Input-Output based Estimation of Power Interruption Costs in Economic Sectors

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Overview

Concerns regarding supply security are increasingly raised in reaction to the transition of the German energy system towards a renewable and nuclear-free system called "Energiewende". The goal of this work is to contribute to a measurability of supply security by quantifying the consequences of power interruptions monetarily. The focus lies within the investigation of power interruption costs in 51 economic sectors in Germany.

Two Input-Output based models are used to estimate the Value of Lost Load for each of the 51 sectors for the years 2000, 2005, 2006 and 2007. The first model does not take inter-linkages of the sectors and possible cascading effects on outage costs into account. The second model, however, is based on the Ghosh-Input-Output model and tries to incorporate and quantify these effects. It is assumed that the first model is adequate for short power interruptions, whereas the second model is more appropriate when estimating costs of long power interruptions.

Methods

Following the microeconomic theory, profit maximization is the most important goal of companies through which their market behaviors can be explained. Companies combine multiple inputs in order to create value and generate profit. One of these inputs is usually electricity. If one of the production inputs is not accessible, the value adding process is often impossible or restricted. The gross values added of the sectors are seen as their opportunity costs, due to the assumption that a company cannot add any value during a power outage. In this work, two top-down models based on this idea are used that estimate the utility of electrical supply security or the costs of power interruptions.

The first model neglects that different economic sectors are usually linked to each other by supply and demand. Under these conditions, the Value of Lost Load $VOLL_{i,\mathrm{I}}$ of a directly affected company in sector i is given by the ratio of the sector's gross value added GVA_i to the annual electricity consumption EC_i.

$$VOLL_{i,I} = \frac{GVA_i}{EC_i} \quad (1)$$

The second model tries to take inter-sectoral linkages into account. Different sectors in a value chain are often economically and technologically intertwined. Production losses in a sector i due to power interruptions can therefore cause production losses in following sectors j. For this reason, the $VOLL_{i,\mathrm{II}}$ was introduced in addition to the $VOLL_{i,\mathrm{I}}$. The Roman numeral II stands for the second model. The $VOLL_{i,\mathrm{II}}$ includes not only the $VOLL_{i,\mathrm{I}}$ but also consequently losses in the downstream sectors j in a national economy that can occur due to a power outage in sector i. Thus, the consequent losses take inter-sectoral forward linkages into account. In order to do so, a methodology based on the forward-linked Ghosh's input-output model is used instead of the Leontief model that uses backward linkages.

$$VOLL_{i,\mathrm{II}} = VOLL_{i,\mathrm{I}} \cdot f_i \quad (2)$$

with

$$f_i = \sum_{j=1}^{j=n} f_{ij} \quad (3)$$

and

$$f_{ij} = \frac{GPV_i}{GVA_i} \cdot \frac{\alpha_{\mathrm{G},ij}}{\alpha_{\mathrm{G},ii}} \cdot \frac{GVA_j}{GPV_j} \quad (4)$$

where α_G are elements of the Ghosh inverse matrix.

Results

Figure 1 shows the resulting Values of Lost Load as a Merit-Order curve. The ordinate has been cut off at 30 EUR/kWh for reasons of visualization. Figure 2 represents a detail of the Merit-Order curve. Shown in the three figures are the mean averages of the results over the four examined years.

