoming a backwater for nuclear power, as "most reactors currently planned are in the Asian region."[16] Despite several decades of experience, construction projects are beset by problems, as the delays with Finland's new reactor at Olkiluoto serve to attest. Even before Fukushima, the second atomic age looked like a lukewarm follow-up, devoid of the hopes and utopias of the first. So German developments may not be so unique after all. In most European countries, the history of nuclear power is

16 "Plans for New Reactors World-Wide," World Nuclear Association, last modified February 2012, http://www.world-nuclear.org/info/inf17.html.

a history of disappointments and diminished expectations. The difference is that other countries have not yet drawn the drastic conclusion that Germany has.

After Fukushima, the prospects for nuclear power look more dismal than ever. It is likely that the disaster will spur a new interest in safety. Engineers and operators will be more cautious. They will spend even more money on safety, further reducing profits. Local authorities will be more skeptical than ever, making it more expensive to buy local support. Meanwhile, public debt is high all over the West, making it unlikely that countries will invest billions into nuclear technology. In short, the German policy differs from the rest of Europe merely in its speed and its vigor. Elsewhere in Europe, the general situation is one of indecision: nuclear energy is sputtering on, too strong to die but too weak to flourish. After Fukushima, signs are strong that, when it comes to Europe, nuclear power is heading for a long, slow, and probably painful death.

III. Writing Nuclear History after Fukushima

The history of nuclear power bears the marks of a tragedy, and yet the label leaves the historian with a sense of unease. It only takes a reference to the controversy over Hayden White's metahistory to understand the delicate nature of this kind of emplotment.[17] The second part of this essay thus seeks to highlight the methodological pillars that the first part rests upon. It does so for a double purpose: to show how these concepts can enlighten policy decisions and to rethink scholarly debates in the light of recent events. It would certainly go too far to say that we need to rewrite history after Fukushima; after all, past debates over large technological systems and their inherent risks provide much of the foundation for this article. But these debates have arguably languished in recent years, and Fukushima may be a good occasion to dust them off and reflect on opportunities and needs.

Local Roots

As the previous discussion stressed, it is important to recognize the local roots of antinuclear protests. However, it is far more difficult to discuss them in depth, as we are still lacking case studies for many sites of conflict. As it stands, Bavaria is now the only

17 Hayden V. White, *Metahistory: The Historical Imagination in Nineteenth-Century Europe* (Baltimore: Johns Hopkins University Press, 1973).

German state where we have a comprehensive overview of nuclear conflicts up to 1980;[18] elsewhere, research has been patchy. That has as much to do with the small cadre of environmental historians as with the exceeding emphasis on a single site for numerous case studies: Wyhl, in the Black Forest. Not only has the plethora of Wyhl studies provided few new insights, they have also produced a rather benign picture of the nuclear opposition. Protests in Wyhl remained peaceful, whereas places like Brokdorf and Grohnde became synonymous with violent clashes between activists and the police. The experience of violence touches people deeply, and yet we know very little about the views and debates on either side.

Case studies could also shed light on the networking of activists, particularly across national borders. As it stands, we have little more than anecdotal evidence. For instance, Joachim Radkau noted that Holger Strohm, who published the first critical compilation of nuclear facts in 1973, was heading the German branch of Friends of the Earth at that time, which provided him with access to information from the United States.[19] In a way, the anti-nuclear movement was at its most international during the early stages, as debates became entangled in national contexts from the mid-1970s. The widely divergent reactions to the Fukushima disaster mirror the extent to which our thinking about nuclear issues is framed by national traditions and customs.

Momentum and Path Dependency

It is difficult to understand the trajectory of nuclear power without an understanding of the inner dynamics that a huge network of researchers and artifacts develops over time. There was little chance to pause and reflect while atomic-age fantasies shrank to mundane reactor programs. Nuclear technology today bears the marks of these early decisions—for instance, in its penchant for light water reactors with their precarious emergency cooling systems. When it comes to the development of large technological systems, momentum and path dependencies are clearly important concepts.

