The value of supply security: the costs of power outages to Austrian Households, Firms and the Public Sector

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Evaluation process preamble: In this paper an economic tool for assessing simulated power cuts is presented. The tool was implemented as Excel-based Visual Basic software and will be made available on the authors' website for downloading after completion of the evaluation process.

KEYWORDS: Power Outage; Value of Supply Security; Empirical Analysis

Abstract

This paper presents a model for assessing economic losses caused by electricity cuts as an approximation of the value of supply security. Economic losses are calculated for simulated power cuts with a duration from 1 to 48 hours, taking the respective day of the week and time of day into consideration. The simulated power cuts can be defined for the 9 Austrian provinces and the costs due to power cuts are computed separately for all sectors of the economy and for households. For instance, the average Value Of Lost Load for a power cut lasting one hour on a workday morning in summer was calculated to be € 17.1.

1 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 supply security during the last few decades.

This need for action is increasing, mainly because electricity production and distribution are currently undergoing restructuring. The transformation is taking place at three levels, of which the legislative component of market deregulation and that of unbundling have progressed the furthest. This first level[1] was to be implemented in accordance with EU directive 2003/54/EG (European Commission, 2003) by July 2007 (graded with regard to different customer groups) as well as the liberalization of the electricity market in every EU member state. While these provisions were transposed into national law in Germany in 2005, the electricity market in Austria had already been completely liberalized in 2001. This early implementation of liberalization steps in Austria made it possible to examine the effects of the legislative changes regarding supply security through empirical analysis (Reichl et al., 2008). Reichl et al. (2008) reached the conclusion that, while market deregulation does in fact lead to lower prices for electricity, the influence it has on supply security largely depends on the design of the accompanying regulatory framework. In line with international specialist literature the authors concluded that liberalization and unbundling do not automatically contribute to long-term electricity supply security, and that quality-orientated regulation is needed to create incentives which lead the grid operators (now independent) to focus on long-term electricity supply security and appropriate investments.

The second challenge of the future, alongside market liberalization, is the significant growth in input from renewable energy sources (RES) across Europe in coming years. This development is mainly due to major EU policy changes[2], and also to measures in individual countries[3]. This has far-reaching repercussions on the level of supply security, as various standards developed over time in the electricity industry have to be adapted, as they had been tailored to ways of generating electricity with little intermittency, such as fossil fuels,

[1] Divestiture of previously vertically integrated electric utilities

[2] E.g. defining the "20/20/20 goals", see European Commission (2011)

[3] Germany's planned nuclear exit strategy, various programs to reduce greenhouse gas emissions or new legislative frameworks with incentives to promote renewable energy sources such as the "Erneuerbare-Energie-Gesetz" (Renewable Energy Law) in Germany and the Ökostromgesetz (Eco Electricity Law) in Austria should be mentioned as influencing factors.

nuclear power and large-scale hydro-power, which still predominate today. By now the effects of expanding electricity generation with intermittent feed-in patterns on grid security (Borggrefe and Nüßler, 2009) are visible from a number of indicators. For example, the North German transmission grid operator Vattenfall Europe reported more than 197 days with "critical grid situations" in 2009 to the German Federal Grid Agency, compared with 175 days in 2008, 155 days in 2007 and only 80 days in 2006. The increasing number of critical grid situations can be interpreted as an indicator of the risk of power cuts, and is primarily due to the massive increase in wind farm output during this period.

The third level of change with respect to supply security involves growing electricity consumption (see for instance Consentec et al., 2008). Particularly in Austria, but also in Germany, the consumption of electricity has steadily risen in recent decades. Only since 2008 has the incipient economic crisis interrupted this trend (presumably not for long). Before that, from 1970 to 2008, the consumption of electricity in Austria had been increasing by about 2.9 % annually on average; in 2009 renewable energy sources accounted for 68.2 % of electricity production (Statistik Austria, 2009a).

Grid-related measures to secure the electricity supply usually entail considerable costs. Whereas measures to improve staff members' ability to cope with crises, and standardized and streamlined communication channels between the companies and institutions involved, can improve security at comparatively low cost, primary measures such as expanding capacities and creating extra redundancy throughout the grid are costly. Investments in the security of SCADA ("Supervisory Control And Data Acquisition") systems also involve massive costs and are of increasing importance.

