ASSESSING THE SOCIO-ECONOMIC EFFECTS OF POWER OUTAGES IN THE EUROPEAN UNION AD HOC USING WWW.BLACKOUTSIMULATOR.COM

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ABSTRACT

This paper presents the methodology and the results from SESAME, a large European research project on electricity supply security. This collaborative EU FP7 research project analyzes businesses' electricity dependencies and surveyed 8,300 households in 27 member states regarding their vulnerabilities in the case of power outages. Nine project partners from eight European countries are working on this project. Among them are utilities (Transelectrica), regulating authorities (E-Control), technical universities (Politecnico di Torino), policy makers (BKA, the federal Austrian chancellery, which is in charge of ensuring the security of electricity supply), consultants (Deloitte), and other distinguished partners. The Energy Institute at the Johannes Kepler University Linz is the leading partner regarding the socio-economic analysis of the economic value of electricity supply security. We present the applied econometric outage cost assessment techniques, results for businesses, institutions, and the public sector, households' willingness-to-pay (WTP) to avoid power outages, as well as an *ad hoc* analysis tool for the socio-economic assessment of power outages at any user-defined time and duration in all of the European countries (at the NUTS II specification level).

Elaborated economic assessments of the value of electricity supply security are essential especially in the discussions on necessary investments for maintaining and upgrading the current transmission and distribution infrastructure. Thus, we provide a rationale for electricity supply security enhancing investments and energy policy decisions. Profound knowledge of the damages faced by businesses in the case of power outages and of households' preference structures is paramount with regard to the challenges for the future electricity system. Additionally SESAME's approach is in line with EU directive 2003/54/EG which requires the quantification of power outages' damages, which is again highly relevant for regulatory decisions (especially in countries with quality-based incentive regulation).

Finally, our contribution encompasses a power outage simulation tool (blackout-simulator.com) which draws upon value-added data on businesses, institutions and the public sector as well as on the conducted household WTP survey. The macroeconomic damage of power outages in all of Europe can be assessed by the interested user of blackout-simulator.com. This is a valuable input for regulation, utilities' infrastructure investment evaluations, insurance policies, etc.

INTRODUCTION

Securing an uninterrupted electricity supply is essential for any advanced economy to function economically, socially and politically. Europe has enjoyed a high degree of electricity supply security (ESS) during the last few decades. However, the need for action to ensure high levels of ESS in the future is increasing, mainly because electricity production and distribution are currently undergoing significant restructuring.

While developing the necessary measures to secure the electricity grid and future supply is primarily a challenge for the engineering disciplines, it is the task of economic research to support the development of a system of incentives to counterbalance possible market failure and therefore enable the implementation of societally optimal technical measures. One central prerequisite for developing an efficient regulatory system is quantifying the value of electricity supply security. As ESS constitutes a non-market good, and can be purchased only in combination with the physical product (electricity), the value of supply security cannot be determined directly. That is why usually the failure of electricity supply, and in particular the cost of power outages, is used to assess the value of supply security (see [1], [2] and [3]). Elaborated economic assessments of the value of electricity supply security are essential especially in the discussions regarding necessary investments for maintaining and upgrading the current transmission and distribution infrastructure.

Methodology

In order to model the economic costs of widespread power outages, losses due to electricity outages are typically classified into three categories [4]:

- Direct costs
- Indirect costs
- long-term costs of macroeconomic relevance

In the public eye direct economic losses are usually at the top of the list. They are a direct result of the failure, e.g. repair costs for defective electrical infrastructure facilities. However, direct economic losses are usually limited and subordinate to indirect economic losses. These indirect costs also arise in direct connection with the failure, yet they belong to that part of the total losses resulting from the absence of electricity supply in the aftermath of the failure. Examples are the loss of productive activity, or lost value added. Through multiplier effects due to the marked dependence of some industries on the flawless functioning of other

economic sectors, these indirect costs make up a significant proportion of the total costs [5].
The analysis of the damages inflicted on businesses (non-households) in the case of power interruptions relies on two different methods. On the one hand, production data on the gross value added of businesses, industry and public administration were incorporated as a central indicator of economic activity. This is because economic activity is in most cases very closely connected to electricity supply.
The second part of the assessment of non-households is based on a comparison of typical damages per kWh not supplied in certain industries and sectors. This value of lost load (VoLL) approach assigns every unit of electricity not supplied a damage for a certain country and sector. The different VoLL values were regressed on the characteristics of the outage under scrutiny. The VoLL influencing factors were incorporated into the model to assess a broad variety of power outages which are not restricted to the characteristics of the original power outage settings.