Within the history of technology, the debate over technological momentum was strongly influenced by Thomas Hughes, who defined momentum as analogous to physics: "The

18 Ute Hasenöhrl, *Zivilgesellschaft und Protest: Eine Geschichte der Naturschutz- und Umweltbewegung in Bayern 1945-1980* (Göttingen: Vandenhoeck & Ruprecht, 2011).
19 Joachim Radkau, *Die Ära der Ökologie: Eine Weltgeschichte* (Bonn: Bundeszentrale für Politische Bildung, 2011), 144.

systematic interaction of men, ideas, and institutions, both technical and nontechnical, led to the development of a [sociotechnical] supersystem . . . with mass movement and direction."[20] While later studies focused on human agency, from expert mentalities to consumer habits, the concepts of momentum and path dependency remained theoretically unrefined. Even more, both concepts easily lead to tautologies: momentum fosters growth, and growth creates momentum.

In this context, we might take the Fukushima disaster as a cue that momentum depends on a wide array of supportive factors, most of which are inconspicuous in normal times. Japan's nuclear complex would still be going strong if only TEPCO had built a higher seawall. Likewise, the concentration of six reactors in one place made for synergies before 11 March and for trouble thereafter. And Fukushima is not alone here: one year earlier, we witnessed how one of the largest companies in the world, British Petroleum, almost went bankrupt because of a valve malfunction. Path dependencies hinge on countless small details, and failure in marginal components have the potential to break the momentum. Seen from the ground, momentum looks more like a series of makeshift solutions that stabilize an inherently unstable technological system. Thus, the famed "momentum" is the result of many delicate improvisations that somehow perpetuate a technological system—until someone drops the ball.

Utopias

It is hard to recount the trajectory of nuclear visions without an air of degeneration. In the beginning, the "peaceful atom" was the key to the future; in the twenty-first century, the talk is about "bridging technologies"—a temporary solution until we have found something better. That makes it all the more important to take a critical look at the nuclear utopias of the 1950s: Who created them? How did they separate the bomb from the peaceful atom? And were they truly popular, or did people simply not care enough to make their dissent heard?

Indications are strong that the nuclear euphoria was first and foremost an elite phenomenon. For the broad public, energy was not something to worry about—it was simply

20 Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore: Johns Hopkins Press, 1983), 140. See also Thomas P. Hughes, "Technological Momentum," in *Does Technology Drive History? The Dilemma of Technological Determinism*, eds. Merritt Roe Smith and Leo Marx, 101–13 (Cambridge, MA.: MIT Press, 1994).

there. Energy scarcity, and even nuclear power itself, was a distant projection. Indeed, it is strange that enthusiasm for all things atomic emerged prior to the establishment of commercial reactors. The more one reflects on the psychology of the first atomic age, the more mysterious it appears.[21]

When talking about nuclear elites, it is important to recall that military and civilian uses of nuclear power were closely intertwined. Even Germany, officially a happy protégé of the US nuclear umbrella, maintained a stockpile of plutonium for many years, just in case international relations changed dramatically. In the history of nuclear power, military interests are the elephant in the room, lurking behind the public celebrations of the atomic age—a fact that should remind scholars not to take public enthusiasm at face value.

A critical reassessment of energy utopias has political as well as academic relevance. While nuclear utopias are a fading memory (the atomic airplane is nowadays a sure laugh at conferences) the enthusiasm for renewable energy evokes unpleasant memories, recalling earlier quests for the ultimate energy fix. However, there is no panacea when it comes to energy troubles. In fact, there is good reason to doubt that renewable energy is really profiting from its new aura. In his discussion of the history of solar energy, Gerhard Mener has argued that solar utopias decoupled research from market pressures and thus deprived companies of practical "learning by using" experience.[22] Utopias can have multiple roles: nuclear utopias were short-lived but left a lasting imprint on the technology; solar utopias endured longer but did little to guide research and development.

