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The value of lost load for electricity in the Netherlands

Final report

Client: The Netherlands Authority for Consumers and Markets

Rotterdam, June 2022

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Nederlandse samenvatting

Inleiding

In EU-verordening 2019/943 is bepaald dat lidstaten de vrijheid moeten hebben om hun eigen niveau van voorzieningszekerheid te bepalen. Wanneer een lidstaat echter maatregelen wil nemen om de voorzieningszekerheid te verbeteren, zoals een capaciteitsmechanisme, moet hij eerst een “Reliability Standard” (RS) vaststellen op basis van een transparant en verifieerbaar proces. De RS moet worden berekend aan de hand van (ten minste) de “Value of Lost Load” (VoLL) en de “Cost of New Entry” (CoNE).

In Verordening 2019/943 wordt de VoLL gedefinieerd als een raming in €/MWh van de maximale elektriciteitsprijs die afnemers bereid zijn te betalen om een stroomonderbreking te voorkomen. Bij de vaststelling van de VoLL moeten alle lidstaten dezelfde methode toepassen.

Daartoe heeft ACER (European Union Agency for the Cooperation of Energy Regulators) een uniforme methodologie bepaald voor de berekening van de VoLL. Deze methodologie is vastgelegd in ACER-besluit 23/2020: “Decision on the Methodology for calculating the value of lost load, the cost of new entry, and the reliability standard” (hierna: ACER-methodologie).

De VoLL is een kwantitatieve maatstaf voor de bereidheid van elektriciteitsafnemers om te betalen voor voorzieningszekerheid en is daarmee een nuttige input voor het bepalen van het punt waar zowel de voorzieningszekerheid als de betaalbaarheid van de elektriciteitsvoorziening zich op een maatschappelijk optimaal niveau bevinden.

Dit rapport bevat een beschrijving van het onderzoek dat Ecorys en SEO gezamenlijk hebben uitgevoerd om de Nederlandse VoLL te bepalen volgens de methodiek zoals beschreven in ACER-besluit 23/2020.

Doel van het onderzoek

Het doel van dit onderzoek is het bepalen van de Nederlandse VoLL, uitgedrukt in €/MWh, volgens de ACER-methodologie.

Methode

De ACER-methodologie laat enige ruimte voor verschillende methodologische keuzes en interpretaties. Onze aanpak voor het bepalen van de VoLL volgt de ACER-methodologie en vult deze nader in waar nodig. De belangrijkste methodologische keuze die we hebben gemaakt is om de betalingsbereidheid van elektriciteitsafnemers te bepalen met behulp van een vignettenanalyse. Onze aanpak bestaat uit vijf hoofdstappen:

1. Bepalen van de kenmerken van de typische stroomonderbreking waarvoor de VoLL moet worden berekend.
2. Het houden van een enquête onder een representatieve groep van elektriciteitsafnemers voor elk van de verschillende gebruikerscategorieën. De enquête bepaalt de betalingsbereidheid van een respondent voor het voorkomen van een typische stroomonderbreking aan de hand van een vignettenanalyse. Ook wordt de respondenten direct gevraagd naar hun betalingsbereidheid en worden een aantal relevante kenmerken van de respondenten

opgevraagd (zoals de grootte van het huishouden of de sector waarin een bedrijf actief is, het jaarlijkse elektriciteitsverbruik en de jaarlijkse elektriciteitskosten).

3. Analyse van de enquêtegegevens om de betalingsbereidheid van elke gebruikerscategorie te schatten als functie van de verschillende kenmerken van een stroomonderbreking.
4. Berekenen van de sectorale VoLLs. Dit gebeurt door de in €/onderbreking gemeten betalingsbereidheid om te rekenen naar een in €/MWh gemeten VoLL en de VoLLs van individuele respondenten te aggregeren tot sectorale VoLLs. Prijsgevoelige gebruikers worden bij de berekening van de sectorale VoLL buiten beschouwing gelaten voor het gedeelte van hun verbruik dat prijsgevoelig is.
5. Berekenen van de enkele VoLL. De enkele VoLL wordt bereikt door het vaststellen van een afschakelvolgorde, die is gebaseerd op de actuele afschakelplannen van de Nederlandse transport- en distributienetbeheerders. De afschakelvolgorde bepaalt welk type afnemer in welke mate wordt afgeschakeld, afhankelijk van de omvang van een stroomonderbreking. Op die manier levert de afschakelvolgorde wegingsfactoren op voor de sectorale VoLLs. Samen bepalen de sectorale VoLLs en de wegingsfactoren de enkele VoLL.

Daarnaast voeren wij een aantal gevoeligheidsanalyses uit om de effecten op de uitkomsten te testen van verschillende aannames en verschillende manieren om de VoLL te berekenen.

Resultaten

Typische stroomonderbreking

Op basis van modelstudies van TenneT en aanvullende analyses zijn de kenmerken van de typische stroomonderbreking als volgt vastgesteld:

- Duur van de onderbreking: 1 uur;
- Tijdstip van de onderbreking: een doordeweekse winteravond;
- Waarschuwingsperiode (de tijd tussen een waarschuwing dat de elektriciteitsvoorziening van een afnemer zal worden onderbroken en de eigenlijke onderbreking): één dag;
- Omvang van de onderbreking: 10 procent van de totale consumptie in Nederland.

Enquête

In de periode van november 2021 tot en met maart 2022 zijn enquêtes gehouden onder huishoudens, het midden- en kleinbedrijf (MKB) en grote ondernemingen. We ontvingen bruikbare antwoorden van 1.011 huishoudens en 301 ondernemingen.

Betalingsbereidheid

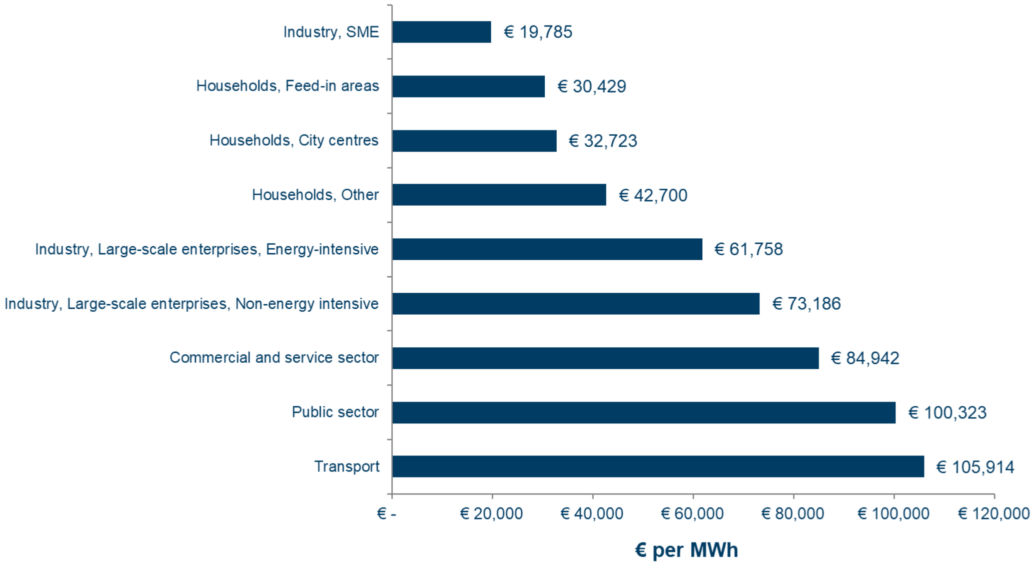
Met behulp van een vignettenanalyse en discrete keuzemodellen werden de volgende waarden gevonden voor de betalingsbereidheid van verschillende afnemerscategorieën:

- Voor huishoudens in stadscentra: 3,28 procent van de jaarlijkse elektriciteitsrekening;
- Voor huishoudens in teruglevergebieden: 3,05 procent van de jaarlijkse elektriciteitsrekening;
- Voor huishoudens in overige gebieden: 4,28 procent van de jaarlijkse elektriciteitsrekening;
- Voor kleine en middelgrote ondernemingen: 4,16 procent van de jaarlijkse elektriciteitsrekening;
- Voor grote ondernemingen: 14,01 procent van de jaarlijkse elektriciteitsrekening;

Sectorale VoLLs

Zoals blijkt uit figuur S.1 variëren de sectorale VoLL's van 20 tot 106 duizend €/MWh.

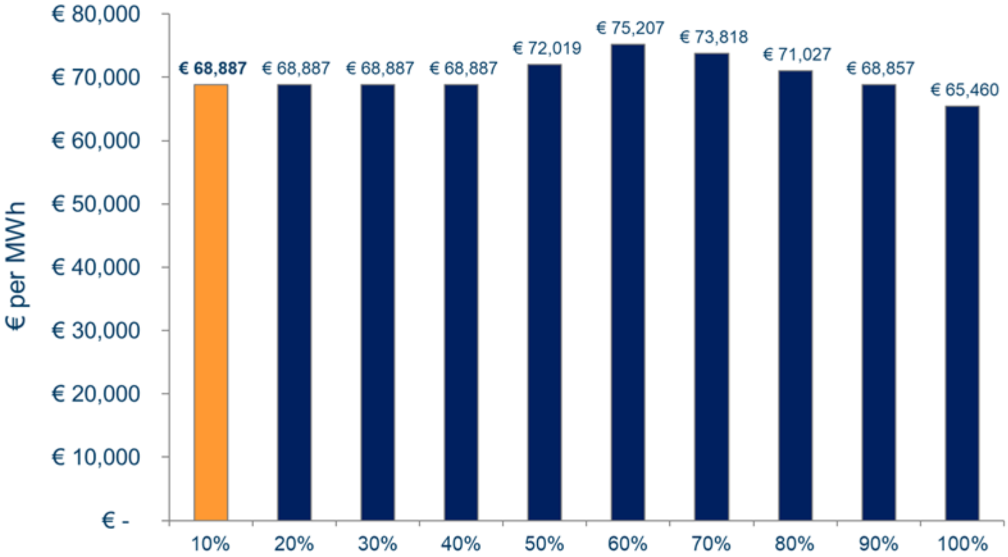
Figuur S.1 De sectorale VoLLs per afnemerscategorie



Enkele VoLL

Op basis van de afschakelvolgorde die wordt gehanteerd door de landelijke en regionale netbeheerders, is de enkele VoLL voor Nederland bepaald. Voor een typische stroomonderbreking (zoals hierboven beschreven) is deze gelijk aan 68,887 €/MWh. Voor een stroomonderbreking met een omvang van 10 procent komt dit overeen met een totale economische schade van 87 miljoen euro.

Figuur S.2 De enkele VoLL voor een stroomonderbreking van verschillende groottes



Zoals uit figuur S.2 blijkt, is de enkele VoLL relatief ongevoelig voor veranderingen in de omvang van de onderbreking. Hij blijft binnen een bandbreedte van 65 tot 75 duizend €/MWh. Dit betekent ook dat de enkele VoLL vrij robuust is voor veranderingen in de afschakelvolgorde. Merk op dat de VoLL voor een stroomonderbreking van 100 procent gelijk is aan de gewogen gemiddelde VoLL van alle elektriciteitsafnemers samen. Dit is equivalent aan een scenario waarin een stroomonderbreking gelijkmatig over alle gebruikers is verdeeld.

Vergelijking met andere studies

Tot dusver hebben vier andere EU-lidstaten een enkele VoLL vastgesteld. De resultaten variëren van 7.689 €/MWh in Zweden tot 20.000 €/MWh in Italië. Deze zijn aanzienlijk lager dan de Nederlandse VoLL. Op basis van de beschikbare informatie is het niet mogelijk met zekerheid te zeggen wat de oorzaak van dit verschil is. Wij geven drie mogelijke verklaringen, maar ook andere factoren zouden een rol kunnen spelen:

- Elektriciteitsgebruikers in Nederland zouden een structureel hogere waardering voor betrouwbaarheid kunnen hebben dan gebruikers in andere landen, bijvoorbeeld door een grotere kwetsbaarheid voor storingen of een andere economische structuur.
- De elektriciteitsprijzen in Nederland waren ongebruikelijk hoog en wisselvallig op het moment dat het onderzoek werd uitgevoerd. Hoewel deze prijzen niet in de enquête werden gebruikt, kunnen zij de antwoorden van de gebruikers hebben beïnvloed.
- Andere landen hebben een aantal andere keuzes gemaakt bij de toepassing van de ACER-methodologie, wat tot andere resultaten kan hebben geleid. Onze gevoeligheidsanalyse toont echter aan dat het gebruik van een directe uitvraag van de betalingsbereidheid in plaats van een vignettenanalyse, niet leidt tot een lagere VoLL voor Nederland.

Recente academische studies die gebruik maken van een vignettenanalyse om de betalingsbereidheid voor een betrouwbare elektriciteitsvoorziening te schatten, komen uit op een resultaat van 3 tot 14 procent van de jaarlijkse elektriciteitsrekening. Hieruit blijkt dat de resultaten van deze studie in overeenstemming zijn met de resultaten van andere vignettenanalyses. Het toont echter ook aan dat de berekening van de VoLL gevoelig is voor het prijsniveau van elektriciteit. Als de betalingsbereidheid als percentage van de elektriciteitsrekening constant blijft, betekent dit dat de VoLL stijgt en daalt met veranderingen in de elektriciteitsprijs. Er is wel een grens aan deze correlatie. Wanneer de elektriciteitsprijzen tot boven een bepaald niveau stijgen, zal er een substitutie-effect optreden.

Toepassingen en beperkingen van de enkele VoLL

In deze studie zijn de enkele VoLL en de bijbehorende sectorale VoLLs bepaald met een specifiek doel voor ogen en volgens een wettelijk bindende methodologie die hiervoor is ontwikkeld. Daarbij zijn een aantal methodologische keuzes gemaakt die geschikt zijn voor deze context, maar die voor andere contexten mogelijk niet juist of optimaal zijn. Hiermee moet rekening worden gehouden bij het interpreteren van de resultaten en het gebruik van de VoLL bij verschillende beleidsbeslissingen.

Summary

Introduction

EU regulation 2019/943 determines that Member States should have the freedom to determine their own level of security of supply. However, when a Member State wants to implement measures to enhance the security of supply, such as a capacity mechanism, it must first determine a Reliability Standard (RS) based on a transparent and verifiable process. The RS must be calculated using (at least) the Value of Lost Load (VoLL) and the Cost of New Entry (CoNE).

Regulation 2019/943 defines the VoLL as “an estimation in €/MWh of the maximum electricity price that customers are willing to pay to avoid an outage”. When setting the VoLL, all Member States must apply the same methodology.

To this end, the Agency for the Cooperation of Energy Regulators (ACER) has decided on a uniform methodology for calculating the Value of Lost Load (VoLL). This methodology is set out in ACER-decision 23/2020: “Decision on the Methodology for calculating the value of lost load, the cost of new entry, and the reliability standard” (hereafter: ACER methodology).

The VoLL provides a quantitative measure of the willingness of electricity users to pay for supply security and is, therefore, a useful input for determining the point where both security of supply and affordability are at a socially optimal level.

This report contains a description of the research jointly performed by Ecorys and SEO to determine the Dutch VoLL following the ACER methodology.

Research goal

The goal of this study is to determine the VoLL for the Netherlands, expressed in €/MWh, following the ACER methodology.

Methodology

The ACER methodology leaves some room for different methodological choices and interpretations. Our approach to determining the VoLL follows the ACER methodology and further elaborates it where necessary. The most important methodological choice we made was to determine the willingness to pay of electricity users with the help of a conjoint analysis. Our approach consists of five main steps:

1. Determining the characteristics of the typical supply interruption for which the VoLL is to be calculated.
2. Holding a survey among a representative group of electricity users for each of the different user (sub)categories. The survey determines a respondent’s willingness to pay to prevent a typical supply interruption using a conjoint analysis. It also asks respondents for their willingness to pay directly and retrieves a number of relevant respondent characteristics (e.g. household size or operating sector, annual electricity use, annual electricity cost).
3. Analysis of the survey dataset to estimate the willingness to pay of each user (sub)category as a function of the different attributes of a supply interruption.
4. Calculation of sectoral VoLLs. This is done by translating the willingness to pay measured in €/interruption into a VoLL measured in €/MWh and aggregating the respondent VoLLs into

sectoral VoLLs. Price-responsive users are excluded from the sectoral VoLL calculation for the part of their consumption which is price responsive.