Economically efficient decisions about investments to preserve or improve supply security require that supply security first be classified as a private or public good. If supply security is classified as a private good, then an efficient level is achieved when the marginal benefit for consumers (i.e. households, companies, establishments, institutions, including the public sector) equals the marginal cost of further improving supply security (cf. for instance Bliem, 2007; Jamasb and Pollitt, 2005). If supply security is regarded as a public good, then efficient providing is represented by the Samuelson rule (Samuelson, 1954). In that case the sum of marginal rates of substitution between private goods and the public good in question must equal the marginal costs of providing the public good. Extensions of this condition, as for instance in Lohse et al. (2006), also appear to be suited to the good of supply security, in particular investments to secure supply. Lohse et al. (2006) stress that certain goods do not benefit consumers directly but are centered around security considerations. That is why investments in the field of supply security (e.g. extra grid redundancy) do not benefit consumers during regular service. But these unused capacities are potentially capable of averting or reducing economic losses in the event of a failure. Extensive discussion regarding the question whether supply security is to be qualified as a private or public good is discussed in detail, and conclusions are drawn, in Engerer (2009) and Keppler (1996).

In any case, regarding electricity supply and the assessment of measures to secure this, it cannot be taken for granted a priori that the market will flawlessly and autonomously provide the macroeconomically optimal level of supply security. In the authors' opinion the factors leading to a potential market failure can be grouped into three categories:

1. Consumers and producers having insufficient information
2. Lack of adequate substitution options in the case of grid-based energy sources
3. Time dimension of investment decision regarding long-lived infrastructure facilities

So it seems justified to assume that consumers are only inadequately equipped to assess the benefit of supply security improvements. The excellent supply situation in Germany and Austria in the past has prevented people there from acquiring experience regarding the significance of widespread and long-lasting supply cuts, apart from a few, regionally very limited exceptions. In addition, neither consumers nor grid operators have precise knowledge of the effects of grid security measures. The effect of extra grid redundancy to avoid a power cut, or of increasing the capacity of existing infrastructure facilities, can be calculated only if the relevant data for every power supply line connected with the section of the grid under examination are available to the institution making the calculations. The risk can then be estimated on the basis of assumptions about the maximum load flow to be expected. Yet these grid data are among the most sensitive a grid operating company has, so they are not shared with others.

As a second factor for market failure in connection with supply security one has to acknowledge the lack of substitution options. In the area of grid-bound electricity supply customers do not have the option of choosing an operator with a more adequate level of supply security for them (at a correspondingly more adequate price). Here it is important to realize that consumers providing the electricity themselves (e.g. through an emergency power supply) does not constitute a solution on a par with a functioning grid-based supply. A considerable portion of the negative effects which ordinarily arise during power cuts are due not to local phenomena which could be mitigated by means of emergency power supplies, but to the outage of dependent infrastructure such as the water supply, transport system or communication facilities.

A third factor militating against market-driven, economically efficient grid security measures is the time dimension. The Austrian and German grid capacities are on a scale such that neglecting investment has so far not immediately resulted in extended power cuts. Schlemmermeier (2011), for instance, has held that the German grid operators' medium-term financial requirement amounts to about € 8 to 10 billion. The short-term resilience of the grids in spite of security-preserving investments not being made creates incentives to postpone investments which are necessary in the medium and long term. This seems particularly problematic as an ad-hoc response to a deteriorating quality of supply is almost impossible. For instance, it often takes more than 10 years (from the planning stage to approval and final completion) for new transmission lines to be implemented (cf. Boxberger, 2005). This makes timely action by companies as well as forward-looking and security-oriented incentivizing by regulatory authorities essential.

While eveloping the necessary measures to secure grid and supply security (as outlined above) is mainly a challenge to 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 further the implementation of these technical measures. One central prerequisite for developing an efficient regulatory system is quantifying the value of supply security. As supply security constitutes a non-market good and can be purchased only in combination with the physical product (electricity)[4], the value of supply security cannot be determined directly. That is why usually the failure of electricity supply, and in particular the

[4] Whereby "supply security" is a prerequisite for supplying electricity.

cost of power cuts, is used to assess the value of supply security (see Baarsma and Hop, 2009, De Nooij et al. 2007, or Woo and Pupp, 1992, for instance).