Finally, the economic losses of individual non-households were clustered to make it possible to form complete aggregates of sectors or regions subsequently. A key factor is the utilization of control variables for holidays, weekends and after work hours. This implies for example, that a grocery's daily value added is considerably higher on workdays than on public holidays. However, damages occur on holidays as well (e.g. the lack of cooling and security appliances), which is accounted for in the model as well.

For a comprehensive analysis of the household sector it is necessary to represent non-monetary effects as well as material losses. Thus, an unprecedented household-level survey with a total of 8,336 participants (250-300 per country) was conducted to evaluate European households' WTP to avoid power cuts. The econometric assessments which yielded the inputs for blackout-simulator.com are state of the art in the economic science.

RESULTS AND APPLICATION OF BLACKOUT-SIMULATOR.COM

Being a main contribution of SESAME, the recent software development blackout-simulator.com provides a tool for placing a value on the non-market good of "electricity supply security" for all member states of the European Union. Efficient decisions on investing in infrastructure are possible only if the value of supply security is determined. To obtain an objective result, a household survey unprecedented in scope and dimension (over 8,000 households across all EU-27 nations) as well as an assessment of the macroeconomic costs to businesses, institutions and governments in the case of power outages were conducted.
Using this comprehensive approach to calculate the monetary value of a reliable supply of electricity for every NUTS 2 region (usually provinces or regional states), a fairly fine-mesh quantification of all economic sectors is possible. As a result, not just particularly vulnerable sectors (such as the semiconductor industry, papermaking or data-generating processes), but all sections of the economy as per NACE 2008 are modelled. The wide range of possible blackout scenarios, lasting from one to 48 hours, covers many different conceivable outages for most of the provinces of the EU (266 in total); it is thus possible for the first time to assess every subsector of the European economy as well as households province by province as regards their degree of dependence on a reliable supply of electricity.
The costs due to damage to or the destruction of electricity infrastructure have for comparability reasons not been included into the model, as the model simulates the resulting blackout, independently of what caused it.

Specification of outage characteristics

Several indicators of the economic impact of the widespread blackout investigated on non-households and households can be calculated using blackout-simulator.com. Economic loss and especially the electricity shortfall due to the outage are used as the key indicators in the case of non-households and are derived from the synthetic load profiles of the various sectors. Furthermore an indicator used is the damage per unit of electricity not supplied (VoLL).

Case study: Italian Power outage 2003

As an example of the functionalities of blackout-simulator.com, a very prominent power outage, namely the large-scale supply interruption which occurred in Italy September 28th, 2003, is investigated in the following case study. Table 1 presents the summary of this power outage which affected over 55 million (m). persons and lasted 3 hours in the north, 9 hours in the center, 12 hours in the south and 16 hours in Sicily.

Table 1: Case Study Power Outage in Italy on September 28th 2003

Date of start of outage	28th September 2003
Start time of outage	03:00 am
Duration in hours	3-16 depending on the region
Provinces affected	Italy (except Sardinia)
Public holiday	Yes (Sunday)

Figure 1 depicts the characteristics of this power outage graphically

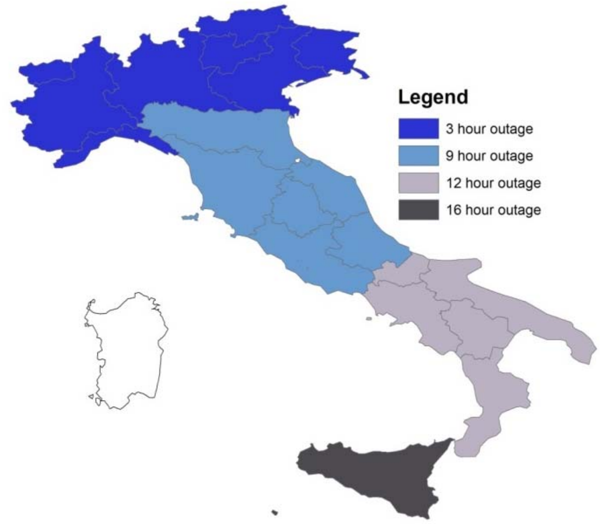

Figure 1: Power Outage in Italy on September 28th, 2003 lasting from 3 to 16 hours