5. Calculation of the single VoLL. The single VoLL is attained by determining a load shedding sequence, which is based on the actual load shedding plans of Dutch transmission and distribution system operators. The load shedding sequence determines which type of user is disconnected to what extent as a function of the magnitude of an interruption. In this way, the load shedding sequence provides weighting factors for the sectoral VoLLs. Together, the sectoral VoLLs and weighting factors determine the single VoLL.

Furthermore, we conducted a number of sensitivity analyses to test the effects of different assumptions and different ways to calculate the VoLL.

Results

Typical supply interruption

Based on model studies by TenneT and additional analysis, the characteristics of the typical supply interruption were set as follows:

- Duration of the interruption: 1 hour;
- Timing of the interruption: a weekday winter evening;
- Pre-notification period (the time between a notification that a user's electricity supply will be interrupted and the actual interruption): one day;
- Magnitude of the interruption: 10 percent of the total load in the Netherlands.

Survey

Surveys were conducted from November 2021 until the end of March 2022, among households, small and medium sized enterprises (SMEs), and large enterprises. We received useful responses from 1,011 households and 301 enterprises.

Willingness to pay

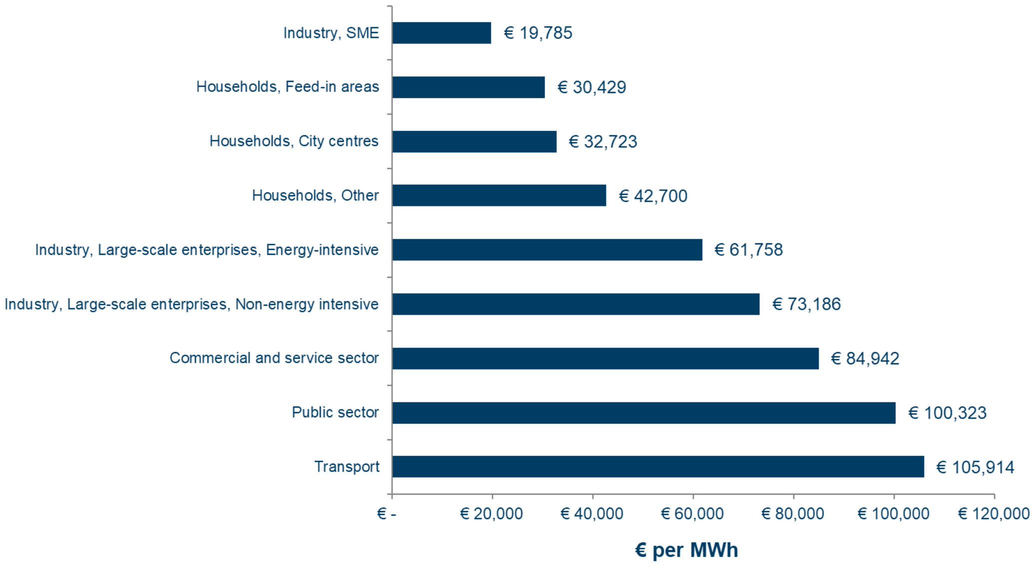
Using a conjoint analysis and discrete choice models, the following values were found for the willingness to pay of different user categories:

- For households in city centres: 3.28 percent of the annual electricity bill;
- For households in feed-in areas: 3.05 percent of the annual electricity bill;
- For households in other areas: 4.28 percent of the annual electricity bill;
- For small and medium sized enterprises: 4.16 percent of the annual electricity bill; and
- For large enterprises: 14.01 percent of the annual electricity bill.

Sectoral VoLLs

As shown in Figure S.1, the sectoral VoLLs range from 20 to 106 thousand €/MWh.

Figure S.1 The sectoral VoLLs per user category

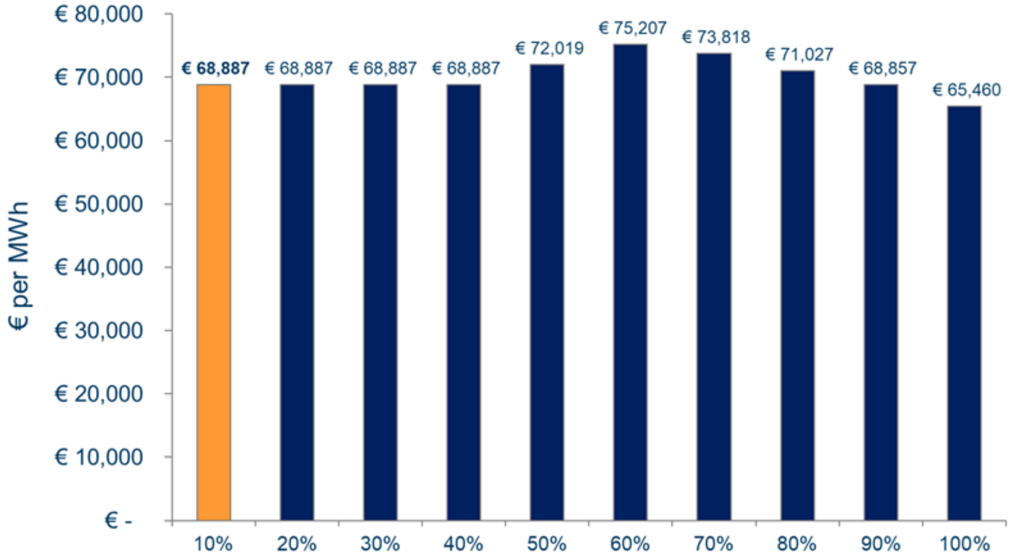


Single VoLL

By following a load shedding sequence based on those used by the national and regional grid operators, the single VoLL for the Netherlands was determined. For a typical supply interruption (described above), it was found to be equal to 68,887 €/MWh. For a supply interruption with a magnitude of 10 percent, this corresponds with a total loss of value of 87 million euro.

As shown in Figure S.2, the single VoLL is relatively insensitive to changes in the magnitude of the interruption. It moves within a bandwidth of 65 to 75 thousand €/MWh. This also means the single VoLL is fairly robust to changes in the load shedding sequence. Note that the VoLL for a supply interruption of 100 percent is equal to the weighted average VoLL of the total population, which corresponds to a scenario where a supply interruption is spread out evenly over all users.

Figure S.2 The single VoLL for different magnitudes of the supply interruption



Comparison with other studies

Until now, four other EU Member States have determined a single VoLL. Results range from 7,689 €/MWh in Sweden to 20,000 €/MWh in Italy. These are significantly lower than the Dutch VoLL. Based on the available information, it is not possible to determine with certainty what causes this difference. We offer three possible explanations, but other factors could play a role as well:

- Electricity users in the Netherlands could have a structurally higher valuation of reliability than users in other countries, for example, because of a greater vulnerability to interruptions or a different structure of the economy.
- Electricity prices in the Netherlands were unusually high and volatile at the time the survey was held. Although these prices were not used in the survey, they may have influenced users' responses.
- Other countries made some different choices in the application of the ACER methodology, which may have led to different results. Having said that, our sensitivity analysis shows that asking for the willingness to pay directly, rather than using a conjoint analysis does not lead to a lower VoLL for the Netherlands.

Recent academic studies using a conjoint analysis to estimate the willingness to pay for a reliable electricity supply yield a range of 3 to 14 percent of the annual electricity bill. This shows that the results of this study are in line with the results of other conjoint experiments. However, it also shows that the calculation of the VoLL is sensitive to the electricity price level. If the willingness to pay as a percentage of the electricity bill stays constant over time, it means the VoLL increases and decreases with changes in the electricity price. There is a limit to this correlation: when electricity prices increase beyond a certain level, a substitution effect will occur.

Uses and limitations of the single VoLL

This study determined the single VoLL, along with the accompanying sectoral VoLLs it is based on, with a specific goal in mind and following a legally binding methodology tailored to this goal. For that reason, several methodological choices were made that are appropriate for this context but may not be correct or optimal for other contexts. This should be kept in mind when interpreting the results and using them for different policy decisions.

1 Introduction

1.1 Background

The energy transition in the Netherlands has many implications for the electricity supply. The switch to renewable power sources with a variable load leads to a decentralisation of electricity supply and means supply can no longer follow demand as easily as in a traditional, centralised system powered mainly by large, fossil fuel power plants. Energy users are encouraged to save energy, but also to switch from fossil fuels to electricity as an energy source. This leads to large scale electrification of energy use and an increase in the electricity demand. Electricity system operators are tasked with maintaining and expanding the network to accommodate these changes. However, this is becoming increasingly difficult due to a lack of resources and the difficulties around spatial planning and permitting.

In the midst of all this, the security of the electricity supply remains of paramount importance. The Dutch system is one of the most reliable in the world, which is an impressive feat. Ultimately, however, the goal is not to maximise the security of supply, but to attain the optimal level. After all, there is a trade-off to be made between the security and the affordability of the electricity supply. In general, a higher level of security implies higher costs and therefore a decrease in affordability. To strike a balance between security and affordability, insight into the willingness of electricity users to pay for a secure supply is essential.

EU regulation 2019/943 determines that Member States should have the freedom to determine their own level of security of supply. However, when a Member State wants to implement measures to enhance the security of supply, such as a capacity mechanism, it must first determine a Reliability Standard (RS) on the basis of a transparent and verifiable process. The RS must be calculated using (at least) the Value of Lost Load (VoLL) and the Cost of New Entry (CoNE).

Regulation 2019/943 defines the VoLL as “an estimation in €/MWh of the maximum electricity price that customers are willing to pay to avoid an outage”. When setting the VoLL, all Member States must apply the same methodology.

To this end, the Agency for the Cooperation of Energy Regulators (ACER) has decided on a uniform methodology for calculating the Value of Lost Load (VoLL). This methodology is set out in ACER-decision 23/2020: “Decision on the Methodology for calculating the value of lost load, the cost of new entry, and the reliability standard” (hereafter: ACER methodology).

The VoLL provides a quantitative measure of the willingness of electricity users to pay for supply security and is ,therefore, a useful input for determining the point where both supply security and affordability are at a socially optimal level.

This report contains a description of the research jointly performed by Ecorys and SEO to determine the Dutch VoLL in accordance with the ACER methodology.

1.2 Research outline

Research goal

The goal of this study is to determine the Value of Lost Load (VoLL) for the Netherlands, expressed in €/MWh, following the ACER methodology.

Methodology

While the ACER-methodology offers a complete framework for calculating the VoLL, it leaves some room for interpretation and requires additional choices to be made in the application of the methodology. Chapter 2 provides a step by step description of the approach we took in this study. Where choices have been made within the framework boundaries, this is noted explicitly.

Single VoLL and sectoral VoLLs

The VoLL for the Netherlands as a whole is also called the single VoLL. The single VoLL is a function of several sectoral VoLLs. The single VoLL is calculated by assigning the appropriate weight to each sectoral VoLL and taking their weighted average.

A sectoral VoLL is the VoLL for a subset of Dutch electricity users. The required user categories are specified in the ACER methodology. This study has added a number of subcategories. Three types of households are distinguished to take into account the order in which they are disconnected in case of an inadequacy situation (see chapter 2). Furthermore, large industrial users are divided into energy-intensive and non-energy intensive users. Table 1.1 provides a complete overview of the sectoral VoLLs determined in this study.

Table 1.1 Sectoral VoLLs for electricity user categories and subcategories

User category	User subcategory
Households	• Households in city centres • Households in feed-in areas (areas with a net production of electricity >1.500 hours per year) • Other households
Commerce or service sector	
Public service sector	
Small and medium-sized enterprises in the industrial sector	
Large enterprises in the industrial sector	• Users with energy-intensive production processes • Users with non-energy intensive production processes
Transport sector	

Inadequacy situations

An inadequacy situation is defined as a situation in which the supply of electricity is interrupted as a result of insufficient production to meet demand. Inadequacy situations are characterised by:

- the duration of the interruption,
- the timing of the interruption (season, day of the week and part of the day),
- the pre-notification period, which is equal to the time elapsed between the notification of a customer and the actual interruption.

The VoLL is determined for a ‘typical’ inadequacy situation in the Netherlands. This is operationalised as the circumstances under which an inadequacy situation is most likely to occur. Inadequacy situations are assumed to occur at a national level as a result of a general shortage of electricity production. This means specific local and regional circumstances are not taken into account. The capacity and availability of the transport and distribution networks are assumed to be sufficient.

Validity

The VoLL is based on the current situation in the Netherlands, i.e. late 2021 / early 2022. Electricity prices in the Netherlands rose sharply just before the start of this study and have remained at a high level since. Based on the results of our study, we expect that the VoLL will change along with future electricity price movements.

More generally, the Dutch electricity system as a whole is in transition. In the future system, the flexibility sources used to continuously match supply and demand will shift from large fossil-fuel power plants to demand response, local production and storage facilities. In this context, it is likely that the valuation by users of a reliable power supply will change as well.[1]

1.3 Reading guide

- Chapter 2 contains a step by step description of our approach for calculating the VoLL.
- Chapter 3 provides detailed information about the survey used to gather data for the VoLL calculation. It describes the contents of the survey, the process followed, the characteristics of the respondents, and the survey results.
- Chapter 4 describes the results of the calculation of the sectoral VoLLs and single VoLL.
- Chapter 5 answers the main research question and draws a number of conclusions regarding the results of the study.

[1] One distribution system operator also mentioned in this respect that their current load shedding plan is not sustainable. Due to the increase in decentralised production, the exclusion of all feed-in areas will cease to be feasible within five years.

2 Methodology

2.1 Overview

The ACER methodology leaves some room for different methodological choices and interpretations. Our approach for determining the VoLL follows the ACER methodology and further elaborates it where necessary. The most important methodological choice is to determine the willingness to pay of electricity users with the help of a conjoint analysis.

Our approach consists of five main steps:

1. Determining the characteristics of the typical supply interruption for which the VoLL is to be calculated.
2. Holding a survey among a representative group of electricity users for each of the different user (sub)categories. The survey determines a respondent's willingness to pay to prevent a typical supply interruption using a conjoint analysis. It also asks respondents for their willingness to pay directly and retrieves a number of relevant respondent characteristics (e.g. household size or operating sector, annual electricity use, annual electricity cost).
3. Analysis of the survey dataset to estimate the willingness to pay of each user (sub)category as a function of the different attributes of a supply interruption.
4. Calculation of sectoral VoLLs. This is done by translating the willingness to pay measured in €/interruption into a VoLL measured in €/MWh and aggregating the respondent VoLLs into sectoral VoLLs. Price-responsive users are excluded from the sectoral VoLL calculation for the part of their consumption which is price responsive.
5. Calculation of the single VoLL. The single VoLL is attained by determining a load shedding sequence, which is based on the actual load shedding plans of Dutch transmission and distribution system operators. The load shedding sequence determines which type of user is disconnected to what extent as a function of the magnitude of an interruption. In this way, the load shedding sequence provides weighting factors for the sectoral VoLLs. Together, the sectoral VoLLs and weighting factors determine the single VoLL.

Furthermore, we conduct a number of sensitivity analyses to test the effects on the outcome of different assumptions and different ways to calculate the VoLL (see section 4.4).

The characteristics of the typical supply interruption are described in section 2.2. The surveys used in step 2 are included in Annex 1. Our approach to determining a user's willingness to pay using a conjoint analysis is explained in section 2.3. Our approach for calculating the sectoral VoLLs and single VoLL is described in sections 2.4 and 2.5 respectively.