In recent years the importance of analysing potential losses caused by power cuts has attracted more and more attention in national and especially European politics. EU Council Directive 2008/114/EG (2008) requires member states to quantify the *"economic after-effects*[5]" of the power supply infrastructure failing, starting in January 2011. In this paper a model which meets this requirement of the directive (APOSTEL – *Austrian Power Outage Simulation of Economic Losses*), for scenario-based evaluation of the after-effects in widespread blackouts, is presented. It is thus possible for the first time to collect data on the value of supply security on the basis of blackout costs for companies, institutions and establishments, and of households' willingness to pay to avoid power cuts.

Chapter 2 introduces the methods utilized in this paper to evaluate losses due to power cuts. The chapter 3 evaluates two scenarios as examples of possible widespread power cuts in Austria. In chapter 4 international comparative studies are analysed and the data they provide on economic losses from power cuts, on willingness to pay to avoid blackouts and various approaches to putting a value on supply security as a good are compared with the results of this study. Chapter 5 contains the gist of the paper, and adds a conclusion on the need for further research.

2 Modelling the economic losses due to power cuts

In this chapter we elaborate on methodical aspects of modelling economic losses in the event of widespread blackouts and explain their significance for the interpretation of the figures for such losses. To do this, possible losses due to electricity outages need to be classified. The economic aftereffects can be divided into three categories (following Munasinghe and Sanghvi, 1988):

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

[5] *Whereby this is valued according to economic losses and/or losses in product and service quality.*

In the public eye direct economic losses are usually at the top of the list. Of the total economic losses they are the part which is a direct result of the failure, e.g. repair costs for defective electrical infrastructure facilities. 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 cost of production outages or lost value added. Through multiplier effects due to the marked dependence of some industries on the flawless functioning of other industries, in particular these indirect costs mostly make up a significant proportion of the total costs (cf. Centolella et al. 2006).

On the other hand there are the long-term economic effects of blackouts. These are understood to be the economically relevant changes in the behaviour of market participants as a result of a perceived long-term change in the level of supply security. Part of this category of losses is for instance the potential influence on the choice of a place as a business location[6], the potential price rise for production facilities due to the increased need for backup-systems, or customer churn due to unreliability regarding delivery deadlines. As long-term economic effects can not be assigned to individual events long-term results are not taken into consideration for the analysis of this paper for the evaluation of a single failure event, in accordance with the literature (see chapter 1).

A number of indicators are suitable for evaluating of power cuts. In the authors' opinion aggregated observations of the after-effects of a power cut, such as the electricity shortfall or the sum of losses to all market participants, are the most important parameters for judging the macroeconomic significance of a failure incident. However, these aggregated figures are not a suitable basis for evaluating the various market participants (e.g. differentiated by sector) as regards their degree of dependence on an uninterrupted electricity supply. To make this necessary comparability nevertheless possible and thus be able to identify priority targets for state intervention, such as subsidies for appropriate insurance policies or for

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[6] Examples from the field of business suggest that the specific supply security of a region can further the setting up of businesses heavily reliant on electricity. For example, in 2008, after years of searching, Kronsdorf in Upper Austria was chosen to house Google's new server station, as two particularly reliable hydro power plants and Austria's largest voltage transmission substation are nearby; thus the new location offers ideal conditions for the system-inherent uninterrupted supply of electricity which data centers need.

backup systems (e.g. emergency electricity supply facilities), it is necessary to standardize anticipated economic losses. The specialist literature often draws upon "Value of Lost Load" (VoLL); in this case the economic losses are given per kWh of electricity shortfall (see Wacker and Billinton, 1989, or Kariuki and Allen, 1996a, for instance).

Then again, some authors use indicators which refer to peak load consumption (mostly specified as kW_{peak}) (see Kivikko et al., 2007, for instance). Expressing the loss this way (in $€/kW_{peak}$) reduces the distorting effect of VoLL, which allocates lower unit costs to consumers with high electricity consumption. On the other hand it has the disadvantage of using a less well-known reference figure (kW) as well as a tendency to allocate lower costs to consumers with a very stable consumption pattern. Less commonly used indicators, such as the unit of measurement $€/kWh_{annual}$ relating to annual electricity consumption, or the indicator $€/kWh_{peak}$ relating to peak load consumption behaviour/pattern, are in the authors' opinion less suitable as inputs for optimizing regulatory systems in the context of assessing supply security.