Totalitarian Technology

If the first atomic age proved anything, it is that nuclear power does not sell itself. Everywhere we looked, we found government interventions on a grand scale that coaxed reluctant utilities into going nuclear. Without subsidies, state guarantees, and generous endowments for research institutions, nuclear dreams would never have become reality. The second atomic age will need equally generous governments, now that Fukushima has pushed the price of nuclear energy upwards. More money will

21 Cf. Allan M. Winkler, *Life Under a Cloud: American Anxiety About the Atom* (Urbana: University of Illinois Press, 1999).

22 Gerhard Mener, *Zwischen Labor und Markt: Geschichte der Sonnenenergienutzung in Deutschland und den USA 1860–1986* (Baldham: LK-Verlag, 2001).

be needed for additional security, for buying local support, and for the utilities. After Fukushima, the economic case against nuclear power looks stronger than ever. Why should a manager risk the collapse of his or her company, TEPCO-style, if there are plenty of alternatives to expensive reactors that will not pay off until far into the twenty-first century?

What all this comes down to is that nuclear reactors may emerge as a technology for authoritarian regimes, for only they can meet the necessary requirements. They can allocate money more easily than debt-stricken Western democracies. They can suppress criticism and calls for accountability. While Western democracies will have a hard time sponsoring nuclear projects after Fukushima, authoritarian regimes may follow a different rationale. In the twenty-first century, nuclear energy may turn into a totalitarian technology.

All of this may force us to rethink the status of nuclear technology in Western societies. If we recognize nuclear power as a totalitarian technology, what does that say about countries that have dabbled in it over several decades? After Fukushima, we can see clearer than ever how expert systems, like those of the nuclear complex, challenge our democracy. At the very least, we have learned enough about TEPCO shenanigans to conclude that Japan's nuclear complex was not democratically controlled.

In Search of Heroes

Historians of large technological systems have long noted that narratives of their development are often short on the human element. The individual is dwarfed in the presence of complex technology, and the present text is no exception. The nuclear complex has turned men and women into functionaries. Many became tragic heroes as they strived to create the atomic age only to realize (if they could stomach the awful truth) that they themselves had become puppets of anonymous technological transitions. At the risk of sounding sentimental, it is painful to see how much idealism went to waste in the first atomic age.

In retrospect, it seems that nuclear energy had a peculiar ability to make people of all camps look stupid: scientists, engineers, operators, and even protesters, who attacked a monolithic nuclear complex that never was. To be sure, the "liquidators" (clean-up workers) of Chernobyl may qualify as heroes, but most people do not like to think of them that way (quite apart from the fact that they had little choice when commanders sent them to their clean-up jobs). In the ruins of Fukushima, another group of faceless laborers is currently doing its job outside the purview of the public. Another tragic turn of events: while the atomic age turned scientists into the priests of a new epoch, it depended on a supply of reserve labor to do the dirty work as long as radiation dosimeters allowed.

Nuclear energy made a lot of people look dumb, even those who sought a middle ground between the extremes. Take, for instance, the advisory Enquete Commission "Nuclear Energy Policy of the Future," which the West German parliament set up in November 1978. During several months of talks and negotiations, the issue of nuclear power proved more complex than both sides thought. In the end, the Enquete Commission successfully outlined a path towards a nuclear consensus, arguing for the development of different scenarios for the future that both camps could agree to. The commission's report outlined four possible energy paths, two with nuclear power and two without. The report noted that a decision for one of these paths was not imminent: not until 1990 was there a need to opt for one of the four paths. From an intellectual viewpoint, it was a brilliant idea, but also one that quickly got lost in the trenches of politics. For all its wisdom, the middle ground was an uncomfortable place to be.[23]

Fukushima has once more underscored the dilemma of individuality in the age of nuclear power: many people have lost face as a result of the disaster, and those who would deserve credit remain faceless. So the lack of human agency in nuclear history is probably not really a deficit. It may be how things are.