2.2 Characteristics of the typical supply interruption

An inadequacy situation can be characterised based on four characteristics:

- The typical *duration* of a supply interruption;
- The typical *moment* a supply interruption occurs;
- The typical time elapsed between the *notification* of a customer and the actual interruption; and
- The typical *magnitude* of a supply interruption, i.e. which share of electricity users is affected.

Another important parameter in the context of security of supply is the typical *frequency* with which supply interruptions occur. However, this parameter is not used to characterise a single, typical interruption.

Supply interruptions rarely occur in the Dutch power grid and when they do, they are usually caused by local infrastructure issues. Therefore, insight into the characteristics of a supply interruption on a national level cannot be gained from real-life examples and has to come from model studies.[2]

To find out what an inadequacy situation 'typically' looks like in the Netherlands, we used the datasets underlying TenneT's annual resource adequacy report for electricity ("Rapport Monitoring Leveringszekerheid 2020", or "RMLZ-2020").[3] To compile the RMLZ-2020, TenneT used an energy model developed in cooperation with other high-voltage grid operators within ENTSO-E.[4] The data used to obtain an estimate of the above characteristics are the model predictions for the year 2030.

The relevant metrics from this dataset are the *Loss of Load Expectation* (LOLE) and the *Expected Energy Not Served* (EENS). ACER defines the LOLE as "the expected number of hours, in a given geographic area and in a given time period, during which capacity resources are insufficient to meet the demand and hence positive ENS occurs". The 'energy not served' (ENS) is defined by ACER as "the energy which is not supplied due to insufficient capacity resources to meet the demand for a given geographic area and time period". Finally, the EENS is simply defined as "expected ENS".

In the RMLZ-2020, TenneT defines five scenarios and analyses them using a national as well as a European model.[5,6] We base our current analysis on the results of Base Case Projection 3 (BS3), obtained from the European model. BS3 represents the most ambitious scenario in terms of achieving Dutch climate objectives. It is not necessarily the most likely scenario to be realised in 2030, but it is the scenario with the highest EENS and therefore provides the most information about when supply interruptions are the most likely to occur and what they will look like.

Figure 2.1 shows the distribution (in numbers) of the duration of the 77 inadequacy events generated by the European model in BS3 and forms the basis of the LOLE determination. Their duration ranges from 1 to 6 hours. The most common duration of a supply interruption is one hour.

2 Ideally, a combination of real-life examples and model studies would be used.

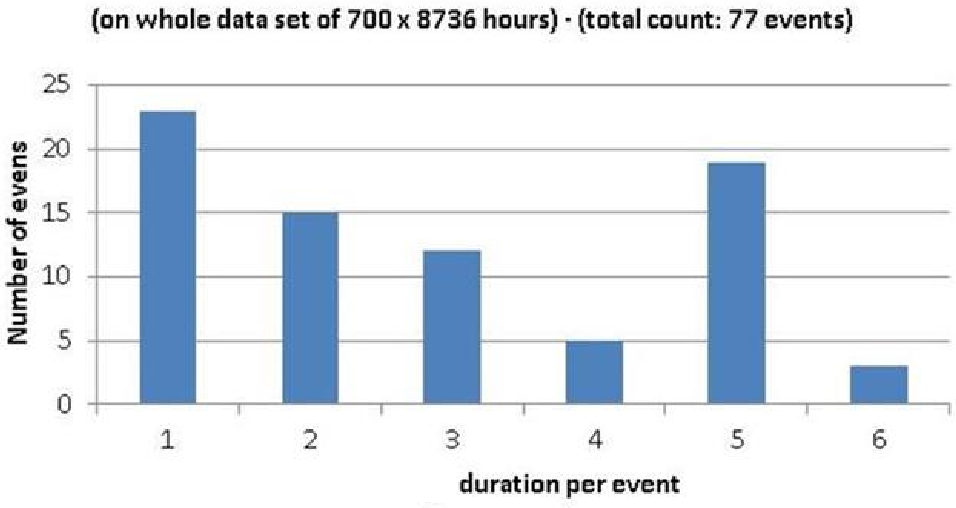
3 https://www.tennet.eu/nl/bedrijf/publicaties/rapport-monitoring-leveringszekerheid/

4 This model is also used for Midterm Adequacy Forecast and Pentalateral Energy Forum studies.

5 The difference between these two models is that the national model excludes the international transmission of electricity from the analysis.

6 The five scenarios used by TenneT are coined: BS0, BS1, BS2, BS3 and FSI. Where 'BS' stands for 'Base Case Projection' and FSI for 'Foundation for System Integration'. BS0 serves as a baseline scenario. The assumptions underlying the developments of demand and supply of electricity in this scenario can be found in chapters 3.1 and 3.2 of the RMLZ-2020. BS1 adds to BS0 a modification of the assumption regarding the (un)availability of the means of electricity production. BS2 is similar to BS1, except that from 2030 onwards the biomass-fired coal capacity (0.7 GW) is no longer operational. BS3 adds a reduction in operational gas capacity of 1.6 GW beginning in 2021.

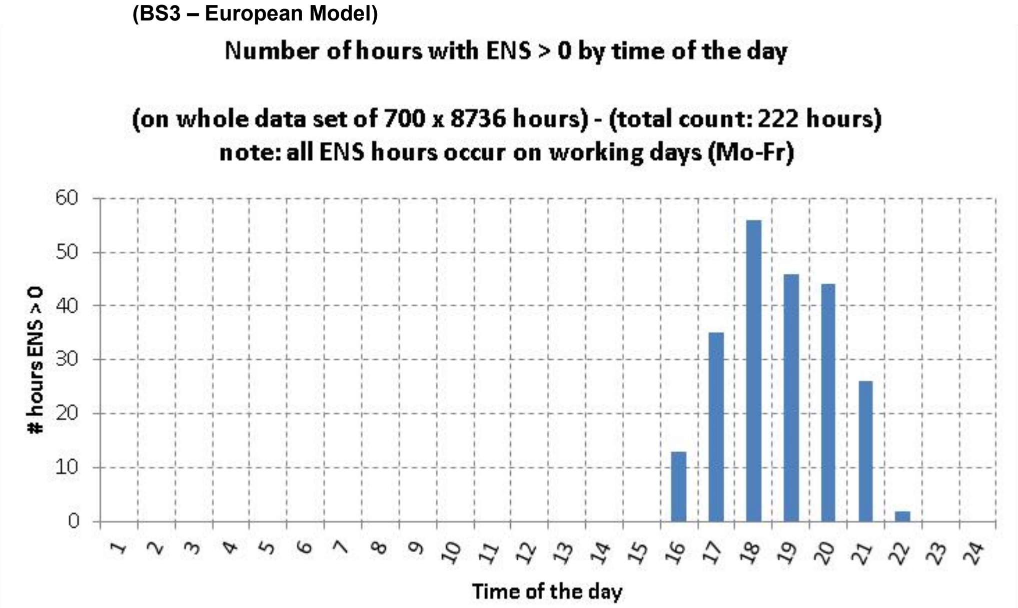
Figure 2.1 Distribution of supply interruption durations in the TenneT RMLZ-2020 study (BS3 – European Model)



Source: Tennet (2020)

Figure 2.2 shows that the interruptions generated by the TenneT model occur on weekdays from the 16th up to the 22nd hour (15:00-22:00h). Furthermore, the data show that the interruptions occur mainly in the winter months of January and February with small amounts in March. This is caused by both the relatively high demand for electricity during the winter months (due to fewer hours of daylight) and low supply (due to less production from sun and wind).

Figure 2.2 Occurrence of interruptions over the day in the TenneT RMLZ-2020 study (BS3 – European Model)



Source: Tennet (2020)

The magnitude of the supply interruption in BS3 varies from (almost) 0 to 4 GWh per hour, which translates into 0 to 32 percent of total demand.[7] Based on information from other countries, ACER advises the use of a magnitude of 5 to 10 percent of peak demand for the calculation of the Single VoLL. Based on their simulations, TenneT advises the use of a magnitude of 2 GWh per hour or

7 Given that the total hourly consumption of the entire Dutch population during a winter weekday evening amounts to 12.7 GWh/h; see Annex II for a breakdown of this consumption by sector.

approximately 10 percent of total demand. Based on these sources, in this study we use a magnitude of 10 percent of the expected total demand at the time of the supply interruption.

The expected pre-notification period was not part of the RMLZ-2020. Based on conversations with TenneT, we estimate it at one day.

Table 2.1 summarises the expected values for the relevant characteristics of a typical supply interruption.

Table 2.1 Characteristics of the typical supply interruption based on the TenneT RMLZ-2020 study (BS3 – European Model)

Characteristic	Unit	Expected Value
Duration	Hour	1
Moment	Season	Winter
	Type of day	Weekday
	Part of the day	Evening
Pre-notification period	Days	1
Magnitude	Demand percentage	10

2.3 Conjoint analysis

Background

A conjoint analysis is a survey-based statistical technique to identify the willingness to pay for attributes (characteristics) of products and services in an experimental setting. Conjoint analysis is one of the main tools for researchers to study consumer behaviour and the underlying explanatory variables of the behaviour. In the 1980s, Louviere & Woodworth (1983) and Nobel laureate McFadden (1986) were amongst the first to study consumer behaviour using experiments in which consumers were asked to choose their most preferred alternative out of multiple alternatives in a hypothetical choice setting. One of the main conclusions of these early contributions is that the indirect way of measuring preferences is better for predicting and understanding actual consumer behaviour, than directly asking consumers for their willingness to pay.

The core benefit of conjoint analysis is that respondents are required to make a trade-off between different attributes, for example between the price and the quality of a product. Because alternatives differ in multiple attributes, the probability of strategic or socially desirable behaviour is lower compared with a direct question on the willingness to pay for a certain attribute. The choices respondents make reflect their preferences and are used to measure/identify the willingness to pay for attributes.

Conjoint analysis uses stated preferences instead of revealed preferences This implies studying choice behaviour in hypothetical situations/scenarios (stated preferences) instead of analysing current or past consumption patterns in actual markets (revealed preferences). Due to its nature, analysing stated preferences has a few important advantages compared with revealed preferences analysis.

First, using stated preferences enables the researcher to study choice behaviour in situations that may not (frequently) occur in real markets for example by looking at combinations of levels of attributes of new products or services.

Second, by designing the experiment the researcher can include greater variability of combinations of levels of attributes than experiences in current markets. Revealed data on actual markets often lacks the necessary data variability to identify consumer preferences, because, for example, in real markets price variability (around an equilibrium price) is low.

Third, stated choice experiments provide the researcher with more control over factors that may influence choices. The researcher determines the choice set, the attributes and the accompanying attribute levels for each of the alternatives to be considered by the respondent. In choice experiments with actual demand data, for example transaction data, researchers need to make additional assumptions on the choice set and attribute levels as experienced by the respondent at the moment of the choice.[8]

The main disadvantage of using stated preferences is that it analyses behaviour intentions instead of real behaviour. Intentions can sometimes deviate from real behaviour, which means that results based on stated preferences have to be interpreted with caution. Deviation from real behaviour might be systematic, for example for strategic reasons, or of a random nature, for example because of having difficulties in carrying out the stated-preferences survey. The systematic deviation might warrant more attention compared with a random deviation. Irrespective of the cause of the deviation, the design of the stated preference survey should be such to minimise the possible deviation from real-life choices. The possible deviations can be influenced by the formulation of the questions and the specific stated preference method that is used.[9] Furthermore, the design of the choice set is determined by the researcher and may not always be complete. Some other characteristics could be relevant for choices, but cannot be included in the analysis if they are not part of the used design.

Current conjoint analysis and discrete choice model

The current conjoint analysis is targeted at households, small and medium-sized enterprises, large enterprises and (semi-) public organisations. Each respondent to the survey is asked to make ten choices, each time between three hypothetical electricity contracts. The energy contracts only differ in the following six characteristics describing the interruption:

1. frequency;
2. length;
3. day of the week;
4. time of day;
5. season;
6. whether or not, and if yes when, the interruption has been announced.

These six characteristics are in line with the proposed parameters of Article 5 of the ACER methodology.[10] To be able to identify the willingness to pay for the main attributes of interest, i.e. frequency and potentially length of the interruptions, we also include the price of the energy contract as an attribute and let it vary between the three contracts. Earlier conjoint studies on the same topic used a percentage price reduction and asked the respondents how much money – in discount – they would need to accept a typical interruption. This latter approach is the so-called willingness to accept framework whereas the aim of this study is to measure the willingness to pay to avoid a typical interruption. Measuring the willingness to pay is one of the requirements in the ACER methodology.

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8 In both revealed and stated preferences studies, researchers may need to take into account the unobserved heterogeneity among respondents, but with stated-preferences studies the researcher can exclude the unobserved heterogeneity of information and available alternatives.

9 Deviations for example generally occur less with conjoint analysis than with contingent valuation, another stated preference method.

10 Frequency is included as an optional parameter in the ACER methodology.

Ten times in a row, the respondent (e.g. a household) is offered three alternatives. The offered alternatives vary over each of those ten choice situations. With each set of three alternatives, the respondent is asked to choose the contract they prefer. In making this choice, the respondent has to weigh the different attributes and attribute levels of the three alternatives offered. In the design of the conjoint analysis, it is important on the one side to maximise the variation in (combination of) attribute levels whilst on the other side to avoid showing illogical or unrealistic alternatives. The variation in attribute levels is necessary to be able to identify the preferences for attributes, and, hence, the willingness to pay for the reliability of the electricity network. Based on this willingness to pay, the value of lost load (which is a closely related concept) can be determined.

The outcome is a discrete variable, in this case, the choice between energy contract 1, 2 or 3. To study the collected data and estimate the willingness to pay, we employ so-called discrete choice models. The discrete choice model provides the framework to link the discrete choices of respondents to utility-maximizing behaviour (Train, 2009). By using individual utility maximising behaviour as the backbone of the model, the framework is firmly based in economic theory. McFadden (1978) has been one of the first to explicitly link discrete choice models – i.e. multinomial logit models – to utility theory.

The utility that respondents derive from the alternative, or the choice set, is based on the characteristics of each of the alternatives. The respondent chooses the alternative that maximizes their own utility. For example, one would expect that all else being equal, lower costs of the energy contract would yield higher utility. For frequency and duration one would hypothesise that a higher frequency and greater lengths of interruptions would decrease utility. For receiving a notification one would hypothesise that (most) participants prefer to receive a warning in advance (information value). The other characteristics of the energy contracts may have less strong predictions beforehand because they may be more correlated with the respondent (e.g. whether or not a certain weekday of the interruption yields more or less utility may depend on the individual working schedule).

To be precise, the indirect utility respondent *n* derives from energy contract *i* can be defined as:

$$V_{in} = \beta_1 \cdot frequency_i + \beta_2 \cdot duration_i + \beta_3 \cdot day\ of\ week\ _i + \beta_4 \cdot time\ of\ day_i$$
$$+\beta_5 \cdot season_i + \beta_6 \cdot notification_i + \beta_7 \cdot price_i + z_i \cdot \theta_n + \varepsilon_{in},$$

where the β parameters denote the parameters of interest relating to several attributes (e.g. frequency or duration) and capture the impact of the attribute on utility, z_i denotes a vector of alternative specific parameters for the vector of θ_n, respondent specific variables, such as household characteristics. The error term is captured by ε_{in} and accounts for any unobserved part of the choice behaviour.[11]

The above specification – for reasons of clarity – considers all of the variables as continuous variables, whereas the day of the week, time of day, season and notification may be better specified as discrete variables. This does increase the number of parameters to be estimated – e.g. one would get four parameters for the season with one of them being constrained to zero for identification purposes – but does not alter the basic explanation and functioning of the model. Another specification choice is the functional form in which the variables enter the indirect utility function. In our case, this mainly refers to the price and duration variables. To take into account differences in price levels between respondents due to differences in electricity consumption we

[11] By assuming the error term is independent and identically Gumbel distributed, the above specified model returns the multinomial logit model with the expected demand functions specified as the usual logit probabilities.For a thoroughly discussion of the multinomial logit model and its properties, we refer to Train (2009).

specify the price variable as the logarithm of the variable. In this way, the analysis focuses more on the relative price variation (e.g. as percentage of the current energy contract). As a consequence, the impact of one additional euro in electricity costs is not imposed to be the same for all respondents. Similarly, the log of the length of the interruption allows for increasing lengths of interruptions having a less than proportionate impact on the utility.