Apart from the definitions given in the preceding paragraphs, the specialist literature provides three basic paradigms for assessing supply security in monetary terms (cf. Woo and Pupp, 1992):

- Proxy methods
- Market-based valuation methods
- Contingent valuation methods

Proxy methods rely on observable variables linked indirectly to supply security. Amongst them are, for instance, expenditure on standby generating facilities, the monetarized value of lost income and production output as well as other losses to be taken into account. Proxy methods are therefore suitable in those cases where the losses anticipated can be expressed with sufficient precision by such observable variables.

Market-based valuation methods rely on actual, observable consumer decisions and, as representatives of the revealed-preference approach, can deliver very robust data. However, within natural monopolies such as grid-bound electricity supply almost no market-based consumer decisions are observable which would permit valuating supply security (as an immaterial quantity). Ultimately consumers are by definition not in a position to make decisions along market-economy lines within natural monopolies.

Contingent valuation methods permit valuing the losses incurred from the customers' (partly subjective) perspective. With this group of methods customers themselves assign a value to the loss from failure by making their willingness to pay to avoid precisely specified power cuts known (directly or indirectly). This stated-preference method is also employed for the monetary valuation of non-material losses such as stress or lost recreational benefit, which is why this method is often used to assess households' economic losses.

Each of these three valuation paradigms focusses on different causes of losses, and how suitable they are thus varies with the relevance of these causes to any particular group of consumers. While a company suffers monetary/economic losses, households suffer not only monetary losses but also a reduction in recreational benefits, additional inconvenience and mental stress, which occurs for instance if it is not known when electricity will be available again or as a result of a complete breakdown of communications. That is why Directive 2008/114/EG requires that apart from purely financial losses *"Effects on the public[7]" should also* be valued and outlined. This is the main reason why, while further subcategorisation of market participants can make sense, the specialist literature always differentiates between households and non-households (companies, establishments and institutions) and this differentiation is reflected by the methodology chosen. In this paper the losses within the segment of non-households are represented (in accordance with the specialist literature) by means of a method which maps the lost production value (see chapter 2.1), while a contingent valuation method is used to value losses within the household segment

2.1 Methodology for assessing non-households' economic losses

As non-households have to expect solely material losses in the event of power cuts, market-based loss valuation often follows an accounting approach (see for example De Nooij et al. 2007, who recommend the use of top-down methods based on a production function and lost added value). This approach requires that all (key) activities within a non-household are checked regarding their dependence on electricity being available from the grid and the impact of possible restrictions on the process of adding value. For the level of detail in analysis described above participants need to scrutinize individual dependence on a secure

[7] *Whereby they are valued according to the effects on public trust, physical suffering and disruption of daily life, including the breakdown of essential services.*

electricity supply within their institution closely; to answer the questions for each firm in the analysis gathering these characteristics comprehensively is a prerequisite, so the questionnaire takes longer to complete than other less extensive questionnaires. Still, 267 business locations of 201 companies in all were persuaded to participate in the study. Of these 35 % were very small enterprises with 1 to 10 staff members. Small businesses with 11 to 50 employees represented 21 % of questionnaire participants. Medium-sized companies with 51 to 250 employees made up 23 % and large companies with more than 250 employees 21 %. 29.2 % of the companies were based in Vienna, 20.6 % in Lower Austria and 16.6 % in Upper Austria. Even though the largest and economically most prosperous provinces of Austria were slightly over-represented, a balanced mix of all nine Austrian provinces was still achieved. The participants came from all sectors of Austrian business and the public sector, and represented entities with a total turnover of more than € 10 billion, amounting to about 3 % of Austrian GDP. With regard to experience of power cuts 33 % of the managers participating stated that they had never observed one in their own establishment. In the event of a supply cut 27 % of survey participants regarded their establishment as not at all vulnerable. On the other hand, 32 % of participants declared it to be vulnerable or very vulnerable. The percentage share (calculated deterministically) of the total losses in the average daily value added within the establishments participating was regressed on the characteristics of the blackout *CA* analysed (date, starting time and duration) and the sector *Br* of the non-household examined. Thus for every combination of simulated blackout characteristics CA^{sim} and every sector *Br* the anticipated loss can be simulated as a proportion of the daily value added, and through aggregation of losses for a certain region and/or sector this percentage can be applied to the public economic statistics. The share $\pi(CA^{sim}, BR)$ of losses caused by a simulated power cut with the characteristics CA^{sim} in sector *Br* in the daily value added is then expressed as