The Next Catastrophe

Some three decades ago, Charles Perrow changed our view on the risks of technological systems. Perrow had worked for the President's Commission on the Three Mile Island accident near Harrisburg, Pennsylvania. In his published conclusion, Perrow argued that Three Mile Island was an example of what he called "normal accidents:" due to the complexity of large technological systems, there was a technological rationale for little incidents to turn into disasters. Furthermore, Perrow suggested two pa-

23 Cornelia Altenburg, *Kernenergie und Politikberatung: Die Vermessung einer Kontroverse* (Wiesbaden: VS Verlag für Sozialwissenschaften, 2010).

rameters that determined the likelihood of such escalations: complex versus linear interaction between the individual components of technological systems and their tight versus loose coupling. The risk was particularly grave when interaction was complex and coupling close. In fact, Perrow provided a graph to rank technological systems according to these two parameters. The technology that came out as the most dangerous in this graph was nuclear power.[24]

Perrow's approach is helpful for a fuller understanding of the disaster at Fukushima Daiichi. From such a perspective, the earthquake and the ensuing tsunami were not simply an unfortunate coincidence; these natural events met with a technological system that tended to react unpredictably to these disturbances. The existence of no less than six reactor units in close proximity to each other—one of the key factors for the hazardous escalation after 11 March—was exactly the kind of close coupling that Perrow was talking about. In fact, Perrow's systemic approach suggests Japan was fortunate that engineers succeeded in stopping the escalation. The chain reactions, both nuclear and technological, eventually slowed down, the result of heroic and improvised actions that are still awaiting a scholarly investigation. Containment never collapsed completely and the reactors, though leaking, never turned into nuclear volcanoes spewing radioactivity into the water, ground, and atmosphere without inhibition.

One drawback of Perrow's scheme is that it focuses on the technological layout, thus downplaying the human element in the design, management, and collapse of technological systems. Perrow sensed that himself and his more recent publications highlight human agency, most notably with regard to deliberate manipulation of technological systems by terrorists—an obvious choice given the debates in post-9/11 America.[25] However, human agency in design decisions still appears notably undertheorized in the history of technological disasters, remaining an erratic element that seems to defy comprehensive analytical schemes.

With that, the call is to bring humans back in to the debate over technological hazards. The two defining technological disasters of 2010 and 2011, Deepwater Horizon and Fukushima, demonstrate what might emerge as a key theme for the sociology of technological disasters: how technological fixes become endpoints for disaster prep-

24 Charles Perrow, *Normal Accidents. Living with High-Risk Technologies* (New York: Basic Books, 1984).
25 Charles Perrow, *The Next Catastrophe. Reducing Our Vulnerabilities to Natural, Industrial, and Terrorist Disasters* (Princeton: Princeton University Press, 2007).

aration. The failure of certain devices turns into a taboo even in the wake of abundant evidence that failures do occur. The blowout preventer, whose failure turned the Deepwater Horizon explosion into a massive oil spill, provides a case in point: emergency crews were clueless once the device had failed. In the absence of ideas and concepts, engineers started using a number of improvised devices that looked all the more embarrassing as they were put together under the watchful eye of impatient media crews. The blowout preventer was the last line of defense and thinking beyond it had obviously been discouraged, even though blowout preventers are inherently delicate pieces of technology. Like emergency cooling systems in light water reactors, they are lying dormant most of the time until called to duty, at which point they are supposed to function perfectly. Unsurprisingly, they have not done so in the past: according to a report for the U.S. Minerals Management Service of 1999, there have been 1,031 events where blowout preventers had failed between 1978 and 1999.[26]

Fukushima also highlighted similar taboos in nuclear disaster preparedness thinking: the failure of electric power supply. The loss of control occurred after the tsunami had destroyed the connection to the power grid and put the diesel-powered emergency units under water. The result was a frantic search for electric power that reportedly had engineers heading for their cars in order to rip out the battery. Once supplies were exhausted, it was carte blanche.