The above specification only concerns the main effects. One may, however, want to test whether the utility impact – and hence the willingness to pay – of an interruption depends on the length of the interruption. To do so, one needs to specify so-called interaction terms, for example:

$$V_{in} = \beta_1 \cdot frequency_i + \beta_2 \cdot duration_i + \beta_3 \cdot day\ of\ week\ _i + \beta_4 \cdot time\ of\ day_i + \beta_5 \cdot season_i \\ +\beta_6 \cdot notification_i + \beta_7 \cdot price_i + z_i \cdot \theta_n + \beta_8 \cdot (frequency_i \cdot duration_i) + \varepsilon_{in},$$

where β_8 now denotes the additional utility impact of the interaction of frequency and duration. If this parameter is negative and statistically significant, the impact on the utility of the frequency increases when the length of the interruption is greater. In a similar manner, one may also test other interactions with frequency, for example whether the frequency of interruptions has a different impact on utility over different seasons, days of the week or times of day.

The parameters of the model are determined via estimation. Due to the specification within the multinomial logit framework, the parameters do not have a direct interpretation, other than their sign and whether or not being statistically different from zero. For a meaningful interpretation we need to look at the willingness to pay implied by the estimates of the β parameters. The willingness to pay is the amount of money the respondent is willing to give up in order to get a better alternative via one other attribute. For example, the amount of money the respondent is willing to give up (to pay) for avoiding one additional interruption. The willingness to pay for frequency is defined as:

$$\frac{\partial V_{in}}{\partial frequency_i} \Big/ \frac{\partial V_{in}}{\partial price_i} = \frac{\beta_1 + \beta_8 \cdot duration_i}{\beta_7},$$

or when considering the specification with log price and log duration:

$$\frac{\partial V_{in}}{\partial frequency_i} \Big/ \frac{\partial V_{in}}{\partial price_i} = \frac{\beta_1 + \beta_8 \cdot \ln duration_i}{\beta_7} \cdot price_i.$$

In the log specification, one would find the willingness to pay as a percentage of the electricity bill while not multiplying by the average price of the electricity bill $price_i$. Furthermore, irrespective of whether the interaction between duration and frequency is statistically significant, $\left(\beta_1/\beta_7\right) \cdot price_i$ gives the willingness to pay to avoid an interruption with a duration of one hour.[12]

[12] Duration is measured in hours and the log of 1 (hour) equals zero, hence the interaction parameter does not change the willingness to pay in that case.

2.4 Calculation of sectoral VoLLs

Concerning the calculation of sectoral VoLLs, Article 6(7) of the ACER methodology states the following:

> **"For each category (and/or sub-category) of consumers, sectoral VOLLs expressed per supply interruption in the surveys shall be converted in sectoral VOLLs per MWh. For this purpose, the amount of electricity consumption of the interviewee cut off during the interruption scenario shall be estimated, by combining the interviewee's monthly or yearly consumption with standardised consumption profiles defined per consumer type (or more precise information if available)."**

This is a fairly broad and general description, which leaves some room for choices to be made within the boundaries of the methodology. We calculate the sectoral VoLLs in three steps:

1. Converting the willingness to pay (in €/interruption) of survey respondents into so-called individual VoLLs (in €/MWh), using yearly consumption figures and standard within-year consumption profiles;
2. Determining to which VoLL sector each respondent belongs based on respondent characteristics (for the list of sectors, see section 1.2);
3. Aggregating the individual VoLLs into sectoral VoLLs by taking the weighted average of the individual VoLLs.

The result of the conjoint analysis is the willingness to pay of electricity users to avoid a typical supply interruption. The first step in determining the sectoral VoLLs is then to convert a user's willingness to pay to avoid a single interruption (in €/interruption or €/hour) into a VoLL for each user in €/MWh. In general, this is done using the following formula:

$$VoLL = {}^{WTP}\!/_{interruption\ volume}$$

In this formula, WTP is the amount in euros that a respondent is willing to pay to avoid a typical supply interruption and the interruption volume is the amount of electricity in MWh that a respondent would consume during the interruption period if the interruption did not occur.

In this study, the willingness to pay is estimated as a percentage of the annual electricity bill. This gives us a number of euros in the numerator.

$$WTP = x * annual\ electricity\ bill$$

The interruption volume is obtained starting from a respondent's annual electricity use. This is divided by 8,760 to yield an average hourly use in MWh. A dimensionless profile correction factor (PCF) is added to take into account that the electricity use at the time of interruption may be different from the average hourly use. We determine the PCF using the standard consumption profiles from the Dutch Energy Data Exchange Association (NEDU). Multiplication of the average hourly use with the PCF yields the interruption volume in MWh in the denominator.

$$interruption\ volume = {}^{PCF\ *\ annual\ electricity\ use}\!/_{8760\ hours}$$

The VoLL-formula then becomes the following:

$$VoLL = {}^{x\ *\ annual\ electricity\ bill}\!\Big/_{\left({}^{PCF\ *\ annual\ electricity\ use}\!/_{8760\ hours}\right)}$$

As the annual electricity bill is equal to the annual electricity use times the electricity price, it follows from the formula that the VoLL for an individual user does not depend on its absolute consumption level, but rather on the relative magnitudes of its 'x-factor', its electricity price and its profile correction factor.

Exhibit 2.1 Example calculation of individual VoLLs

A numerical example can clarify this procedure:

1. A household may have a willingness to pay equal to 5 percent of its annual electricity bill to avoid a supply interruption. An average household uses about 3 MWh of electricity each year at a price of 200 €/MWh, giving him an annual bill of 600 euros and a total WTP of 30 euros. At the time of a typical interruption (a winter evening), a household typically consumes twice as much electricity as in an average hour. It is therefore given a PCF of 2.
   The total VoLL for a household then becomes: 30 / (3 * 2 / 8,760) = **43,800 €/MWh**

2. A large industrial user is generally more sensitive to a supply interruption and so may have a willingness to pay equal to 15 percent of its annual bill. Its electricity price is usually much lower, because of a lower tax level and a much higher use to spread out the fixed supply costs. Its annual bill could therefore be equal to 50,000,000 euros (based on annual use of 1,000,000 MWh at a price of 50 €/MWh), giving it a WTP of 7,500,000 euros. Since a large industrial user has a fairly flat consumption profile over the year, it is given a PCF of 1.
   Its VoLL then becomes: 7,500,000 / (1,000,000 * 1 / 8,760) = **65,700 €/MWh.**

At first glance, it may seem confusing that a household's VoLL is much higher than its annual electricity bill. It is important to realise that the loss of load for a household caused by the average interruption has a magnitude of less than a kWh. As a consequence, converting the willingness to pay into an amount per MWh results in a very large number.

The second step in determining the sectoral VoLLs is to determine in which user category each user belongs. To this end, several user characteristics are employed:

- The sector to which a company belongs is based on the Dutch Standaard Bedrijfsindeling (SBI), which in turn is based on the activity classification of the European Union. The mapping of SBI codes to VoLL sectors is provided in table 2.2.
- The division between SMEs (small and medium-sized enterprises) and large companies is based on two characteristics: annual turnover and number of employees. Using the definition of the Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland), a company counts as an SME when it has an annual turnover of no more than 50 million euros and no more than 250 employees. [13]
- The division between energy intensive and non-energy intensive companies is made by dividing a company's annual electricity cost by its annual turnover. If this is more than 3 percent, it counts as energy intensive (note that this is in fact a measure of its electricity intensity rather than its energy intensity.)
- The division between households in city centres, households in areas with net production (also referred to as 'feed-in areas') and other households is based on data provided by Statistics Netherlands (CBS)[14] and the Climate Monitor[15]. Specifically, municipal-level data on urbanity is combined with volume data on electricity generation and consumption within municipalities.

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13 https://www.rvo.nl/subsidie-en-financieringswijzer/tvl/mkb-grote-onderneming
14 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84378NED/table?ts=1648213773494
15 https://klimaatmonitor.databank.nl/

Households in municipalities whose urbanity or ‘address density’[16] is 1,500 or more are designated as urban centres. Households in municipalities with an address density less than 1,500 unique addresses per km^2 *and* an electricity production of more than 10 percent of its annual consumption are considered to live in feed-in areas. Households that do not fall within either of these two categories are labelled as ‘other’. The three categories are mutually exclusive, i.e. there is no overlap between the categories.

Table 2.2 Mapping of SBI-codes to VoLL-sectors

ID	SBI description	VoLL sector
A	Agriculture, forestry and fishing	Industry
B	Mining and quarrying	Industry
C	Industry	Industry
D	Production and distribution of and trade in electricity, natural gas, steam and chilled air	Industry
E	Water collection and distribution; sewerage, waste management and remediation activities	Industry
F	Construction	Industry
G	Wholesale and retail trade; repair of motor vehicles	Commerce or service
H	Transportation and storage	Transport
I	Accommodation, food and beverage service activities	Commerce or service
J	Information and communication	Commerce or service
K	Financial intermediation	Commerce or service
L	Real estate renting and trade	Commerce or service
M	Advisory, research and other professional services	Commerce or service
N	Renting of movable property and other business services	Commerce or service
O	Public administration, public services and compulsory social security	Public service
P	Education	Public service
Q	Health and welfare activities	Public service
R	Culture, sport and recreation	Public service
S	Other services	Commerce or service

The third step in determining the sectoral VoLLs is to take the volume-weighted average of all individual VoLLs within a sector. More specifically, the sectoral VoLLs are calculated as the weighted sums of respondent-level VoLLs, where the weights are represented as the relative shares of hourly volumes of electricity consumed.

In Article 7(2)(a) of the ACER methodology, ACER states that the calculation of the single VOLL shall exclude price-responsive consumers for the proportion of their offtake which is price-responsive, provided sufficiently detailed data is available. As we have data concerning price responsiveness at an individual level rather than at the population level, we already exclude such respondents in the calculation of the sectoral VoLL. This means that if 30 percent of a respondent’s offtake is price responsive, its VoLL is included in the sectoral VoLL with a weight equal to 70 percent of its total volume.

[16] Expressed as the number of distinct addresses per square kilometre.

Exhibit 2.2 Example calculation of sectoral VoLL

The following example illustrates how a sectoral VoLL is computed from individual VoLLs.

Assume we collected information on five companies active in the industrial sector. The VoLLs of these companies and their hourly consumption volumes (corrected for demand-side responsivity) are depicted below:

Company	Individual VoLL (€/MWh)	Hourly consumption volume* (MWh)	Volume share (%)	Weighted VoLL (€/MWh)
A	€ 40,000	100	27%	€ 10,667
B	€ 60,000	75	20%	€ 12,000
C	€ 80,000	90	24%	€ 19,200
D	€ 70,000	110	29%	€ 20,533
Total		**375**	**100%**	**€ 62,400**

* = excluding price-responsive respondents, for the proportion of their offtake which is price-responsive

To compute the VoLL of the industrial sector, we first compute the relative consumption volumes for each company. This is done by dividing each company-specific hourly consumption volume by the sectoral total (which is 375 MWh in this example). These shares are then used to weigh the company VoLLs. Weighing the company VoLLs is done by multiplying them with their volume shares. These weighted VoLLs are then summed to obtain the sectoral VoLL, which, in this example, totals **€ 62,400 per MWh**.

2.5 Calculation of the single VoLL

ACER describes the methodology for calculating the single VoLL in Article 7 of the ACER methodology. The basis of the calculation is taking the volume weighted average of the sectoral VoLLs (Article 7(4)). However, as not all users are affected equally by a typical supply interruption, ACER specifies that the weight attributed to each sectoral VoLL shall reflect the applicable load shedding processes used by grid operators (Article 7(5)).

This means two things. First, when 10 percent of total load is shedded (as is the case for the typical supply interruption defined in section 2.2) only 10 percent of all electricity users is affected and therefore only these users shall have any weight in the single VoLL calculation. Second, the order in which the load of different users is shedded, determines which electricity users are part of this 10 percent and which are not.

Article 7(5) provides two options for calculating the single VoLL:

- A marginal approach, where the degree to which an electricity user is affected by a decrease in shedded load (e.g. from 10 to 9 percent of the total load) determines its weight, and
- An average approach, where the volume weighted average of all electricity users affected is taken.

In this study, these approaches are equivalent, because the users affected by a 10 percent load shedding event are affected equally by a reduction of shedded load. (See below for an explanation of why this is so.)

Finally, ACER specifies how to attribute weights to different sets of VoLL parameters (i.e. different supply interruptions, Article 7(4) and 7(5)). However, this is also not relevant to this study, because we define only one typical supply interruption.

Based on conversations with the national grid operator and the three largest regional grid operators, we interpret the Dutch load shedding sequence as follows:

National grid operator (TenneT):

- TenneT aims to maintain a frequency of 50.0 Hz on the grid, in cooperation with other TSOs. When the generation of electricity is at any time lower than consumption, the frequency will decrease below 50.0 Hz and a number of measures can be taken to restore the frequency. These include deployment of the frequency containment reserve (FCR), the frequency restoration reserve (FRR), the mandatory scale-up of production units (limited frequency sensitivity mode underfrequency, or LFSM-U) and the mandatory switch to generation mode (or shutdown) of storage units.
- If these measures are insufficient to restore the frequency and it drops further to 49.0 Hz, the low frequency demand disconnection (LFDD) is activated. This entails that TenneT will automatically shed 45 percent of the total load in six steps of 7.5 percent. The first 7.5 percent is disconnected at 49.0 Hz, the second at 48.8 Hz and so on, until the sixth step is taken at 48.0 Hz. The maximum number of 45 percent follows directly from EU law.[17]
- TenneT distinguishes between four types of users connected to the national grid: large industrial users, regional grid operators, closed distribution system operators (CDSOs) and high priority significant grid users. High priority significant grid users are excluded from the LFDD. The other three user categories are each required to contribute to the shedding of load proportionally to their own electricity use. Regional grid operators and new installations of industrial users and CDSOs are required to implement the six steps of 7.5 percent themselves. Existing industrial users and CDSOs can make individual arrangements with TenneT if they are not able to implement the six steps in their own systems. Such an arrangement could mean that different amounts of load are disconnected at different thresholds, to accommodate an industrial user's production processes. However, the total disconnected load volume will add up to 45 percent at the end. Users can also opt not to implement automatic load shedding. In that case, 100 percent of their load is shedded by TenneT as part of the total load shedding process.
- For the purpose of the VoLL calculation, we assume that regional grid operators, industrial users and CDSOs all shed their load in six steps of 7.5 percent. While this is a simplification, it is on average correct.

Regional grid operators

- As outlined above, regional grid operators are required to participate in the LFDD process and shed their load in six steps of 7.5 percent.
- Furthermore, regional grid operators are required by Dutch law[18] to distinguish between three types of users when designing their load shedding sequence:
  - First, all industry, public buildings, companies and households which are not part of the two other categories (see below) are disconnected.
  - Second, critical industrial processes, utilities and processes fulfilling other basic societal needs are disconnected;
  - Third, institutions involved in maintaining public order and security and intramural health care facilities are disconnected.
- In practice, regional network operators cannot distinguish between these types of users perfectly. Their sequence is therefore set up at transformer station level, which means different types of users are grouped together to some extent. As a rule of thumb, city centres are placed in the third category, as a proxy for institutions involved in public order and security.

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[17] EU Regulation 2017/2196, establishing a network code on electricity emergency and restoration.

[18] Artikel 22 van de Regeling van de Minister van Economische Zaken, houdende regels inzake tariefstructuren en voorwaarden voor elektriciteit (Regeling inzake tariefstructuren en voorwaarden elektriciteit).

