Natural Hazard Risk and Energy Supply

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Natural hazard risk (NHR) represents a major challenge for most societies. Hundreds of thousands of people die every year due to geological (earthquake, tsunami, landslide, volcanic eruptions) and hydro-meteorological (hurricanes, storms, floods, droughts) events. Direct economic losses amount to tens of billions of dollars (1). Energy supply is disrupted by these events; the socio-economic and environmental consequences may be dramatic.

The wind storm that hit Quebec in 1998 destroyed 1’400 power pylons, damaged 3’000 Km of transmission lines, and left more than 3 million people in the dark for several weeks is perhaps the most quoted example of the impact of natural hazard on energy supply. However, natural events always hit the energy infrastructures, as experienced more recently in New York, USA (hurricane Sandy, 2012), Tacloban, Philippines (typhoon Haiyan, 2013) or in Cannes, France (floods, 2015).

In general, experts define the NHR as the product of a hazard (H), vulnerability (V) and elements at risk (E) (2, 3). H represents the probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon. E includes population, build-up area, infrastructures, economic activities, etc. V measures the proportion of E that can be lost as a result of the occurrence of a natural phenomenon and is usually expressed on a scale from 0 to 1 (from no to total losses). In terms of vulnerability, one makes the distinction between physical and systemic vulnerability. The former concerns for instance a building that can be impacted in a seismic region; the latter, a network disruption, for instance an electric power system, which may collapse due to cascading effects of an outage.

NHRs are sometimes called “Un-Natural risks”, because the Force of Nature is most of the time only partially responsible of a disaster (4). In fact, NHR can mainly be mitigated by reducing the elements at risk vulnerability. In some cases (landslide and floods), it is also possible to avoid or reduce the size of a natural event, or at least not to increase it, for instance by avoiding cutting trees over an area prone to landslide or making the soil impermeable to infiltration of water. In case of volcanic eruption or earthquake, nothing can be done to avoid their occurrence.

In the field of energy transformation, consumption, and transportation, one should also consider the risk definition used by engineers. In their perspective, the technological risk (TR) is given by the probability of occurrence of a certain event (P) times the consequences (C) (5, 6). Haimes states “risk is defined as a measure of the probability and severity of adverse effects” (7). Engineers focus on the probability of occurrence of adverse effects to mitigate risk.

The risk definition as an “expected value” is sometimes used in economics, although here the consequences of a certain event may be either negative or positive. The risk management goal in that case is to tip the balance towards positive outcomes. In the field of NHRs, only negative outcomes are considered. But E, for instance a power plant, which may be jeopardized by a natural event, should still be able to provide a net benefit to society.

The “expected value” approach is appropriate as far as one focus on objective risk, and not on a decisional or behavioural phenomenon. Indeed, thanks to Bernoulli, we know that what matters in the decisional process is the “expected utility” and not the “expected value”. The expected utility theory and later the prospect theory have shown how risk attitude and risk perception (subjective risk) influence our decisions and behaviour (8, 9).

The challenge when we deal with natural hazard, energy, risk assessment and management is that one should consider different types of risk associated with this combination. At present, there is no approach that allows integrating in a single “formula” all aspects. Although the “formulas” mentioned above are quite similar, one should recognize that it is very difficult to integrate the concepts and analytical tools from different disciplines. At present, one should develop a semi-quantitative synthesis of the more relevant risks in order to have a broad picture of the chain of events that can be provoked by a phenomenon like hurricane Katrina (USA, August 2005), the Tōhoku earthquake and tsunami (Japan, March 2011) or the floods in Thailand (October 2011).

The Tōhoku earthquake had a Mw magnitude of 9.0 and triggered a huge tsunami, which hit the Fukushima Daiichi nuclear power plant with a wave 15 meters high (10). The flooding switched off the cooling system. The partial meltdown of reactors 1, 2 and 3 as well as several hydrogen explosions could not be avoided. Hundreds of thousands hectares of soil were contaminated by the radioelements escaped from the reactors thousands of people were evacuated.

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Relatively large amounts of contaminated water were dumped into the Pacific Ocean. The consequences of this accident are many and concern the natural environment, the society and its economy as well as its energy supply.

The Fukushima nuclear accident clearly shows how complex the assessment of the entire spectrum of risks related to a cascading event is. Two other examples allow being more precise. The health risk for the people that were exposed to radiation is defined by the probability of developing a cancer or leukaemia in the coming years or decades after the exposure (11, 12). The probability for an individual is very low, but when it is applied to a large population, it can affect a quite large number of people. One should recognize that uncertainties are quite high, in particular the dose-effect relationship, as shown in the case of Chernobyl (13).

54 nuclear power plants (50 GW) were closed in the aftermath of the Fukushima accident. To avoid blackouts, Japan had to take drastic measures to reduce power consumption. Furthermore, to partially compensate for the nuclear power plants closure, it had to import huge quantities of natural gas. As a result, the balance of trade turned negative. This huge event shows the necessity to assess all risks related to such a natural event, considering vulnerabilities, in order to manage this kind of “major risk” in an appropriate manner.

In conclusion, “integrated risk management” is a necessity in a world prone to major risks. “Integrated risk assessment” is a pre-condition for an “integrated risk management”. However, the methodology is still in its infancy. Specific problems, such as the role of uncertainty, make the problem even more complex. Furthermore, as mentioned above, one should also take into consideration the subjective side of risk, which is fundamental for risk management. Case studies that consider a broad spectrum of risks are very important. Among these risks, the risk related to energy supply is an essential piece of the puzzle, because energy, in particular electricity, plays an increasingly important role in society. These are the topics that we are developing in an article to come.

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