What all this comes down to is that we need a sociology of technological taboos. Why is it that planners and operators treat some emergency procedures as infallible, thus ignoring common-sense notions that everything is prone to failure? How did they impose these taboos, and what happened to people who disregarded them? The answers may relate to psychological and social aspects as well as to economic ones. Is it possible that large technological systems need these kinds of taboos in order to keep expenses for research and development within certain boundaries?

The Strange Renaissance of Energy Planning

In the wake of the Fukushima disaster, it became a matter of common sense that Germany needs to invest into renewable energy. The result was a plethora of blueprints

26 Per Holand, *Reliability of Subsea BOP Systems for Deepwater Application, Phase II DW,* SINTEF Industrial Management (7 November 1999), 38; available online at http://www.boemre.gov/tarprojects/319/319aa.pdf.

for what came to be called the "energy transition" (*Energiewende*). Authorities of all stripes came up with plans for sustainable energy production by 2030, 2040, or 2050, leaving this author to wonder whether they had really come to terms with what had happened. How were we to trust blueprints that ran decades into the future, now that the federal government had shown unable to sustain its nuclear policy of 2010 for just twelve months?

Fukushima and its aftermath has undermined the idea of long-range energy planning. To be sure, it was not the first such verdict. In a way, the entire path of nuclear energy is poised to cast doubts on the concept of energy policies that look decades into the future—especially when one recalls that nuclear energy once figured as the epitome of wise, science-based long-range planning. It seems that decision makers have yet to understand the full tragedy of the nuclear age: nothing happened as expected.

It would be bad enough if that merely showed an unwillingness to learn from history. However, the current penchant for long-range energy plans may also be a result of the merger of civic and state interests that lay at the root of the success story of German environmentalism. As I have shown elsewhere, politicians and administrators have embraced environmental issues because they have provided one of the last realms for massive budgetary expansion in the late twentieth century.[27] In the light of this finding, current energy planning looks like an act of wishful thinking, if not autosuggestion: governments can act as if their powers had not been eroded in the age of globalization, and states behave as if they still have the ability and wisdom to plan decades ahead. In all likelihood, future historians will talk about these plans with the same mixture of bemusement and contempt that we now bestow upon the nuclear plans of the post-war years.

To be sure, energy remains an important field of government policy, all the more so since replacing the 22 percent share of electricity that nuclear reactors provided in 2010 with sustainable alternatives is no mean feat. However, it would seem that clever energy policies would refrain from getting lost in distant decades and emphasize the challenges of the next few years. What can we do to encourage construction of new facilities and encourage diversity in ownership structures? How can we produce a steady and reliable

27 Frank Uekötter, *Am Ende der Gewissheiten: Die ökologische Frage im 21. Jahrhundert* (Frankfurt am Main: Campus, 2011), 109n.

stream of energy from sources like wind and sunlight that are subject to the moods of nature? And how can we react flexibly to the vagaries of future energy demands and avoid decisions that eventually turn into fateful path dependencies? All this calls for a new style of policy that sees energy paths as a work-in-progress, where the ability to respond to unforeseen events and unexpected side effects makes for the sophistication of policy. Self-reflection will be an important part of sustainable energy paths. If we can learn anything from the history of nuclear power, it is surely the need for constant learning.

It would not be surprising if we hear a sigh of relief from energy managers once they have shut down the last German reactor. If they have a sense for the ironies of history (unlikely, but nonetheless possible), they will thank the anti-nuclear movement, for it was their staunch opposition that allowed the utilities to come out of the first atomic age with a profit. More realistically, these managers might remember the trajectory of nuclear power as a cautionary tale. If one agrees with Markus Vogt, abandoning nuclear power was a moral imperative. As this essay has tried to show, it was also the end of a botched path of technological development. However, the full truth may only emerge decades from now; maybe abandoning nuclear power was good business, too.

Further Reading

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