- Finally, feed-in areas, defined as areas which supply rather than consume electricity for more than 1,500 hours each year, are excluded from the load shedding sequence (because they can help to maintain the power balance).

Load shedding sequence

Based on the load shedding sequences followed by the Dutch grid operators, we use the following load shedding sequence for the Netherlands as a whole, outlined in table 2.3. It distinguishes four priority levels and allocates each user category to one of the four levels. Depending on the size of a supply interruption, different user categories will be affected to a different extent. In case of a small interruption, only the first category is affected. With a growing interruption size, other categories will increasingly be affected too.

Table 2.3 Load shedding sequence for the purpose of the single VoLL calculation.

Level	User type
1	• Users connected to the national grid. • Users connected to the regional grid without special status.
2	• Users connected to the regional grid and involved in critical process industry, utilities and basic services.
3	• Users connected to the regional grid and involved in maintaining public order and safety or public health. • Households located in city centres.
4	• Households connected to the regional grid and located in feed-in areas*.

* = feed-in areas are those with a net production of electricity for more than 1,500 hours per year.

For the calculation of the single VoLL, this means the volumes associated with the sectoral VoLLs have to be split in two ways:

- a split between users connected to the national grid and users connected to a regional grid.
- a split between users falling into a protected category and those that do not.

For each sector, the share of its consumption as a fraction of the total consumption in the Netherlands is determined. Where possible, these shares are based on publicly available data from CBS and TenneT. Where such data are lacking, the data from the survey are used as a proxy for the population as a whole. This is the case for the relative shares of several user subcategories. For example, there are no data publicly available concerning the ratio of energy intensive versus non-energy intensive users in the industrial sector.

The single VoLL can then be calculated as the volume weighted average of the VoLLs of all user categories which are affected in a typical supply interruption. It should be noted that if a user category sheds only part of its load, it will receive a smaller weight in the single VoLL. So, if category 1 is disconnected completely and category 2 is disconnected for 50 percent, the sectoral VoLLs of users in category 1 will have a weight of 100 percent of their volume, whereas the sectoral VoLLs of users in category 2 will have a weight of 50 percent of their volume.

Exhibit 2.3 Example calculation of the single VoLL

The following example illustrates how we compute the single VoLL from a group of sectoral VoLLs.

Assume we are interested in computing the single VoLL from a population of 3 sectors. Assume also that the supply interruption has a duration of one hour and a size that equals 60 percent of the total hourly consumption of our hypothetical population. Given these assumptions, the supply interruption generates a total EENS of 900 MWh to be allocated to the three sectors.

In this example, sector C is disconnected after sectors A and B, because it is placed later in the load shedding sequence. This means that sectors A and B are exposed to the EENS generated by the supply interruption first. Any remaining EENS is then allocated to sector C. In this case, the residual or remaining EENS is 900 - 750 = 150 MWh.

The next step is to determine the proportion of EENS that each sector accounts for. These relative EENS shares are used to compute the weighted sectoral VoLLs which are then summed to obtain the single VoLL. In this example, the single VoLL totals **€ 47,222 per MWh** (which is the sum of the VoLLs in the right hand column).

Sector	VoLL	Load shedding segment	Hourly consumption volume* (MWh)	Share of total consumption	Allocated EENS (MWh)	Share of total EENS	Weighted Sectoral VoLL
A	€ 50,000	1	500	33%	500	56%	€ 27,778
B	€ 25,000	1	250	17%	250	28%	€ 6,944
C	€ 75,000	2	750	50%	150	17%	€ 12,500
Total			**1,500**		**900**	**100%**	**€ 47,222**

* = excluding price-responsive consumers, for the proportion of their offtake which is price-responsive

The load shedding sequence described in this section is an approximation, based on incomplete information and data. While this is the best that can be attained within the context of this study, its limitations should be kept in mind when interpreting the results.

In section 4.5, we examine a number of alternatives to the procedure described above to test the sensitivity of the outcomes to assumptions in the methodology we apply (as suggested by ACER in Article 7(8) of the ACER methodology).

3 Results from the survey

3.1 Survey structure and process

We created three different surveys for the three different groups of respondents: households, small and medium-sized enterprises, and large enterprises.[19] The choice experiment part of each of these surveys is the same, but the other questions are tailored to the specific groups of respondents. Each of the surveys is coded as a web survey that respondents can take online.[20] The web survey contains choice experiment questions as well as ordinary survey questions. All three versions of the complete survey (in Dutch) are included in Annex I.

Respondents can fill out the survey anonymously, which means that the provided data on electricity costs and electricity consumption cannot be validated via the actual electricity contract of respondents. In the case of households, we used the number of people in the household and average annual electricity consumption for such a household to scale the price of the electricity contracts to a realistic value.[21] For enterprises, we used the ratio of costs over electricity consumption to check if the implied cost per MWh is realistic.[22] Only respondents with a realistic cost per MWh could fill out the full survey. The main reason for this is that it is important for the reported costs to be realistic because they are used in the choice experiment part of the survey to scale the price of the electricity contracts and make it vary around a value that is relatively similar to what respondents are currently paying. Respondents who have experience with choosing an electricity contract are likely to report realistic values for electricity consumption and costs, and are therefore more likely to be allowed to fill out the full survey.

The survey for households was conducted among a sample of consumers (aged 18 or over) who indicated they decide on the electricity contract of their household.[23] In addition to the ten choice tasks, it includes questions on household characteristics, personal characteristics of the respondent and questions on experience with supply interruptions. This survey was open from 2 December 2021 to 18 January 2022.

The survey for small and medium sized enterprises was conducted among a sample of employees who can provide realistic information on electricity costs and electricity consumption of their employer.[24] In addition to the ten choice tasks, this survey contains questions on company characteristics, demand response, experience with supply interruptions and on measures the company may have taken to mitigate the impact of supply interruptions. This survey was open from 18 January 2022 to 28 March 2022.

The survey for large enterprises was sent out to a number of representative organisations to be distributed among their members. This includes VEMW, an association that advocates for the interests of businesses in the areas of energy and water. It also includes a number of branch organisations in sectors with a high use of electricity: FNLI, VNCI, VNPI, Metaal Nederland, KNB,

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19 The categories of small and medium sized enterprises and large enterprises include (semi-)public organisations.

20 Sawtooth Lighthouse was used to code the web survey. This is specialized survey software (for more information, visit: https://www.sawtoothsoftware.com/products/online-surveys).

21 Data from the Nibud have been used for figures on electricity consumption and the average electricity price, see: https://www.nibud.nl/onderwerpen/uitgaven/kosten-energie-water/

22 For small and medium sized enterprises, we used a range from 60 euro to 350 euro per MWh. For large enterprises we decreased the lower bound to 10 euro per MWh.

23 The respondents were drawn from an existing PanelClix consumer panel (https://www.panelclix.nl).

24 The respondents were drawn from an existing PanelClix business panel (https://www.panelclix.nl).

Meststoffen Nederland, VNP, Glastuinbouw Nederland, FME, VA and NLdigital. In addition, a number of large enterprises in the transport sector and all users with a direct connection to the national grid were contacted directly.

All surveys were sent out to employees of these enterprises that are involved in the decision process of selecting the electricity contract of their company. The only difference between this survey and the survey for small and medium sized enterprises is that the former also includes two questions on being directly connected to the national power grid. This survey was open from 16 November 2021 to 7 March 2022.

All three surveys were conducted during a period in which the electricity price was relatively high compared to earlier years, which received attention in many news outlets. This may have affected the responses of participants.

Each of the surveys also included a question directly asking for the willingness to pay to avoid a typical supply interruption (known in the economic literature as *contingent valuation*).

Choice experiment

Respondents are presented with ten choice tasks in the choice experiment part of each survey.[25] In each task they are asked to make a choice between three electricity contracts that differ in the characteristics of the supply interruptions and the price per year.

Respondents are asked to imagine that they are currently looking for a new electricity contract for the upcoming year and that the three contracts on offer are the only options available. Table 3.1 provides an example of what the three options could look like. The survey explains to respondents that each electricity contract has different characteristics regarding the supply interruptions that take place and has a different price. In all other respects the contracts are the same. Therefore, the price of the contracts only varies due to differences in the quality of electricity supply, not due to differences in electricity consumption.

The attributes and their respective range of possible values are:

1. Frequency of supply interruption - range: 1 time in 10 years, 1 time in 5 years, 1 time in 2 years, 1 time per year, 2 times per year, 4 times per year;
2. Duration of interruption - range: Less than 1 minute, 5 minutes, 15 minutes, 30 minutes, 60 minutes, 2 hours, 4 hours, 6 hours;
3. Day of the week - range: working day, weekend, public holiday;
4. Part of the day - range: morning (6:00 to 12:00), afternoon (12:00 to 18:00), evening (18:00 to 00:00) and night (00:00 to 6:00);
5. Season - range: spring, summer, autumn, winter;
6. Prenotification period- range: none, 1 working day in advance, 3 working days in advance, 1 week in advance, 2 weeks in advance;
7. Costs per year - range: 0.8 to 1.2 times the current estimated/stated annual cost.

The following formulation (original in Dutch) is used for each of the ten presented choice tasks:

> **The electricity contracts and interruptions shown do not necessarily correspond to the contracts and interruptions that exist in reality. What matters is the choice you would make if these were the only options for an electricity contract. Please indicate which of the energy contracts below you prefer.**

25 The optimal number of choice tasks is determined by a trade-off between learning effects and cognitive burden for the respondents. Scientific studies suggest that ten choice tasks is the number that optimizes this trade-off (see, e.g., Caussade et al., 2005).

Table 3.1 Example of choice alternatives

	Contract 1	Contract 2	Contract 3
Frequency	Once per 5 years	Once per year	Twice per year
Duration	2 hours	4 hours	15 minutes
Season	Winter	Summer	Spring
Day of the week	Working day	Weekend	Holiday
Time of day	Morning	Afternoon	Evening
Warning beforehand	3 working days	No warning	2 weeks
Electricity cost per year	1,000 euro	1,150 euro	950 euro

The level of the cost attribute also varies over respondents, besides varying between choice alternatives. In the survey for households, the average annual electricity consumption of households is used to calculate the expected cost of their electricity consumption. We use average annual electricity consumption depending on the number of household members together with the stated number of household members of respondents. The price of the electricity contract varies around the calculated expected cost. For all enterprises (small, medium and large) the price of the contracts they can choose from varies around their stated annual electricity costs, which is asked for at the beginning of the survey.

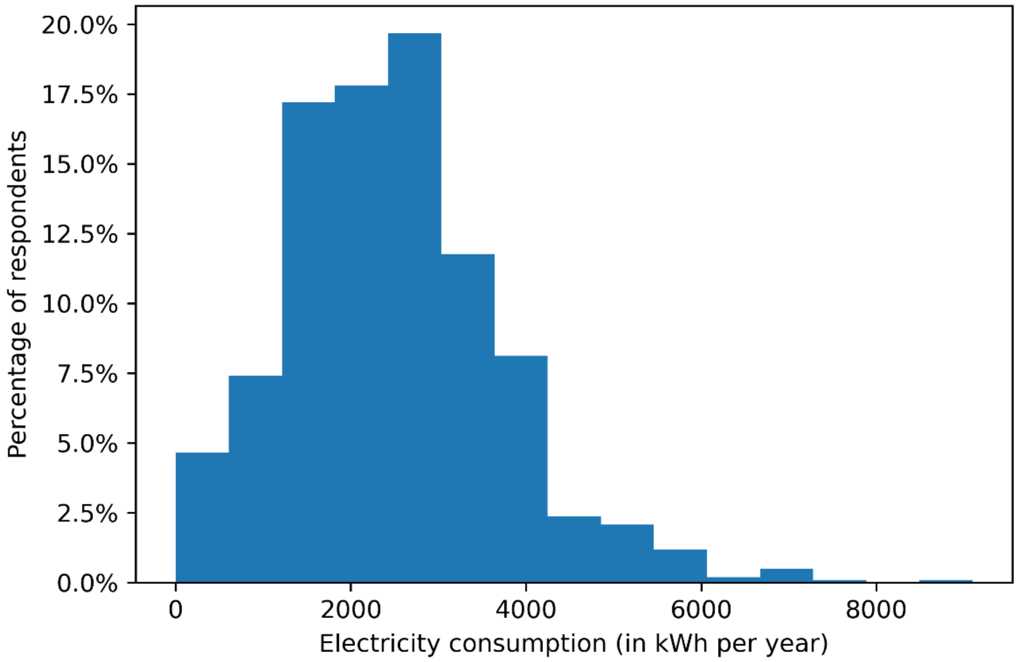
3.2 Characteristics of respondents

Households

A total of 1,011 consumers completed the survey for households. The average age of these respondents is 50 years. Close to half of the respondents is female (52 percent). About 44 percent of respondents is highly educated, which was 41 percent in the Dutch population in 2019 (Ridder et al., 2020). The average number of people per household is 2.4 among respondents, while the national average is 2.1 people per household. Slightly more than one third of the respondents work from home daily (NB: the survey was conducted during a period that overlapped with a lockdown due to Covid-19 and working from home was advised during the whole period), while 38 percent of respondents indicate they never work from home. Close to one third (32 percent) of respondents indicate they have solar panels installed at home. 71 percent of respondents either have not experienced an interruption in the past two years (53 percent) or cannot recall (18 percent). This may explain the satisfaction rate among participants regarding the reliability of electricity supply, scoring on average 4.2 out of 5. Figure 3.1 shows that the distribution of electricity consumption of households is close to normal, although slightly right skewed. The mean value is 2,575 kWh, which is slightly below the national average of 2,760 kWh per year.[26]

[26] These values and the figure are based on reported electricity consumption, which is a response that is not used in the conjoint analysis. In the conjoint analysis we instead use the average electricity consumption based on household characteristics.

Figure 3.1 Distribution of electricity consumption - households

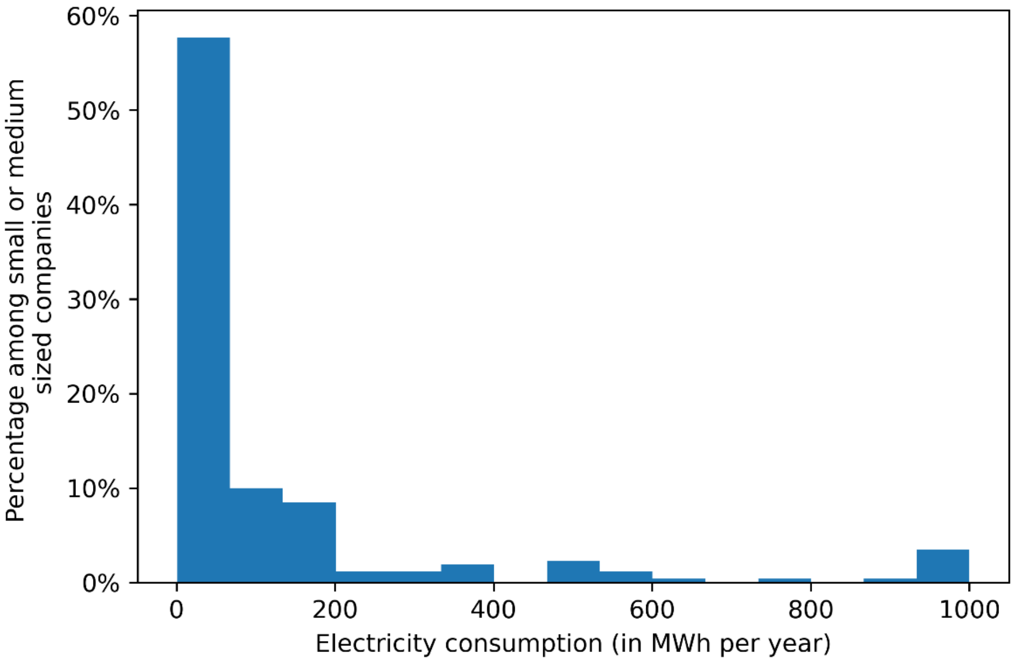


NB: The above figure shows the histogram of households with an annual electricity consumption of up to 10,000 kWh, this is approximately 93 percent of the sample.

