MTEC NEWS Update

Cost versus safety of nuclear energy: an independent academic perspective

Spencer Wheatley and Didier Sornette
ETH Zürich
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Having observed misinterpretations of our MTEC News Article of July 11, 2016 [1], and the related academic paper on the cost risk of nuclear power [2], we would like to offer crucial clarifications, as well as an update on relevant ongoing work.

CLARIFICATIONS:

Our study was focused on cost risk, which is related to, but often very different from, safety risk. Safety relates to specific issues like core damage, radiation release, and human exposure, which may or may not be costly. Cost may be more of interest to an owner/operator, or to the taxpayers, which are liable to pay; while regulators are primarily interested in compliance with legal safety requirements. If safety is the core focus, exploiting our results based on cost analysis is misguided and misleading.

Cost has the advantage of being an encompassing measure, along with the existing less integral definitions of risk. That cost is relevant in the energy market needs no justification. However one must not assume that cost risk and safety are equivalent: As an encompassing measure, there are highly costly events that are practically without safety relevance: a prime example being the Monju unit at Tsuruga, Japan that -- due to incidents and mismanagement -- has spent most of its life in long-term shutdown mode, costing on the order of ten Billion USD (US dollars), with zero revenue [3]. As a reference point, the cost of constructing a plant is on the order of several Billions of USD. Furthermore, there are events of "major safety relevance" with relatively low cost. For instance, a single radiation induced fatality would be deemed more safety relevant than the Monju incident. That said, it is clear that enormously costly events -- like Fukushima and Chernobyl -- are also of the utmost relevance to safety.

These statements require a definition of safety relevance. We employ the standard/official INES (International Nuclear Event Scale) [4] system for this. INES is an eight point scale, with increasing measure of severity. In this context, one must be careful with terms: Deviation, Anomaly, Incident, and Accident all have specific and escalating meanings within this system, and the safety field. Thus, we should also be more careful, as in the News article the term "accident" was incorrectly used, where the generic term "event" should have been, as we have done in our academic publication.

Also important is to mention that our data, which is sound for the study of cost risk, is not sufficient for the analysis of safety in a precise technical sense. Nuclear safety engineering is not our discipline, and it was not our focus. Concerning cost, while not trivial, conservative estimates may be provided based on factors such as the cost of business interruption / plant downtime. These incurred and expected costs are often published and may be collected, and analyzed. To the best of our knowledge, we provide the largest and most comprehensive public database on such cost risks. Crucially, due to the existence of extremely costly events, absolutely precise cost estimates for the vast majority of events (which have relatively low cost) are not necessary for reliable statistical analysis of extreme and total cost issues. Instead, conservative ranges may be used, and in fact should be used, due to inherent uncertainty. In total contrast, safety analysis requires a precise understanding of events and their mechanisms, and one needs to be able to answer "what-if" questions about events that could have occurred but did not (e.g., near misses). Thus a vast quantity of small and hypothetical incidents must be studied in depth, by technical nuclear experts, despite having minor cost relevance. Large databases of such incidents exist, and some are public. The French and Swiss regulators provide fine examples of this, typically for events within the past 15 years or so [5,6], and are valuable resources. At an international level, such data exists (the IRS database of the IAEA). Further, safety analysis is being done at a European level [7]. However, such data and studies are neither fully open to academia nor to the general public. There is certainly potential here for improvement in academic collaboration, and (the resultant) informing of the public.

Another note on our data, and our methods: Our dataset includes events taking place from the 1950's until the current date. To be clear, events in the 1950s, 1960s, and so on do not influence the quantitative assessment of risk today. Trends and abrupt changes of risk safety levels have occurred and have been taken into account. However, questions from the past are still relevant today: What was the effect of the industry response to an accident? Was one response more effective than another? Does the industry continually improve, and in what senses? Furthermore, given that the average operational reactor is almost 30 years old [8], some historical data is directly relevant.