$$\pi\left(CA^{sim}, BR\right) = \beta_{CA} CA^{sim} + \beta_{Br}, \qquad (1)$$

from which the aggregated anticipated total losses caused by a power cut for all provinces and industries of interest is computed as

$$GWV\left(CA^{sim}, BR^{int}\right) = \sum_{Bl} Bl^{int} \sum_{Br} tWS_{Bl,Br} \pi(CA^{sim} + BR^{int}), \qquad (2)$$

whereby β_{CA} are the OLS coefficients of outage characteristics and βBr is the sector-specific *fixed effect*. As the above detailed sample did not have sufficient data to calculate a separate *fixed effect* for every one of the 21 sectors in the NACE business classification[8], the sectors were grouped into 6 subcategories (SC-1 to SC-6), see the appendix[9]. G$WV(CA^{sim},BR^{int})$ represents the total value added lost through a simulated electricity outage with the characteristics CA^{sim} in the sectors examined BR^{int}. $tWS_{Bl,Br}$ describes the daily value added in province *Bl* and sector *Br* (taken from public statistics) in proportion to the corresponding sector load profile. The total preparatory effort wasted (GVV) has been modelled in a similar way. In Table 2-1 the regression coefficients are presented multiplied by 100 so that the respective coefficients can be interpreted as a percentage change. Based on this regression the economic losses caused by an outage on a workday between 7 a.m. and 7 p.m., say, are 13 % greater (in relation to the daily value added) than outside regular working hours.

Table 2-1: Regression coefficients of non-households' economic losses.

		Daily added value	**Daily effort in advance**
β_{CA}	Invariable	13.178**	8.39**
		(2.384)	(2.111)
	Log outage duration	9.88**	6.71**
		(1.493)	(1.320)
	Summer	-5.49	-8.77
		(5.482)	(4.846)
	Workdays 7 a.m. to 7 p.m.	13.05**	4.47
		(3.941)	(3.486)
β_{BR}	subcategory 1	4.14	0.52
		(2.745)	(2.431)
	subcategory 2	-6.46*	-1.26
		(2.798)	(2.478)
	subcategory 3	-10.01**	-1.98
		(2.813)	(2.491)
	subcategory 4	-5.93*	-3.89
		(2.947)	(2.606)
	subcategory 5	-4.42	-2.44
		(2.942)	(2.606)
	F value	**42.8**	**15.1**
	Corrected R2	**0.256**	**0.14**

*Standard errors in brackets: **Significance < 0.01, *Significance < 0.05*

[8] *"Nomenclature statistique des activités économiques dans la Communauté européenne"*
[9] The groups were formed based on the comparability of load profiles of individual sectors and with regard to an approximately balanced number of data sets per subcategory.

For this paper the performance and structure survey (LSE) by Statistik Austria, which is based on the NACE industrial classification ÖNACE 2008, was used as the data basis of public statistics. Along with the number of companies, employees, personnel costs, revenues and production value the LSE also already includes an added-value figure for most sectors. These data are available for each of the nine Austrian provinces and for 14 sectors of the first ÖNACE level; the remaining five sectors required (in particular the public sector) were estimated in line with the methodological inventory of Statistik Austria (2011). To counterbalance distortions caused by the approximation economic losses for the public sector were shown only cumulatively. The two last sectors T[10] and U[11] were ignored in this analysis due to their minimal share of nationwide business output and lack of available data.

2.2 Methodology for assessing households' economic losses

For a comprehensive analysis of the household sector it is necessary to represent immaterial losses as well as material losses. So a household survey was conducted as part of this project to evaluate WTP to avoid power cuts, quite in accordance with the recommendations of "*best practice*" choice of methods for contingent valuation methods (Arrow et al., 1993).

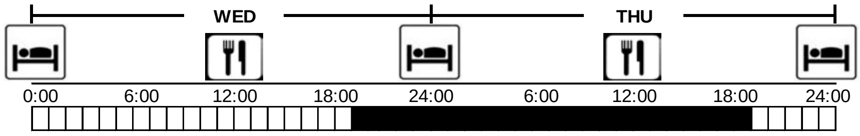
<table>
<tr><td colspan="3">Scenario 5:
Outage area: Upper Austria, Lower Austria, Salzburg
Advance warning: Yes, 3 days in advance
Time of year: from December to February</td></tr>
<tr><td>All power cuts listed here will be avoided if you pay</td><td>Costs during the next 2 years</td><td>Willing to pay?:</td></tr>
<tr><td>Begins: 7 p.m.
Ends: 7 p.m.