Small and medium sized enterprises

A total of 260 respondents completed the survey for small and medium sized enterprises. Most of these respondents work at enterprises with less than 50 employees (28 percent) or between 50 and 250 employees (29 percent). The majority of these enterprises (53 percent) only has one location from where they operate. Close to 70 percent of the respondents work at enterprises with an annual revenue of less than 10 million euro. The enterprises operate in a wide variety of sectors with the highest numbers of respondents from the sectors *industry, retail* and *health care*. The mean of the annual electricity consumption of these enterprises is 2,653 MWh, while the median consumption is 50 MWh. This indicates that the reported electricity consumption has a right skewed distribution, as is confirmed by the histogram of annual electricity consumption in Figure 3.2. This figure shows that relatively many enterprises have a relatively high annual electricity consumption. The same holds for annual electricity costs, as they are a direct function of electricity consumption. About a third of these small and medium sized companies has taken some measures to mitigate the impact of supply interruptions such as getting an electricity generator for back-up.

Figure 3.2 Distribution of electricity consumption - small and medium sized enterprises

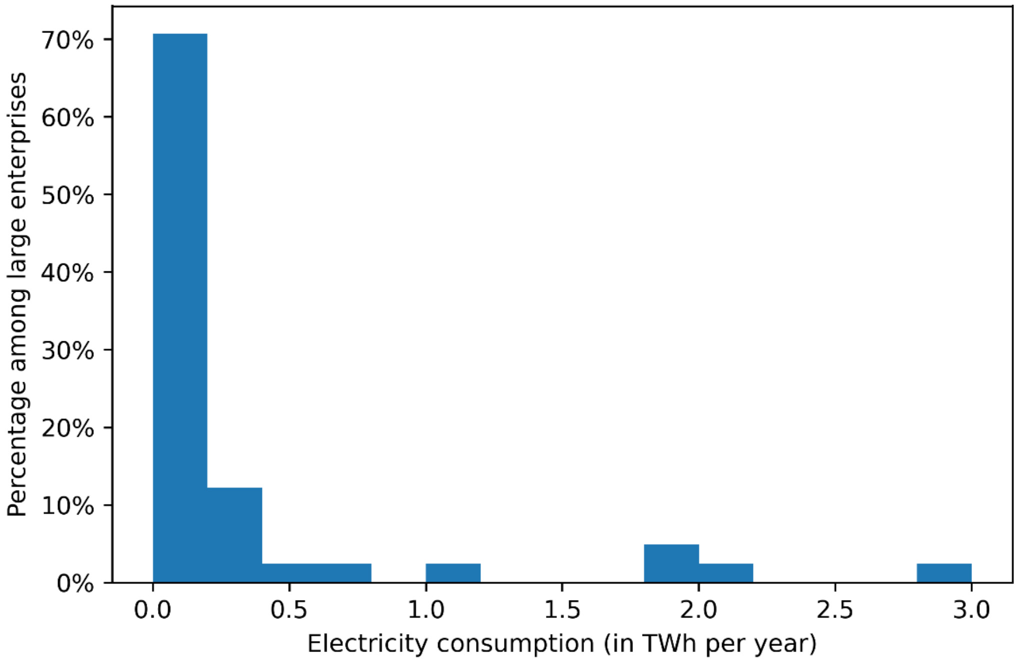


NB: The above figure shows the histogram of companies with an annual electricity consumption of up to 1000 MWh, this is approximately 88 percent of the sample.

Large enterprises

A total of 41 employees completed the survey for large enterprises. Most of these respondents work at enterprises with more than 250 employees (59 percent). The majority of these enterprises (56 percent) operate from more than one location and 85 percent of the respondents work at enterprises with an annual revenue of more than 50 million euro. Over two third of these enterprises operate in the *industrial* sector. The mean of the annual electricity consumption of these enterprises is 346.1 GWh, while the median consumption is 60 GWh. This indicates that the reported electricity consumption has a right skewed distribution, as is confirmed by the histogram of annual electricity consumption in figure 3.3. This figure shows that relatively many large enterprises have a relatively high annual electricity consumption. (the business with the highest annual electricity consumption in our sample uses 3 TWh per year). Again, the same holds for annual electricity costs, as they are a direct function of electricity consumption. Although our sample of large enterprises is relatively low with 41 respondents, these respondents do represent 13 percent of the total Dutch electricity consumption. More than three quarters of these companies have taken measures to mitigate the impact of supply interruptions, such as installing an electricity generator for back-up.

Figure 3.3 Distribution of electricity consumption – large enterprises



NB: In contrast to Figure 3.1, the above figure shows the histogram of the annual electricity consumption of the complete sample of large enterprises that participated in our survey.

3.3 Willingness to pay

Households

The preferred method to determine the WTP is to use the conjoint analysis and discrete choice models as discussed in section 2.3. We estimated multiple multinomial logistic regression models to analyse the data from the choice experiment. We started with a model with all attributes and many interactions and have worked back from there to our preferred specification.[27] With seven attributes and many other socio-demographic or company characteristics, the total number of possible interactions becomes extremely large. The included interactions are therefore based on theoretical expectations of possible interaction effects.[28] We estimated different models for each attribute that can be included in multiple ways (using different functional forms, such as logs or levels), and use the approach that best fits the data. The results of the preferred specification of the model are provided in table 3.2.

The results in table 3.2 show that all of the estimated effects in the preferred specification have the expected sign. Frequency for example has a negative estimate, which means that more frequent supply interruptions make it less likely that the contract is chosen, all else being equal. The seasons and time of day are included as dummy variables with winter and night as reference categories. Because of the choice of reference categories, the positive signs for spring, summer and autumn can be interpreted as respondents on average preferring to have a supply interruption in those seasons instead of winter. The estimates for the morning, afternoon and evening are negative,

27 In each step, the least significant estimate is dropped from the model. The Akaike Information Criterion (AIC) is used to assess whether this improves the fit of the model.

28 For example, an additional interruption may generate more disutility if it occurs in winter. Such a hypothesis has been tested by including an interaction between frequency and a dummy for winter. However, it is for example unlikely that the disutility of a higher cost varies between afternoon and evening. Such hypotheses have not been tested.

implying that respondents rather have a supply interruption at night than during the day time.[29] The positive estimates for the interactions between frequency and urban areas and frequency and feed-in areas suggest that respondents in those areas get less disutility from supply interruptions than respondents in other areas.[30] All reported estimates are statistically significant at the 1 percent significance level, except for the interaction between frequency and the log of duration which is only significant at the 10 percent level.

Table 3.2 Estimation results for households

Parameter	Estimate	Robust standard error	Robust p-value
Frequency	-0.28700	0.02240	<0.000001
Log of duration	-0.21500	0.01000	<0.000001
Frequency*log(duration)	-0.00997	0.00586	0.089100
Log of price	-6.71000	0.12400	<0.000001
No warning	-0.18400	0.03220	<0.000001
Spring	0.14000	0.03670	0.000131
Summer	0.26400	0.03600	<0.000001
Autumn	0.11300	0.03610	0.001800
Morning	-0.30500	0.03550	<0.000001
Afternoon	-0.33100	0.03600	<0.000001
Evening	-0.25900	0.03540	<0.000001
Working day	0.07160	0.02500	0.004100
Urban area*freq	0.06720	0.02630	0.010800
Feed-in area * freq	0.08210	0.03040	0.006880

The estimates can be used to determine WTP using an adjusted version of the expression introduced in section 2.3 (i.e. the derivative of the specified utility function with respect to frequency divided by the derivative with respect to the costs/price). Following our estimation results, the WTP includes the parameters for the interaction between frequency and urban areas and frequency and feed-in areas to allow for differences in WTP between groups living in different areas.

$$WTP = \frac{\beta_1 + \beta_8 \cdot \ln duration_i + \beta_{urban} \cdot Urban_i + \beta_{rural} \cdot Feedin_i}{\beta_7} \cdot price_i$$

$$= \frac{-0.287 - 0.215 \cdot \ln duration_i + 0.0672 \cdot Urban_i + 0.0821 \cdot Feedin_i}{-6.71} \cdot price_i$$

This implies the following WTP to avoid a supply interruption of 1 hour:

For households in urban areas:

$$\frac{-0.287 + 0.0672}{-6.71} \cdot price_i = 0.0328 \cdot price_i$$

For households in feed-in areas:

$$\frac{-0.287 + 0.0821}{-6.71} \cdot price_i = 0.0305 \cdot price_i$$

29 The choice for reference categories is necessary but also arbitrary. The choice for a specific reference category does not change the estimated parameters of the other variables in the indirect utility function as specified in Section 2.3. To be precise, including dummy variables – such as season, day of week, etc. – may alter the estimate of frequency, duration and price, but this is independent of the choice of reference categories for these dummy variables. Furthermore, these dummy variables do not enter the specification of the willingness to pay as defined in Section 2.3. This is easily understood when realizing that the willingness to pay compares a similar situation with and without the supply interruption, hence the effects of these dummy variables on the indirect utility with and without the supply interruption cancel each other out.

30 A multinomial logistic regression estimates the relative importance of attributes and how they affect the choice between alternatives, which are in this case electricity contracts. As a consequence, variables that do not vary over alternatives cannot be included separately in the model. They can only enter the model via an interaction with one of the attributes that does vary over alternatives.

For households in the remaining areas:

$$\frac{-0.287}{-6.71} \cdot price_i = 0.0428 \cdot price_i$$

These formulas show that the WTP of households in terms of their annual electricity costs varies from 3.05 to 4.28 percent. Each of the surveys also includes a question that directly asks for the WTP to avoid a typical supply interruption. Asking for WTP directly has an important disadvantage, which is that participants can easily provide answers that do not correctly reflect their actual WTP (e.g. because of strategic considerations). Our collected data suggest that this indeed occurs. About a third of the respondents indicate that their WTP is zero. Although this may be the case for some respondents, it is unlikely that this holds for one-third of the population. The comments to the survey provide a possible explanation for this high share of respondents with a WTP of zero. Some respondents disagree with the idea of having to pay to avoid a supply interruption, which can be a reason to state a WTP of zero out of protest to this idea. Some other respondents also state very high WTPs of over 1,000 euros. This might reflect their actual WTP, but could also be a strategic answer if for example, respondents assume that the results of the survey might be used as a policy input and therewith decrease the number or duration of supply interruptions.

The stated WTP of respondents of the survey for households varies from 0 to 1,991 euros, with an average value of 126 euros and a median value of 10 euros. More than 86 percent of respondents state a WTP between 0 and 100 euros.

Enterprises

We use the conjoint analysis and discrete choice models as discussed in section 2.3 to determine the average WTP of enterprises. We have estimated multiple multinomial logistic regression models to analyse the collected data from the choice experiment. Just like for households, we started with a model with all attributes and many interactions and have worked back from there to our preferred specification.[31] We have estimated different models for each of the attributes that can be included in multiple ways, and use the approach that best fits the data. The results of the preferred specification of the model are provided in table 3.3.

The results in table 3.3 show that all of the estimated effects have the expected sign. Season dummies have been excluded from this model because they have no statistically significant effect on the contract choices of enterprises. An interaction between a dummy for small and medium-sized enterprises and frequency has been included to allow for differences in WTP between large enterprises and small and medium-sized enterprises. All reported estimates are statistically significant at the 1 percent significance level, except for the interaction between frequency and having a direct connection to the national grid, which is only significant at the 10 percent level, and the estimate for the evening which is not significant.[32] The latter implies that there is no reason to assume enterprises get more disutility from a supply interruption in the evening than from one at night.

Table 3.3 Estimation results for enterprises

Parameter	Estimate	Robust standard error	Robust p-value
Frequency	-0.59000	0.09700	<0.000001
Log of duration	-0.13700	0.01250	<0.000001
Frequency*direct connection to grid	-0.29000	0.16200	0.072700

31 In each step, the least significant estimate is dropped from the model. The Akaike Information Criterion (AIC) is used to assess whether this improves the fit of the model.

32 In contrast to the results of the model for households, in the model for enterprises, the interaction between the log of duration and frequency is not significant at any conventional significance level.

Parameter	Estimate	Robust standard error	Robust p-value
Log of price	-4.21000	0.19100	<0.000001
No warning	-0.34800	0.05750	<0.000001
Morning	-0.26800	0.06170	0.000014
Afternoon	-0.31100	0.06170	<0.000001
Evening	-0.15900	0.05960	0.007780
Working day	-0.15700	0.04450	0.000402
Small/medium enterprises*freq	0.415	0.0989	0.000027

The estimates can be used to determine WTP using an adjusted version of the expression introduced in section 2.3. It now also includes the parameter for the interaction with the dummy for small and medium sized enterprises and frequency.

$$WTP \ = \frac{\beta_1 + \beta_{small/medium} \cdot Small/medium_i}{\beta_7} \cdot price_i$$

$$= \frac{-0.59 + \ 0.415 \cdot Small/medium_i}{-4.21} \cdot price_i$$

This implies the following WTP to avoid a supply interruption of 1 hour for small and medium sized enterprises:

$$\frac{-0.59 + \ 0.415}{-4.21} \cdot price_i = \ 0.0416 \cdot price_i$$

And for large enterprises:

$$\frac{-0.59}{-4.21} \cdot price_i = \ 0.1401 \cdot price_i$$

These formulas show that the WTP of enterprises in terms of their annual electricity costs varies from 4.16 to 14.01 percent for the differently sized enterprises. Using the median annual electricity costs, this translates to a WTP of 301.60 euros and 490,350 euros for small or medium-sized enterprises and large enterprises respectively.

Each of the surveys for enterprises also includes two questions that directly ask for the willingness to pay (WTP) to avoid a typical supply interruption. The first question asks for WTP without specifying if possible own generation can be used in case of a supply interruption. The second WTP question is only asked to respondents whose business has taken measures to mitigate the adverse effects of a supply interruption. It explicitly asks for the WTP if their own electricity generation cannot be used during the interruption. Again, asking for WTP directly has an important disadvantage, which is that participants can easily provide answers that do not correctly reflect their actual WTP (e.g. because of strategic considerations).

The stated WTP of respondents of the survey for small and medium sized enterprises varies from 0 to 10 million euros, with an average value of approximately 89,000 euro and a median value of 250 euros.

The stated WTP of respondents of the survey for large enterprises varies from 0 to 100 million euros, with an average value of approximately 3.1 million euro and a median value of approximately 46,000 euros. Enterprises who have taken measures to mitigate the effects of supply interruptions have a median WTP of 50,000 euros. This median WTP increases to 80,000 euros if own electricity generation cannot be used during the interruption.

4 Results of the VoLL calculations

4.1 Input data for the VoLL calculation

Our sample consists of 1,312 respondents whose distribution across different economic sectors is shown in table 4.1 below. The sample distribution broken down by the lowest category level is detailed in Annex II. Table 4.1 also shows how the volumes in our sample compare to the volumes for the Netherlands as a whole. Our sample performs especially well in covering the electricity volumes of industrial firms (as evidenced by a 26 percent sample coverage ratio).

Table 4.1 Electricity consumption per sector for survey sample and the Netherlands

Sector	[A] Annual electricity consumption population (MWh)*	[B] Annual electricity consumption sample (MWh)	Sample coverage [B/A]	N
Commercial and service sector	20,545,000	47,601	0.2%	131
Industry	53,960,500	14,173,902	26.3%	93
Public sector	9,458,700	457,641	4.8%	62
Transport	5,617,800	201,395	3.6%	15
Households	20,830,000	2,441	0.01%	1,011

* = based on CBS-statistics[33,34]

Ideally, one has perfect information regarding how the hourly consumption of different types of users is distributed at the time a supply interruption typically occurs. This information would greatly enhance the validity of our estimated single VoLL. Unfortunately, population-level data was only available for user categories at the highest level of aggregation, i.e. for the sectors included in the table above. This means we had to base our estimates regarding the distribution of consumption volumes of more narrowly-defined segments on sample data.