In the case of the outage analyzed in this scenario, the chain of restoration is highly relevant as the whole of Italy except Sardinia is affected by this power outage. In order to explicitly account for the different durations of restoration activities the blackout lasts between 3 to 16 hours depending on the region. As a result the economic assessment of the losses and effects due to an outage of this kind is presented in Table 2.

Table 2: Total losses across all regions, sectors and households relevant outage durations (in million €)

Economic Sector	I	II	III	House-holds	Total losses incl. WTP Households
North	5,3	136,7	60,8	43,1	245,8
Center	20,6	217,6	154,6	98,2	491,0
South	20,9	82,8	97,6	94,3	295,5
Sicily	12,4	33,7	54,6	49,5	150,1
Total	59,2	470,8	367,5	285	1182,4
% of GDP	0,004%	0,03 %	0,03 %	0,02 %	0,083%

The macroeconomic damage of this power outage in its entirety was calculated to be €1182 m. In terms of differences between economic sectors, blackout-simulator.com provides a much more detailed analysis, which is aggregated here to agriculture (primary sector, I), production of goods (II) as well as services (III). Knowing particularly vulnerable branches of the economy can be helpful designing special policies in terms of electricity infrastructure planning. For households, the WTP to avoid this power outage in their respective region was calculated to be € 43m. in the north (3h), € 98m. in the center, € 94m. in the south and € 49m. in Sicily. Figure 2 presents the visualization in blackout-simulator.com taking into account the chain of restoration, which can be specified by the duration of the power outage in any of the relevant areas.

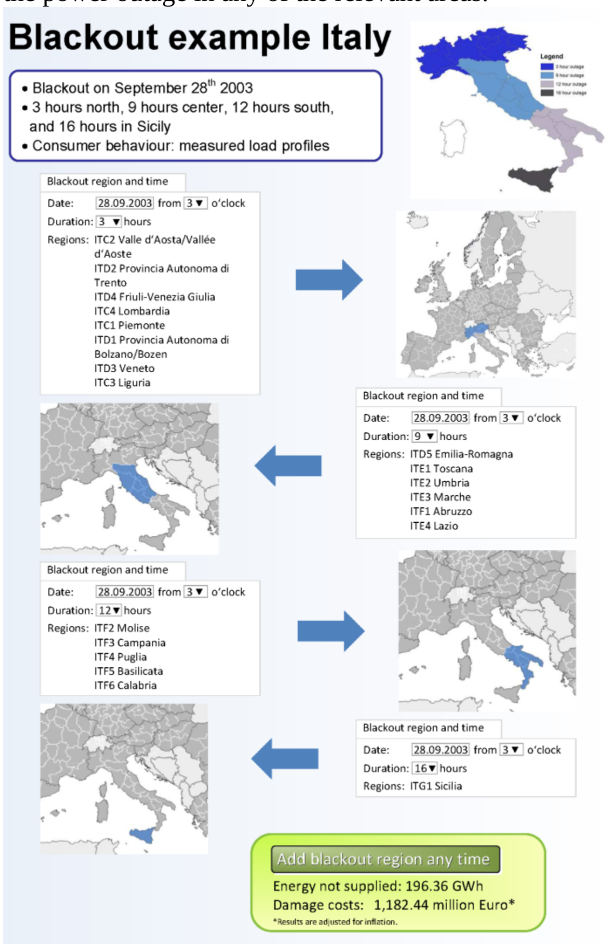

Figure 2: Chain of Power Restoration after the Supply Interruption as selected in blackout-simulator.com

blackout-simulator.com thus offers an intuitive and detailed analysis of power outages in the European union. It is easy to use while providing class-leading precision. For example, a specifically introduced board of Italian experts and scientists [6] conclude that the analyzed Italian outage caused approximately € 640 m in damages. It was found to be responsible for a loss of load of 160 MWh. This only takes into account non-households' damages, while here, the entire country was accounted for. However, in terms of damage and energy loss estimation, this board of scientists' analysis diverges very little from the independently calculated damages and energy not supplied of businesses, households and the public sector using blackout-simulator.com. The opportunities of this tool however are much greater than the assessment of one power outage, as it can be utilized for future projections as well.