</td><td>17 €</td><td>☐ YES
☐ NO</td></tr>
</table>

Diagram 2-1: Scenario questions from the questionnaire on electricity supply security

[10] *Private households with domestic staff, private households producing goods and delivering services for their own requirements without a particular focus*
[11] *Exterritorial organisations and bodies*

All in all 894 households participated in the survey; to avoid influences from the survey mode two subsamples were formed. Part of the sample population were interviewed face to face, the remainder filled in a questionnaire online; the aim here was to insure against interviewing effects. 704 households were interviewed face to face. The questionnaire administered there was also implemented online as far as possible, with the aid of diagrams; a further 190 households responded online. All participants were recruited by a market research centre.

430 households provided complete sets of data; the majority of unanswered questions were the participants' household income or age. Conducting the face-to-face interview took 28.5 minutes on average, answering the online questionnaire an average of 27 minutes. Table 2-3 provides a descriptive analysis of the results from the household survey. For comparison the average figures for the whole of Austria are also provided. The participants of the survey are representative of the population of Austria. The percentage of male participants, household income and the degree of urbanization were slightly higher than the national average, while age and number of children per participating household were lower. 67.5 % of participating households stated that they had already experienced a power cut lasting more than an hour, whereas only 15 % of households stated that they had experienced power cuts lasting more than 8 hours. The participating households were shown 16 different diagrammatic power-cut scenarios one after another (see Diagram 2-1). With each scenario the households could choose whether they would prefer to pay a predefined sum of money or experience the outage depicted in the scenario. The poll participants' decisions were then econometrically assessed by means of a censored random coefficients model (Reichl, 2009) and WTP inferred following McFadden (1996). WTP(CA^{sim},*CH*) *of a* household with characteristics *CH* to avoid a simulated electricity outage with characteristics CA^{sim} is yielded by

$$WTP\left(CA^{sim}, CH\right) = \frac{\beta\left(CA^{sim}, CH\right)}{\alpha} \tag{3}$$

where $\beta(CA^{sim}, CH)$ describes the benefit to a household of avoiding a power cut as a function of its characteristics *CH a*nd the characteristics of the outage CA^{sim}. α describes the marginal benefit of income.

The econometric modelling of willingness to pay (WTP) to avoid power cuts yielded a mean result of € 17.3 per household for a 24-hour outage. In the event of a 12-hour outage a mean WTP of € 9.9 was detected; to avoid a 4-hour power cut households were willing to pay € 3.8

on average, and willingness to pay to avoid a 1-hour power cuts was assessed at € 1.4 on average. Table 2-2 shows the coefficients of the variables which influence this willingness to pay. The coefficients in this multiplicative model are to be interpreted as follows: willingness to pay with respect to an outage of whatever duration increases by the value of the coefficient for the corresponding variable as that variable increases. So willingness to pay to avoid a power cut regardless of its duration is for instance 33.39 % higher in winter. Apart from season, sex, level of education, degree of urbanization, previous blackout experience, point in time, household composition, age and household income, the geographical extent of the outage and the influence of a possible advance warning before the outage began were also investigated. As regards the geographical extent of supply security the questionnaire differentiated between a very limited outage which affected only one's own street/road and an outage which affected one's own home province and two neighbouring provinces. Unexpectedly, it seems to make no statistically significant difference whether advance warning of a power cut is given or not. Considering that the severest restrictions during a power cut affect water supply, communications and space heating, areas where substitutes are rarely available even in the case of an early warning, this result seems perfectly plausible. While age does not play a statistically significant role with respect to the actual sum one is willing to pay, the variables season, size of the outage area, participants' sex, education, household income and previous experience of power cuts do.

Table 2-2: Characteristics of Austrian households' willingness to pay to avoid power cuts

Dependent variable: WTP	Coefficient	Significance
Season = winter	0.3339	**
Outage area=3 provinces	0.2675	**
Sex = male	0.2871	**
Education = at least general qualification for university entrance	-0.2368	**
Place of residence = town (population> 10,000)	0.1173	
Experience of outages = Yes (> 1 h)	-0.1303	*
Warning = Yes(planned)	-0.0109	
Point in time = working hours	0.0153	
Household with children (under 14)	0.0910	
Age (in years)	0.0021	
Household income (in 100 €)	0.0224	**

*** 5 % significance; * 10 % significance*
Model fit statistics have not yet been developed for this model

As with the results for the non-household segment, it is possible to calculate every household's expected willingness to pay to avoid this outage on the basis of the model developed in (3). From the statistical information on the demographic key data of a province it is possible to subsequently aggregate the sum of all households' willingness to pay in the chosen region.