As far as we were able to obtain population-level data we made sure, via sample balancing, that the hourly consumption volumes of the various segments matched the known distributions of the Netherlands as a whole. In this regard, we know that 88 percent of the electricity consumed in the Netherlands is supplied through regional grids and the remaining 12 percent through direct connections to the national grid (based on data received from TenneT).[35] Moreover, the preceding table shows how the total annual volume of electricity consumed is distributed among the five aggregated economic sectors that we focus on in this study.

33 https://www.cbs.nl/nl-nl/maatwerk/2021/21/energieverbruik-bedrijven-naar-belastingschijf-2019

34 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/83989NED/table?dl=22429

35 In our sample, the sectors that contain users connected to the national grid are the industry and the public sector. We balanced the hourly consumption volumes of users *within* these two sectors so that the fraction of nationally vs regionally connected users equals 12 percent and 88 percent, respectively. Balancing hourly consumption volumes simply means that part of the consumption volume accounted for by nationally connected users was shifted to users connected to regional grids. Note that this type of sample balancing only affects the way in which the EENS is allocated over the population, which impacts the calculation of the single VoLL based on a load shedding sequence. The calculation of individual and sectoral VoLLs is done purely on the basis of sample data.

4.2 Results of the sectoral VoLL calculation

The sectoral VoLLs are derived from the willingness to pay of respondents that fall within the various segments depicted in the table below. A respondent's VoLL is calculated as its WTP divided by its hourly consumption at the moment a supply interruption is most likely to occur (that is, on a weekday evening in winter). The WTP figures are estimated using a conjoint analysis (see chapter 2 on methodology and chapter 3 on the results of the conjoint analysis).

The table below indicates the magnitude of WTP figures for different user categories. Large-scale enterprises in the industrial sector are willing to pay a relatively large sum of money for avoiding an inadequacy situation, while households have the lowest WTP.[36]

Table 4.2 WTPs per user category

Sector	WTP relative to annual electricity costs
Commercial and service sector	5%
Industry, Large-scale enterprises, Energy-intensive	14%
Industry, Large-scale enterprises, Non-energy intensive	14%
Industry, SME	4%
Public sector	6%
Transport	7%
Households*, City centres	3%
Households*, Feed-in areas	3%
Households*, Other	4%

* = an electricity price of € 0,21 per kWh[37] was used for determining the WTP of households.[38] For enterprises, we used the electricity prices they reported in the survey.

The hourly consumption volume of various user types is derived from data provided by Statistics Netherlands (CBS) and the Dutch Energy Data Exchange Association (NEDU). CBS provides aggregated data on annual consumption of electricity for various economic sectors, amongst which commercial and service sector, industry, public sector, transport and households. The NEDU provides electricity demand profiles that show how the electricity demand for various user types[39] typically unfolds over the course of an entire year. Demand profiles are constructed by determining, for each quarter-hour (15 min) in a year, the proportion of total electricity consumed during that time step ($ElecProp_t$).

The aggregated consumption data is scaled to the level of hours by dividing the totals by 8,760 (24 hrs * 365 days). The hourly figures are then scaled – using the NEDU demand-profiles – to represent the volume consumed on a weekday winter evening. We determine this *profile correction factor* by first computing the average ElecProp over the entire year ($AvgElecProp_{year}$), and the average ElecProp for time steps classified as falling within the temporal category [*evening, weekday, winter*] ($AvgElecProp_{evening,weekday,winter}$).

36 It seems likely that this is at least partly caused by different tax levels. Households and SMEs pay relatively more taxes over their electricity consumption than large industrial enterprises.

37 For calibrating the costs of household electricity contracts used in the conjoint analysis, the most recent electricity prices available were used. The electricity price for households at the time the survey was conducted was estimated at 0.24 euro per kWh, based on the NIBUD-website.

38 https://opendata.cbs.nl/#/CBS/nl/dataset/81309NED/table

39 Demand-profiles are segmented over various connection types. These connection types are defined by size (as expressed in amperes) and utilization (as expressed in full-load hours).

The so-called profile correction factor or PCF (see section 2.4) then becomes:

$$PCF = \frac{AvgElecProp_{evening,weekday,winter}}{AvgElecProp_{year}}$$

The PCF is computed for various connection types ranging in size (as expressed in amperes) and utilisation (as expressed in full-load hours). We find that the profile correction factor for connection types linked to households is equal to 1.8. This indicates that households on average tend to consume an hourly volume of electricity during weekday winter evenings that is 1.8 times higher than the yearly average. Those connection types used for small- and large-scale enterprises were found to have a PCF approximately equal to 1; indicating no notable deviation from the yearly average.

A final correction is performed on the hourly consumption figures to exclude price-responsive respondents for the proportion of their offtake which is price-responsive (Article 7(2)(a) of the ACER methodology, see section 2.4). Each respondent indicated to what extent they are involved in a demand-side response (DSR) scheme, which means that they are contractually obliged to reduce their consumption at the request of a third party. This part of a respondent's consumption is not included in the computation of the VoLLs. A total of 30 respondents indicated that they were involved in such a scheme. On average, these respondents were obliged to reduce their consumption with 31.5 percent (with a maximum of 100 percent and a minimum of 1 percent). Table 4.3 shows for each sector within our sample the share of hourly consumed electricity volume that falls within a DSR scheme; the commercial and service sector has the highest price-responsiveness.

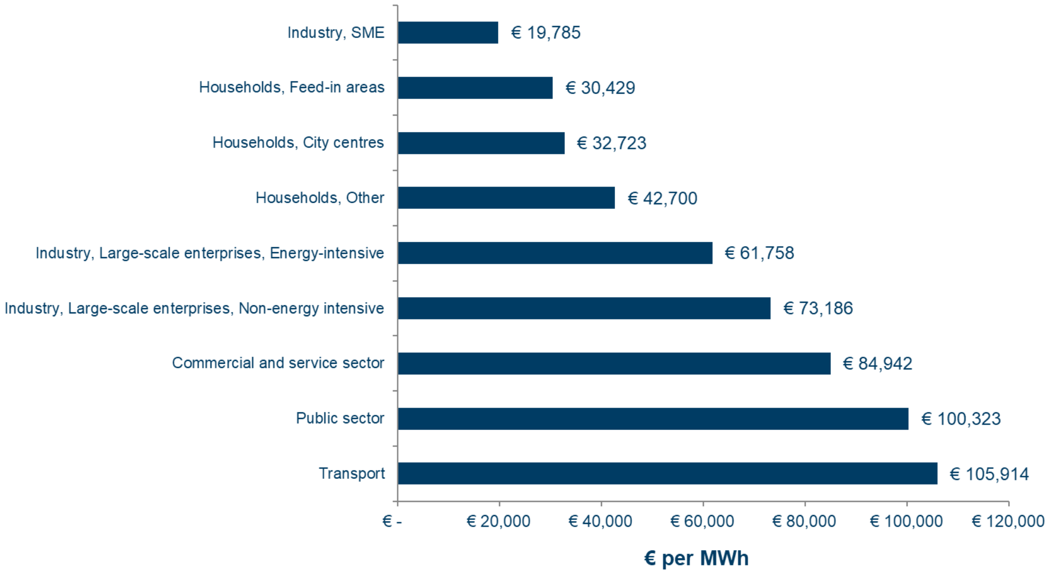
Table 4.3 Price-responsiveness per user category within sample

Sector	Share of consumption volume that falls under DSR-scheme
Commercial and service sector	28%
Industry, Large-scale enterprises, Energy-intensive	26%
Industry, Large-scale enterprises, Non-energy intensive	1%
Industry, SME	14%
Public sector	3%
Transport	15%
Households (all subcategories)*	0%

* = households were not asked about demand side response schemes in the survey, as the topic was deemed to be too complex for most respondents. For the purpose of the VoLL calculation, we assume that households are not price-responsive.

The resulting sectoral VoLLs are shown in figure 4.1. They range from approximately 20 thousand €/MWh for industrial SMEs to roughly 106 thousand €/MWh for the transport sector.

Figure 4.1 The sectoral VoLL for each user category



4.3 Results of the single VoLL calculation

Computing the single VoLL from the various sectoral VoLLs presented in the previous section is done by determining the degree to which different user types are exposed to the EENS generated by an inadequacy situation. By following the load shedding sequence described in section 2.5, users with low protection status are disconnected first in the event of a supply interruption, followed by users with higher degrees of protection.

Table 4.4 shows the absolute and percentual electricity volumes consumed in the Netherlands at the time of a typical supply interruption for each of the four load shedding categories.

Table 4.4 Consumption volumes per load shedding category

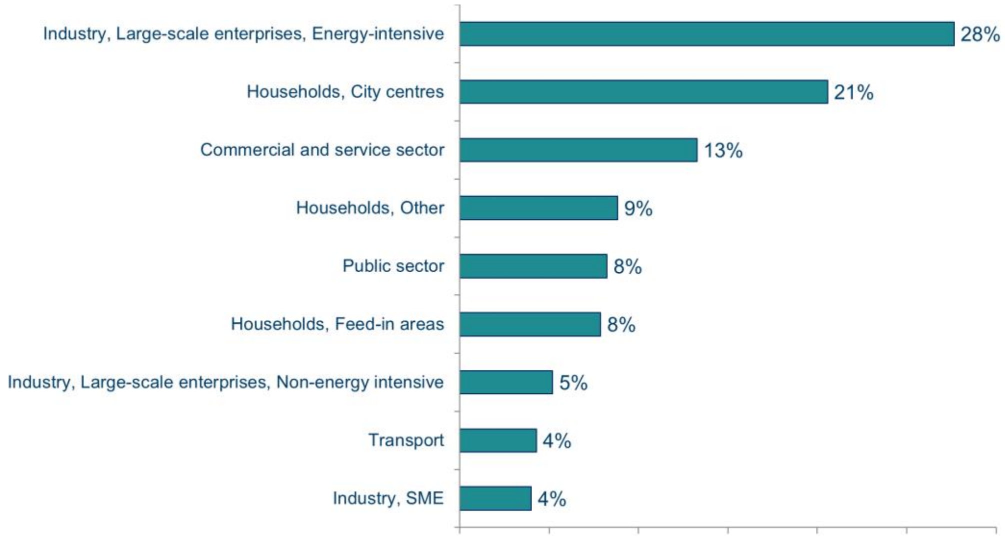
Level	User type	Total hourly consumption (MWh)	Share
1	• Users connected to the national grid. • Users connected to the regional grid without special status.	5,454	43.0%
2	• Users connected to the regional grid and involved in critical process industry, utilities and basic services.	2,611	20.6%
3	• Users connected to the regional grid and involved in maintaining public order and safety or public health. • Households located in city centres.	3,629	28.6%
4	• Households connected to the regional grid and located in feed-in areas*.	1,001	7.9%

* = feed-in areas are those with a net production of electricity for more than 1,500 hours per year.

Because of the stratified allocation of EENS (which is determined by the load shedding sequence), the single VoLL will vary with the magnitude of the supply interruption. This is because the single VoLL is determined by combining the VoLLs of each user category weighted by the EENS allocated to each specific segment.

The figure below shows how the consumption of electricity – in terms of volume – is distributed over the Dutch population during a typical hour on a weekday winter evening. It can be seen that households account for the largest share of electricity consumed[40], followed by industry. Should a supply interruption occur that exposes the entire population to EENS, then this is how the allocation of EENS would be distributed over all user categories.

Figure 4.2 Distribution over user categories of total hourly electricity consumed during a weekday winter evening



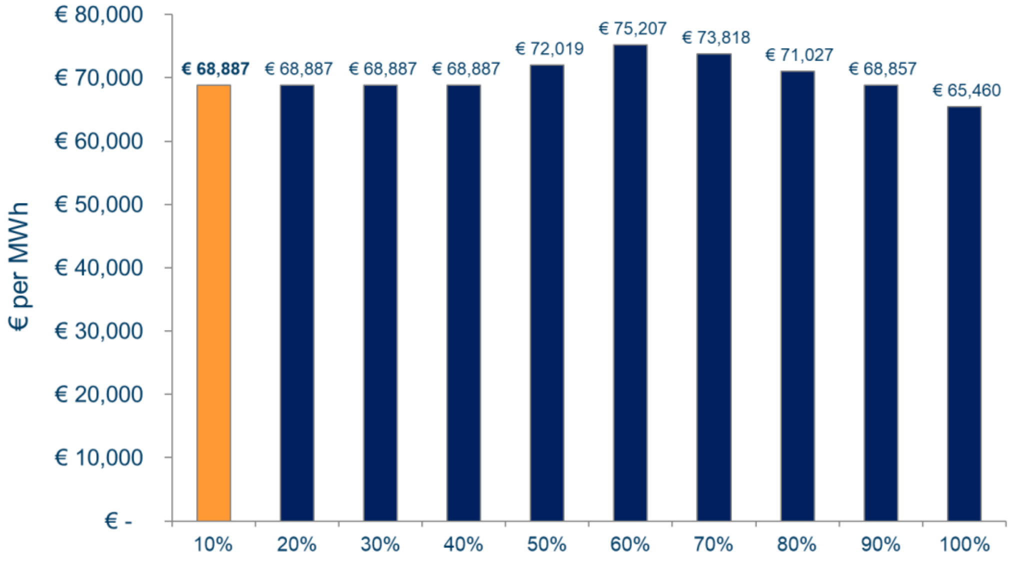
As described in section 2.5, the single VoLL is determined by combining the sectoral VoLLs in a load shedding sequence. The VoLL of each sector is weighted by the proportion of EENS to which that sector is exposed. In this way, sectors not exposed to EENS do not affect the outcome of the single VoLL. As a result, the information contained within the single VoLL only concerns those electricity users which are affected by a supply interruption. The magnitude of a supply interruption determines which electricity users are exposed to EENS and therefore affects the value of the single VoLL.

Figure 4.3 shows how the single VoLL varies according to the magnitude of the supply interruption. The x-axis depicts the size of the interruption relative to the total hourly electricity volume consumed by the Dutch population on a weekday winter evening, the y-axis represents the single VoLL in terms of €/MWh.

Assuming an interruption magnitude of 10 percent (see section 2.2) the single VoLL for the Netherlands is equal to 68,887 €/MWh.

[40] Taken together, the three household categories account for 37 percent of the total hourly electricity consumption on a winter weekday evening in the Netherlands.

Figure 4.3 The single VoLL for different magnitudes of the supply interruption

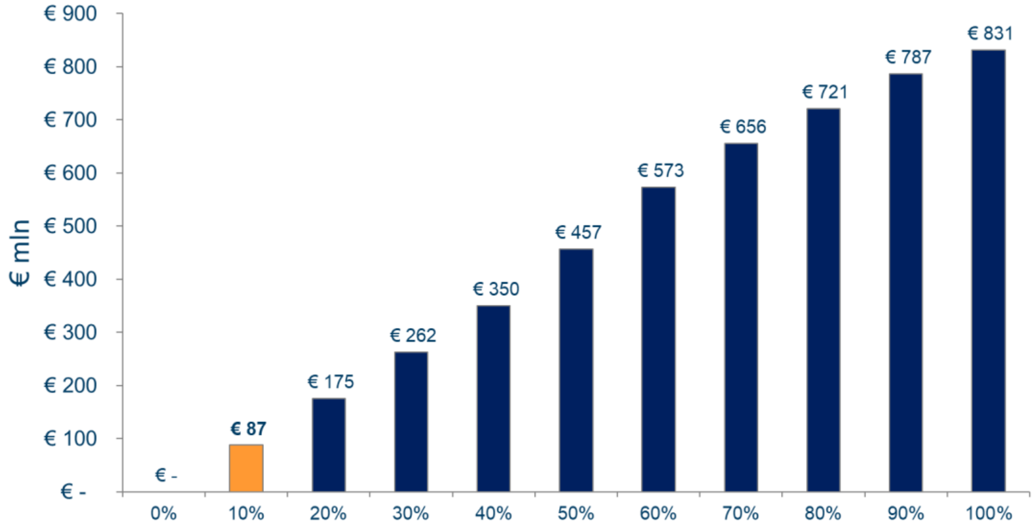


The figure also shows that the single VoLL is constant for a supply interruption ranging from 0 to 40 percent of the total load. This is because 43 percent of the Dutch population (in terms of electricity volume consumed) falls within the first category of the load shedding sequence. When the supply interruption grows in size beyond the 43 percent threshold, the single VoLL starts to change. The single VoLL shows relatively little change when the magnitude of the supply interruption increases. It peaks at 75,207 €/MWh at a magnitude of 60 percent and then decreases again to € 65,460 €/MWh for a supply interruption of 100 percent.