CONCLUDING REMARKS

As the scientific evidence on electricity supply security and its socio-economic dimension is facing growing public interest, there is a need for more research that puts a monetary value on the good of “electricity supply security”, particularly at the transnational level. Given that European markets for electricity are increasingly interlinked, and that interdependence across borders is more and more marked, there seems to be a very strong case for assessing “supply security” uniformly throughout Europe. The interaction of supply security and the implementation and adaption of regulatory frameworks is among one of the most relevant issues with regards to a sustainable, secure and affordable supply of electricity.
The online assessment tool blackout-simulator.com can be used to elicit the costs of power outages to different private and business consumer groups ad hoc; thereby providing an essential economic input for policy decisions, businesses and utilities alike.
The currently free-of-charge tool is one of the main outputs of the EU FP 7 project SESAME, a collaborative research effort performed by nine project partners from various European countries including regulatory authorities.
blackout-simulator.com provides a multifunctional “easy to use” web tool supporting for example infrastructure decisions and energy policy. Serving a variety of interested users, quantitative assessments such as the value of lost load, the outage related damage of each economic sector and households in every country of the EU at the NUTS 2 level, as well as of the energy not supplied in the case of any user defined blackout, can be conducted.
The elicitation of the consequences of power outages used to be a highly complicated issue which required significant scientific resources to accomplish. The developed tool makes it possible for the first time to easily assess the economic effects of trans-European (as well as national or regional) power outages. What was once a multiple month research project is now a matter of two minutes and five to ten mouse clicks.
In the process of collecting the necessary data for blackout-simulator.com, an in-depth analysis of households’ willingness-to-pay (WTP) to avoid power outages was conducted using data from an in-depth survey. Additionally every economic sector according to the NACE nomenclature of 27 EU member states (as of 2012) was included into the tool. The detailed output from the software shows that businesses as well as households face significant damages in the case of power outages. blackout-simulator.com allows the industrial, regulatory or household users to quantify and interpret power outages from the period of 2000 until 2020 using intuitive and highly accurate methods.
In this contribution the Italian power outage which took place on September 28th 2003, was analyzed using blackout-simulator.com.
The supply interruption lasted for three hours in the north and up to 16 hours in Sicily. The economic assessment this outage resulted in aggregated macroeconomic costs of € 1,182 million (m). The amount of energy not supplied amounted to 196 GWh.
To get more specific results, blackout-simulator.com allows the download of custom-made csv tables with detailed tables and a pdf report of the overall damages. Calculations can be differentiated between user groups such as households and economic sectors. The majority of damages for this Italian power outage are due to the outage costs of agriculture, the production sector and public administration, while households show about 24% of the total costs. In total the damage of all economic sectors in the affected regions of Italy was calculated to € 897 m. Households’ willingness to pay to avoid this specific power cut was calculated to be € 285 m in total.

REFERENCES

[1] B. E. Baarsma und J. P. Hop, 2009, „Pricing power outages in the Netherlands,“ *Energy,* Bd. 34, Nr. 9, pp. 1378-1386.

[2] M. de Nooij, C. Koopmans und C. Bijvoet, 2007, „The value of supply security. The costs of power interruptions: Economic input for damage reduction and investment,“ *Energy Economics,* Bd. 29, pp. 277-295.

[3] C.-K. Woo und R. L. Pupp, 1992, „Costs of service disruption to electricity consumers,“ Hong Kong.

[4] M. Munasinghe und A. Sanghvi, 1998, „ Reliability of Electricity Supply, Outage Costs and Value of Service: An Overview.,“ *IAEA Special Issue Electricity Reliability Issue,* Nr. 9, 1988.

[5] P. Centolella, M. Farber-DeAnda, L.A. Greening, and T.P. Kim, 2006, „Estimates of the Value of Uninterrupted Service for The Mid-West Independent System Operator“.

[6] Commissione di Indagine, 2003, „*Black-out del sistema elettrico italiano del 28 settembre 2003 Rapporto della Commissione di Indagine,*“ Rome.