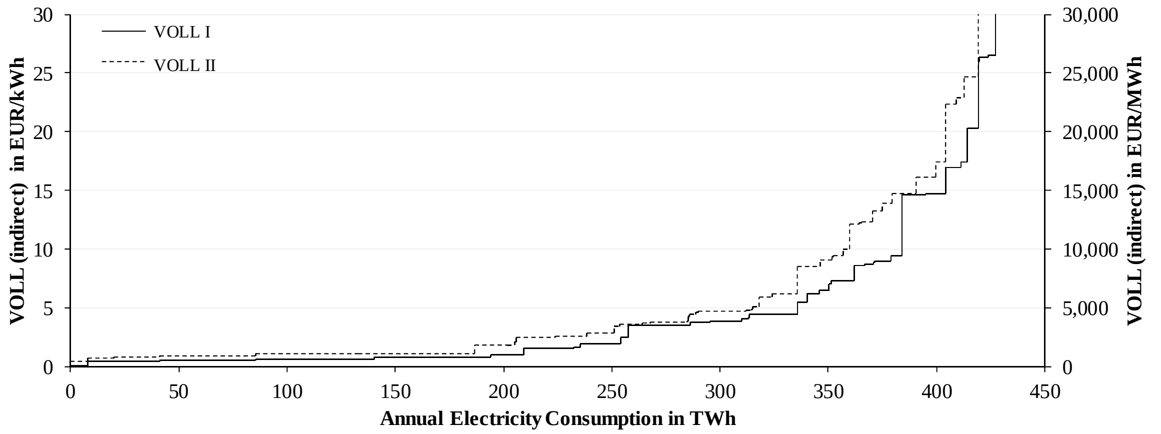

Figure 1: Merit-Order of VOLLs for all 51 economic sectors

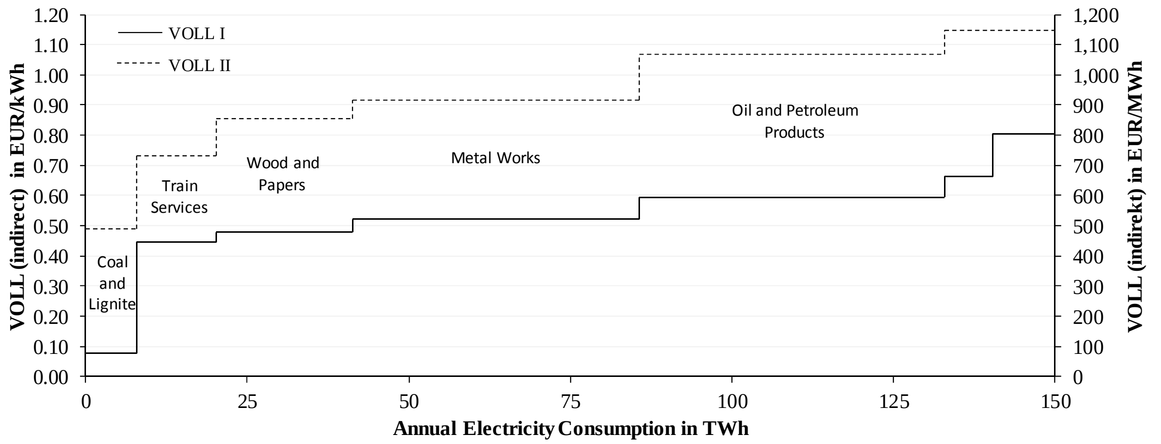

Figure 2: Merit-Order of VOLLs for all 51 economic sectors - first 150 TWh in detail

Conclusions

The results show that supply security generally has a very high utility level for companies. Thus, power supply interruptions lead to high costs. However, the frequency distribution of these costs is widely spread. Some sectors have very low interruption costs whereas other sectors have very high interruption costs. Selective interruptions of costumers with the lowest costs (if technically feasible) may, under certain circumstances, be more cost-efficient than the construction of storage or generation capacities. According to the results, companies of the sectors coal and lignite, railway services, wood and paper and metals could probably be interesting candidates for these measures with a Value of Lost Load of below approximately 0,50 EUR/kWh. The electricity production costs of a peak load power plant that runs 100 hours a year should be around that cost figure (assuming annual capital costs of 40,000 EUR/MW and variable costs of around 100 EUR/MW). However, it should be further examined if, and in which amount, indirect costs that have been a focus in this work may occur additionally to the estimated Value of Lost Load in case of such shutdown actions. This work's results indicate potentials of load reduction measures. In the future such measures might contribute to Germany's ambitious energy transition.

References

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