To conclude, it is likely that an exit from nuclear power is not the optimal strategy. There are substantial risks inherent in other energy sources, as well as in the exit from nuclear power itself [9]. For instance, the German strategy to stop their nuclear reactors following Fukushima led to a massive growth of their coal-based production. Nowadays, it is estimated that coal plants in Germany cause 2'500 premature death each year in Europe due to particle pollution [10]. Extraction, transport, processing, and combustion of the life cycle of coal induce external health and environmental costs that have been estimated at a third to over one-half of a trillion dollars annually for the U.S. public [11]. These things must be made clear so that a proper decision can be made. It is possible that investment in the development of safer (and cheaper) nuclear power (such as in Generation IV and small modular reactors) will turn out to be an attractive strategy – especially for the more and more concentrated urbanized world where, by design, dense energy is needed.

ONGOING AND FUTURE WORK

In new phases of our work (since [2]), we aim to develop data and analysis for both cost-risk and safety purposes. For this, we have engaged nuclear safety experts. One of our goals is to produce a public dataset that is useful for the scientific study of cost, and which is also sound for safety purposes. We have already performed an expert analysis of the 200 events in the database. Another new approximately 200 events (likely to be incidents occurring from the 1960s' to the current date) await such review, which is very time consuming as a result of our aspiration to obtain the highest possible reliability in terms of sources and clear understanding/reporting of the underlying mechanisms. In a statistical sense, the data set is relatively small, only being complete for events above a rather high threshold (e.g., INES >2). With this, we have done basic aggregate statistics. With a more complete dataset, we can use more sophisticated “big-data” statistical techniques, and study more detailed interesting scientific questions. This can involve studying trends, patterns such as fore-runners to accidents, and characterizing cost and safety risks at more granular levels (e.g., for different reactor types).

It is worth mentioning that basic yet fundamental safety insights may be obtained from examination of the present data, including more than 200 carefully reviewed events (and an additional 200 awaiting review): Over 80% of the events occurred at nuclear power plants, rather than other relevant facilities, the vast majority of which were INES anomalies or incidents; at commercial power plants, in about 15'000 years of combined operating experience, there have been only three major core damage events (TMI, 1979; Chernobyl, 1986; and Fukushima, 2011; with Davis-Besse, 2003 [12] luckily being avoided), only two of which resulted in a major off-site release. Further analysis is necessary to understand the current safety level, but safety risk is certainly lower than cost risk, insofar as safety risk outcomes comprise only a subset of the total cost events and cost types. In addition, many safety lessons have, and can still be learned, from the study of such events. For instance, these historical major accidents have tended to be associated with the operation of components beyond technical design limits, often in the presence of problematic individual and societal human factors.

Another interesting point is improved safety measures. For instance, under INES, the maximum score that can be given for a near miss is 3. This means that, even if there were only a single remaining barrier preventing a serious/major accident, and the barrier could fail with probability 1/2, the event is scored as a 3. From a safety perspective, this is not satisfying, as “pure luck” separated us from a severe event. Clearly, a severe event with probability 1/2 should be of similar order as the same event with probability 1 (Note: INES levels are associated with orders of magnitude; INES is approximately logarithmic, not linear). A concrete example of this is the INES=3 event at Davis-Besse-3, USA in 2003 [12] where the severe degradation of the pressurized reactor vessel was discovered just in time to prevent a massive loss of coolant accident. This type of analysis is laborious and requires expert care, but can lead to a truer representation of safety.

Returning to cost, there is important work remaining there. The cost of nuclear energy is a highly complicated issue. Thus far, our approach to this has been conservative. The goal is to enrich our cost estimates, and provide a structure of different cost types to serve different purposes. For instance, at a minimum, one may consider: direct costs and future expected costs; and costs to the operator as well as societal costs. The uncertainty of estimated costs should be included. Consider the major accident at Fukushima in 2011 (INES=7). The industry is preparing to pay, over forty years, for compensation liabilities that have accrued to 60 Billion USD, and continue to grow [13]. This excludes other substantial costs, such as decommissioning. However most substantial is the dominant social cost: Japanese nuclear power plants shut down in response to Fukushima, removing what was expected to provide 40% of Japanese power by 2017 [14], requiring Japan to become the world's largest importer of natural gas. This increased the Japanese spending on power by about 20-40 Billion USD per year [15]. One can go further and look at the impact on the global nuclear industry, as has been mentioned in a highly interesting talk about the cost of Three Mile Island, 1979 [16]. However, at some point, the line must be drawn. To have the costs available, and select the cost scope based on the purpose of the analysis, would be very powerful.

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