Table 2-3: Descriptive statistics of the household survey and the distribution throughout Austria

	This study	**Austria***
Share of men	62.4 %	48.7 %
Share of questionnaire participants with A-levels/high school diploma	54.8 %	11.4 %
Average age of participants	40.3 years	41.6 years
Households living in a town with >10.000 inhabitants	51 %	44.31 %
Average net household income per month	2,202 EUR	1,842 EUR
share of households with children under 14	23.8 %	36.67 %

** Population aged 15 and older - source: Statistik Austria (2009b)*

3 Comparison of findings with international research

In this chapter the findings from using the recently developed model APOSTEL to assess the value of a reliable power supply in Austria are compared with values from the specialist literature. To do this, the authors adapted the various indicators to the VoLL, adjusted all economic losses for inflation (all values below are expressed in 2010 €) and corrected for changes in exchange rates.

Table 4-1: Metaanalysis of various approaches to assessing supply security; VoLL for a one-hour outage under the scenario and for the sector investigated in each survey

Survey	**Scenario**	**Sector**	**€/kWh (VoLL) in 2010 €**
Fischer (1986)	USA, summer, afternoon	Trade	20.78
Woo & Gray (1987)	USA, summer, afternoon	Industry	71.63
Woo & Train (1988)	USA, summer, afternoon	Trade	10.20
Caves et al. (1990)	USA (maximum value)	Firms	26.86
Doane et al. (1990)	USA, winter, evening	Industry	8.03
Sullivan (1996)	USA	Firms	45.94
Sullivan (1996)	USA	Industry	7.62
De Nooij et al. (2007) [a]	Netherlands	Non-households	6.94
Bertazzi et al. (2005)	Italy	Firms	129.91
Bliem (2007)	Austria	Firms	216.10
Reichl et al. (2007)	Austria	Firms	7.80
Baarsma and Hop (2009)[b]	Netherlands	Firms	N/A
De Nooij et al. (2007)[a]	Netherlands	Non-households	19.13
This paper	Austria, winter, morning	Non-households	26.80
Doane et al. (1988)[c]	USA, winter, evening	Households	20.03
Doane et al. (1988)[d]	USA, summer, afternoon	Households	19.93
Sanghvi, (1983)	USA, summer, midday	Households	0.21
Bertazzi et al. (2005)	Italy	Households	4.10
Fickert (2004)	Austria	Households	2.24
Bliem (2007)	Austria	Households	5.61
Reichl et al. (2007)	Austria	Households	3.46
This paper	Austria, winter, morning	Households	2.45

a) De Nooij et al. specify the costs of outages incurred by non-households, comprising firms, institutions and facilities.

b) Baarsma and Hop employ a conjoint method (stated preferences) similar to willingness-to-pay analysis.

c) Direct costs to households.

d) Willingness to accept a tariff increase, comparable with approaches based on willingness to pay to avoid blackouts.

4 Summary

This paper discusses approaches to placing a value on the immaterial good “supply security” and develops a model to estimate the economic costs of simulated blackouts in Austria. Although the supply of electricity is relatively reliable in Europe, maintaining this degree of reliability in future involves a number of challenges. Efficient decisions on investing in infrastructure are possible only if the value of the good “supply security” is determined. To obtain an objective result, the authors carried out polls covering economic costs and personal feelings in the case of a blackout, and derived the macroeconomic effects from the economic costs incurred. The polls were carried out with households, the public sector and firms.

This paper uses a comprehensive approach to calculate the monetary value of a reliable supply of electricity for the whole of Austria, with a fairly fine-mesh classification of economic sectors. 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 all the provinces of Austria; it is thus possible for the first time to judge subsectors of the Austrian economy province by province as regards their degree of dependence on a reliable supply of electricity. This paper does not cover blackouts lasting longer than 48 hours, with their hard-to-assess social impacts, and outages in the second to minute range, which the authors regard as all but impossible to represent objectively in economic terms.

There is a need for more research into monetarizing “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.

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