# *ASSESSING THE INTERDEPENDENCIES AMONG DIMENSIONS OF SECURITY OF SUPPLY IN THE ELECTRICITY SECTOR*

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## Overview

Energy security (ES) became an issue after the oil crisis in the 70s. Since then, different frameworks and indicators have been developed to evaluate ES. While some of this work includes an assessment of part of the electricity sector, security of electricity supply (SoES) has only become an important part of energy policy when the liberalisation processes started in the 90s. Before, electricity supply was taken for granted, at least in developed countries, as it was supplied by public-owned monopolies. However, since deregulation, investments are based on profitability rather than the issue of security of supply. More recently, the increasing penetration of renewable energies (with their inherently variable production), the enhanced interconnection among countries as well as the nuclear power phase-out in some countries threaten the SoES in the medium- to long-term.

These different elements highlight the multidimensional nature of SoES. Hence, Larsen et al. (2015) propose a framework based on eleven dimensions to evaluate security of supply for a single jurisdiction. These are divided in 19 sub dimensions, for which authors suggest one or more metrics. The dimensions are generation adequacy, resilience, reliability, supply flexibility, grid-condition, demand management, regulation performance, sustainability, geopolitics, social-cultural factors and terrorism. However, actions aimed at improving one dimension might impact others negatively, adversely affecting the overall system. For instance, responding to environmental challenges typically leads to higher system costs (Kruyt et al., 2009).

The interdependencies among the different dimensions render achieving a required level of SoES increasingly complex. Understand how these dimensions are interrelated is thus a prerequisite to enable regulators and policy-makers to take appropriate decisions regarding planning and resource allocation.

## Methods

We apply a Cross Impact Analysis (CIA) to the 19 sub dimensions of the framework developed by Larsen et al. (2015) to determine the degree to which the different dimensions affect each other. This methodology is also used to identify the essential variables when they are tightly interrelated, for instance in scenario analysis. This has been applied to analyse socio-economic problems, e.g., the evaluation of global-warming mitigation options (Hayashi et al., 2006). CIA also enables identifying the feedbacks mechanisms among the dimensions, e.g., low supplier profitability may trigger incentives for conventional generators, leading to increased generation capacity adequacy. On the one hand, this could result in lower prices, which decrease suppliers' profitability. On the other hand, this could decrease import dependency, resulting in improved supplier profitability.

## Results

We apply CIA to the 19 sub dimensions of Larsen et al. (2015)'s framework to assess their interdependence. Figure 1 maps the outcome of the CIA. The variables in the upper left quadrant are the independent variables: they significantly affect, but are not influenced by, the other variables, and can thus be interpreted as the drivers of the system. Among others, fossil fuel dependency, market performance and social-cultural factors are thus the driving forces of SoES. The variables in the upper right quadrant are to be interpreted as connecting variables: they influence, and are influenced by the other variables. Grid capacity adequacy, incentives for conventional generators and generation adequacy thus are the key dimensions of the framework. They are the central elements of the feedback mechanisms of SoES, reinforcing or balancing the effect of other dimensions. Consequently, changes in the variables of the upper two quadrants are likely to significantly impact other dimensions, thus affecting system-wide performance, not necessarily in the desired direction.

Variables in the lower right quadrant are the dependent variables: they are influenced by, but do not influence, other variables. Among others, environmental sustainability, suppliers' profitability and reliability are thus to a large extend the consequence of the other dimensions. Consequently, rather than attempting to improve these sub dimensions, policies should focus on improving their drivers. For instance, rather than increasing subsidies to low-income families to directly improve affordability, it might be more desirable to act on the dimensions that will indirectly affect affordability, e.g. relieving grid congestion to reduce prices. Finally, variables in the lower left quadrant are independent of the other dimensions: they neither influence, nor are influenced by, other variables. Among others, grid ageing and supply flexibility thus have a limited relationship to the other parts of the system. Changes to the variables in the lower two quadrants are thus less likely to have system wide implications.

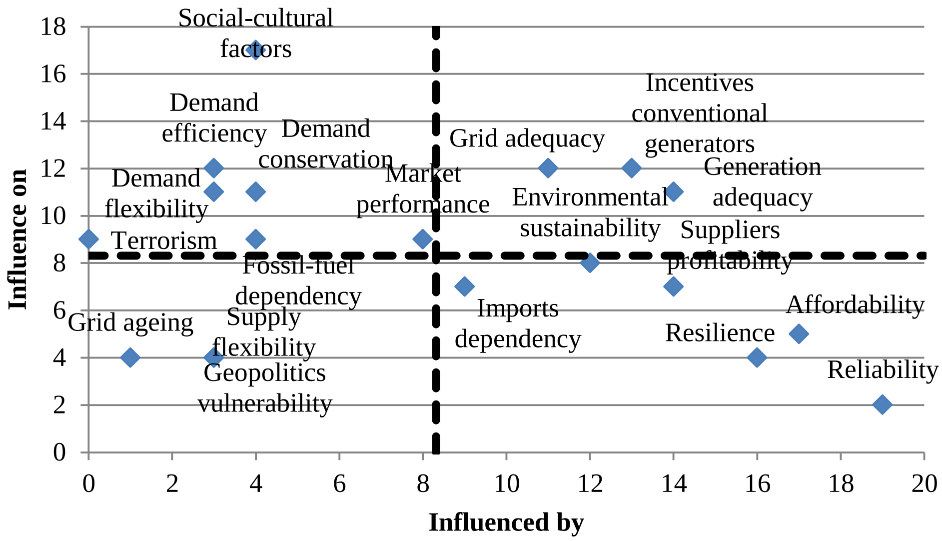


Figure 1. Categorization of SoES sub dimensions resulting from the cross-impact analysis.

## Conclusion

Building on Larsen et al. (2015), who identify eleven key dimensions of SoES, we use CIA to provide insight into the interactions among these dimensions. This analysis allows us to identify the dimensions policy makers should focus on to improve SoES: the drivers and the connecting variables of the system, which have a significant impact on the other dimensions. We also identify the dependent variables, which provide information about the SoES level. Policy-makers should thus not focus on improving these directly, as their level can more efficiently be influenced by acting on the dimensions that drive these variables.

## References


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