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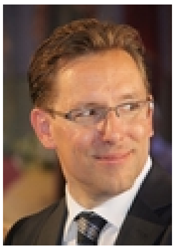

Dr. Peter Burgherr joined the Paul Scherrer Institut (PSI) as a risk analyst in 2001. Since August 2008 he leads the inter-disciplinary Technology Assessment group of the Laboratory for Energy systems Analysis (LEA), which carries out comprehensive assessments of energy systems to support the complex decision-making processes towards a sustainable energy future with objective facts.

His main research interest is the comparative analysis of accident risks in the energy sector, and its relevance in the broader context of energy security and critical infrastructure protection. He is also the primary responsible for PSI's database ENSAD (Energy-Related Severe Accident Database), which is the world's largest database on severe accidents in the energy sector. Furthermore, he is strongly involved in the sustainability assessment of current and future energy technologies as well as their evaluation within Multi-Criteria Decision Analysis (MCDA).

# Abstract


**Intentional attacks and accidents in the energy sector within the broader context of a safe, secure and sustainable energy supply**

The risks of technological accidents in the energy sector and their potentially disastrous effects have been analyzed since the 1990s, and are generally included in a comprehensive assessment of energy security. In contrast, the issue of intentional attacks on energy infrastructures has become increasingly important due to growing dependence of energy imports from and transit routes through regions considered less reliable and politically stable. Both types of risks, however, illuminate different vulnerabilities. Therefore, this contribution focuses on the analysis of these two risk categories: accidents and intentional attacks in the energy sector.

Risk assessment of severe accidents in the energy sector is based on quantitative data from the Energy-related Severe Accident Database (ENSAD), which has been developed and established at the Paul Scherrer Institute (PSI), and was first released in 1998. Since then it has been regularly updated and extended both in content and scope. Random accidents can be caused by technical failures (e.g. explosion, fire) as well as triggered by natural hazards (e.g. earthquake, wind storm). This type of events is considered to be rare and independent, which is why their frequency can be generally modeled by the Poisson distribution.

In contrast, the analysis of intentional attacks on energy infrastructures (EI) by violent non-state actors (VNSA) has only emerged as a major research topic during the past decade. This is primarily due to the growing dependence on oil and gas imports from regions considered less reliable and stable, but also potential large-scale imports of new renewables could lead to increased energy security vulnerabilities. However, available EI attack databases are generally focused on the terrorist threat only, but do not take into account the whole spectrum of intentional attacks, which includes vandalism, sabotage, kidnapping, theft, insurgent tactics, maritime piracy and terrorism. For this purpose, the Center for Security Studies (CSS) at

ETHZ and the PSI jointly built up the Energy Infrastructure Attack Database (EIAD). Compared to accidental events, intentional attacks often show a different behavior, namely a pattern of contagion, which is a known phenomenon from epidemiology. Therefore, their frequency is usually better modeled by the Negative Binominal (NBI) distribution.

The present evaluations examine similarities and differences between technological accidents and intentional attacks in terms of frequencies and consequences, considering time-series trends and regional patterns. A key difference is that accidents are typically rare and independent events, whereas intentional attacks are often multiple events and concentrated both in time and space, resulting in distinct hotspots. Concerning consequences, the severity distribution for accidents generally stretches over a broad range, with low-probability high-consequence events being an important factor of energy chain performance. On the other hand, these types of consequences are often less important for intentional attacks because energy infrastructures are often targeted in remote areas and difficult to protect (e.g. pipelines and transmission lines), but when frequently attacked can result in substantial business and supply disruptions. In summary, the joint analysis of accidents and intentional attacks provides a comprehensive and complementary approach on two types of risks that have rather different properties, but are essential in holistic energy supply perspective addressing aspects of safety, security and sustainability.