Important to note is that the single VoLL for a supply interruption of 100 percent (65,460 €/MWh) is equal to a 'simple' volume weighted average of the sectoral VoLLs, i.e. without provisions for a load shedding sequence that prioritises some users over others.

Multiplying the single VoLL by the EENS generated by the supply interruption indicates the total financial loss caused by the supply interruption. For a typical supply interruption, equal to 10 percent of the total load, the total loss of economic value is equal to 87 million euro. A supply interruption that cuts off the entire Dutch population during a weekday winter evening will cause a loss of approximately 831 million euro. Figure 4.4 shows the economic loss for all magnitudes of the supply interruption.

Figure 4.4 The total loss of value for differently sized inadequacy events



4.4 Sensitivity analysis

Following Article 7(8) of the ACER methodology, this section assesses the robustness of our single VoLL estimation vis-à-vis changes in the structural properties and the assumptions embedded in our approach.

Alternative calculation methods

Importantly, we aim to work with population-level data as much as possible to safeguard the external validity of our single VoLL estimate. Population-level data exist for the volume of electricity consumed by different user categories, but only for the most aggregated categories. For more refined categories, fewer or no population-level data are available, which means we must base the calculations for these groups on sample data. An important assumption is that the various characteristics of sample data, such as how the electricity consumption volumes are distributed, correspond with those of the population. Since we cannot be sure whether this is the case, a robustness check using different statistical measures and computational techniques to estimate the single VoLL is warranted.

By default, we compute single VoLLs from sectoral VoLLs determined based on respondent-level VoLLs, which are calculated from consumer-specific WTPs and hourly consumption volumes. The sectoral VoLLs are calculated as the weighted sums of respondent-level VoLLs, where the weights are represented as the relative shares of hourly volumes of electricity consumed ensuring that users with relatively high consumption count more towards determining the VoLL of the sector group to which they belong. We call this first method the weighted average method. It presumes that the distribution of hourly electricity volumes does not contain influential outliers. In a broader sense, it assumes that the sample distribution of hourly electricity consumption is representative of the population.

An alternative way to compute the VoLLs is to use sample medians instead of individual electricity consumption volumes. The median is a measure of central tendency that is robust against (extreme) outliers. We call this second method the median-based method. To assess the influence of outliers on our computations, we also introduce a third method of VoLL computation that uses group-level means. We call this the mean-based method. Differences between the median-based and the other two methods are attributable to extreme observations within our sample.[41]

For the median- and mean-based methods, respondents are first grouped into their respective sector categories after which either group medians or means are computed for the hourly electricity consumption volumes and annual costs. Costs are used to compute group-level WTP figures, volumes are then used to compute group-level VoLLs. WTPs are directly proportional to costs, volumes are inversely proportional to VoLLs.[42] The following table describes these calculation procedures in more detail.

Table 4.5 Description of different sectoral VoLL calculation procedures

Method	Description	Pros and cons
Weighted-average	By default, sectoral VoLLs are computed as the weighted-average of individual or respondent-level VoLLs. The VoLLs of respondents that belong to the same sector are first weighted by the share of each individual's hourly consumption with respect to the total hourly consumption of the sector to which it belongs. These weighted individual VoLLs are then summed to obtain the sectoral VoLL (see section 2.4 for a numerical example of this procedure).	This method is sensitive to extreme values in the reported consumption volumes or annual costs. For instance, if a respondent reports extremely high consumption volumes compared to other electricity users in the same sector, its VoLL has a disproportionate – and therefore likely undesireable – impact on the calculation of the sectoral VoLL.
Median-based	The median-based approach to calculating sectoral VoLLs works by first determining the median of the hourly consumption volume of users belonging to the same sector. Then, the sector-level WTP is calculated by taking the mean of the respondent-specific WTP-coefficients and multiplying it by the sector median of the annual electricity cost. This sector-level WTP is then divided by the sector median of hourly consumption volume to obtain the sectoral VoLL.[43]	The median-based method is the one most robust against extreme values in reported consumption volumes or annual costs. However, this method also involves doing away with the largest amount of information regarding the within-sector distribution of the variables involved in computing the sectoral VoLL.
Mean-based	The mean-based approach to calculating sectoral VoLLs works by first determining the mean of the hourly consumption volume of electricity users belonging to the same sector. Then, the sector-level WTP is calculated by taking the mean of the respondent-specific WTP-coefficients and multiplying this figure by the sector mean of the annual electricity cost. This sector-level WTP is then divided by the sector mean of hourly consumption to obtain the sectoral VoLL.	Although this method is more robust against extreme values in reported consumption volumes or annual costs than the weighted-average method, it also involves compressing the information present within the sample data. By calculating averages for consumption values and annual costs at the sector level, we lose information about how these variables are distributed within sectors. Moreover, this method is still sensitive to extreme values reported consumption volumes or annual costs. If a respondent reports extremely high consumption volumes and/or annual costs compared to other electricity users in the same sector, it will have a disproportionate impact on the sector-level WTP or sector-level hourly consumption volume, which in turn affects the sectoral VoLL.

41 If the annual costs and consumption data of respondents within the same sector are identical, then all three methods yield the same sectoral VoLL estimates. The weighted-average and mean-based method yield the same results when volumes are identical but annual costs differ and vice versa. When both volumes and annual costs differ across respondents (which is naturally the case), then the three methods yield different estimates. The weighted-average and mean-based method are most sensitive to outliers.

42 As shown in the equations in Chapter 3, WTP is computed by multiplying the annual costs of a respondent with a particular segment-specific coefficient. VoLLs are, on their part, computed by dividing the WTP by hourly consumption volume. Hence, the higher the costs, the higher the WTP and the higher the (hourly) consumption volume, the lower the VoLL.

43 For the WTP coefficients, the mean is taken rather than the median as there are only one or two possible values within a sector (see chapter 3).

The following tables present the single VoLL estimates when using different computational methods for an inadequacy event with a generated EENS of 10 percent of the total hourly electricity consumed within the Dutch population. A comparison shows that the median-based method yields a higher VoLL than the other two methods. The weighted-average and mean-based methods provide quite similar VoLL estimates. The relatively high single VoLL for the median-based method is the result of higher sectoral VoLL estimates because the median of consumption volumes under the influence of outliers is often lower (i.e., closer to zero) than the average. All other things being equal, lower hourly consumption volumes lead to higher VoLLs.

Table 4.6 Sensitivity of the single VoLL to different calculation procedures

Method	Level of focus	Single VoLL (€ per MWh)
Weighted-average*	Individual respondents	€ 68,887
Median-based	Groups of respondents	€ 96,598**
Mean-based	Groups of respondents	€ 63,649

* = Default method.

** = When using the sectoral VoLLs of the aggregated sector categories as they appear in Tables 4.2 and 4.3, the single VoLL becomes € 81,225 (in the event of a supply interruption of 10 percent of the hourly population consumption). This decrease in the value of the single VoLL is due to the fact that when aggregating subcategories, the use of the median causes higher VoLLs to be excluded from further calculations.

Asking respondents directly for their willingness to pay

By default, we use the WTP figures derived from the discrete-choice experiment that is part of the conjoint analysis (see chapters 2 and 3). In addition, we asked respondents directly what they would be willing to pay to avoid a 1-hour supply interruption. This 'direct' query provides us with an alternative input to the VoLL calculation. Table 4.7 shows the resulting single VoLL for a supply interruption generating an EENS of 10 percent the hourly consumption of the Dutch population during a winter weekday evening. The mean-based approach produces a high result (i.e., a single VoLL of roughly 2.4 million €/MWh). The explanation for this is that several respondents reported high amounts while taking the survey, causing the single VoLL to be driven upwards. The same is true, to some extent, for the weighted-average approach. The median-based approach is much less sensitive to the extreme outliers in the reported WTPs, which explains why it lies closer to the single VoLL estimates that are based on the WTP derived from the discrete-choice experiment.

Table 4.7 Sensitivity of the single VoLL to different calculation procedures using the direct WTP as input

Method	Level of focus	Single VoLL (€/MWh)
Weighted-average	Individual respondents	€.252,594
Median-based	Groups of respondents	€.55,641*
Mean-based	Groups of respondents	€.2,395,042

* = When using the sectoral VoLLs of the aggregated sector categories as they appear in Tables 4.2 and 4.3, the single VoLL becomes € 37,908 (in the event of a supply interruption of 10 percent of the hourly population consumption). This decrease in the value of the single VoLL is because when aggregating subcategories, the use of the median causes higher VoLLs to be excluded from further calculations.

Alternative load shedding sequence

Lastly, to assess how robust our findings are to changes in the order of the load shedding sequence we experiment with placing all users connected directly to the national grid into the category that is characterized by the highest level of protection. By default, this level 4 protection category only contains households connected to the regional grid and located in feed-in areas (see Table 4.4).

The rationale of this alternative sequence is that users connected directly to the national grid have the option to participate in an 'automatic demand control' process[44] which is invoked at 49.5 Hz, before the Low Frequency Demand Disconnection process is activated (at 49.0 Hz). In return, they are placed at the end of the load shedding sequence.

The result is a slight increase of the single VoLL. For a supply interruption of one hour with a size of 10 percent of the total load during a weekday winter evening, the single VoLL is equal to 75,188 €/MWh (which is about 9 percent higher than the 'default' single VoLL of 68,887 €/MWh).

4.5 Comparison with results from other studies

Academic studies measuring the willingness to pay for a reliable electricity supply

Multiple academic studies analysing the willingness to pay for electricity and reliability of supply have been published in recent years. Most of these studies make use of conjoint analysis and a fair amount of the studies consider electricity markets in low-income countries. The question of the reliability of supply and the accompanying willingness to pay in these instances does not refer to a marginal change (e.g. one less interruption of an hour), but to a comparison with the current unreliable supply and one without any interruptions.

Abdullah & Mariel (2010) set up a choice experiment and estimate multinomial and mixed logit models to study whether the socio-economic characteristics of consumers influence the willingness to pay for the reliability of these consumers in the rural electricity market in Kenya. Price, the number of blackouts, and duration of interruption are the most important attributes. Taale and Kyeremeh (2016) perform a similar analysis but in Ghana. Siyaranamual et al. (2020) analyse the willingness to pay for reliability in the Indonesian electricity market. They include interruptions in hours per year and the price (electricity bill) as the two main attributes.

Besides the studies looking at low-income countries, a few studies also consider middle- or high-income countries. Naturally, these studies look more into marginal changes in the reliability and are therefore more in line with the research questions of our study. Hensher et al. (2014) study the willingness to pay for the service quality of the Australian electricity network. Using conjoint analysis and discrete choice models they find that residential customers' willingness to pay to avoid an additional electricity interruption of 1 hour is about 4.6 percent of their electricity bill. Ozbafli and Jenkins (2015; 2016) use conjoint analysis and discrete choice modelling and find a willingness to pay in the range of 4 to 14 percent of the electricity bill to avoid interruptions in North Cyprus. Pepermans (2011) uses a choice experiment and conditional logit model to estimate the willingness to pay to avoid a supply interruption among a sample of Flemish respondents. The results suggest a willingness to pay of approximately 20 euros, which is close to 3.3 percent of the annual electricity bill of the representative household consumer.

Table 4.2 shows that the sectoral WTPs resulting from our analysis vary from 3 percent to 14 percent, with the WTP for households being the lowest. It can be concluded that these values are very similar to the values found in academic literature for medium- or high-income countries described in this section.

[44] Dutch Network Code Article 9.26.7.

Single VoLLs for other EU Member States

The ACER methodology for determining the VoLL is relatively new, which means not many Member States have published reports on the determination of the VoLL in this manner. The VoLLs that we are aware of are the following:

- Sweden: 7,689 €/MWh;
- Italy: 20,000 €/MWh;
- Belgium: 16,033 €/MWh;
- Finland: 8,000 €/MWh.

These are much lower than the Dutch VoLL. Based on the available information, it is not possible to say with certainty what causes this difference. We offer three possible explanations, but other factors could play a role as well. Further research would be required to gain more insight into this question.

- Electricity users in the Netherlands could have a structurally higher valuation of reliability than users in other countries, for example because of a greater vulnerability to interruptions or a different structure of the economy.
- Electricity prices in the Netherlands were unusually high and volatile at the time the survey was held. Although these prices were not used in the survey, they may have influenced users' responses.
- Other countries made some different choices in the application of the ACER methodology, which may have led to different results. Having said that, our sensitivity analysis shows that asking for the willingness to pay directly, rather than using a conjoint analysis, does not lead to a lower VoLL for the Netherlands.

5 Conclusions

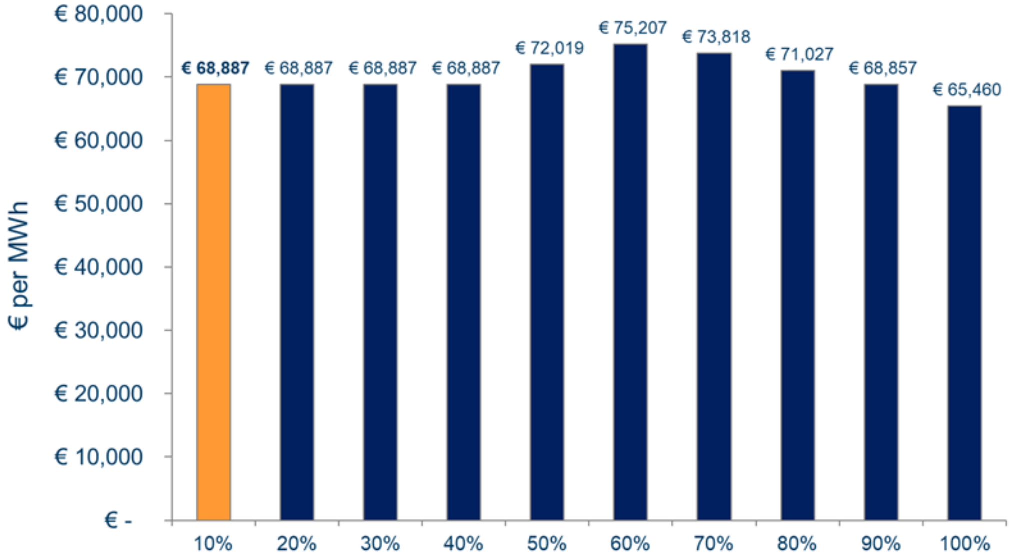
The single VoLL for the Netherlands is equal to 68,887 €/MWh.

This study determined the Value of Lost Load (VoLL) for the supply of electricity in the Netherlands, in line with the methodology described in the ACER methodology. The willingness to pay of electricity users was determined using surveys and conjoint analysis. Application of the methodology results in a VoLL of 68,887 €/MWh. This VoLL is based on a supply interruption with a duration of one hour, which takes place on a weekday winter evening and affects 10 percent of the total volume typically consumed at that time. Users are assumed to have received a notification of the interruption taking place one day in advance. Based on these parameters, a supply interruption of this kind causes a total loss of value of 87 million euro.

The VoLL is relatively stable for changes in the magnitude of the interruption.

The VoLL remains fairly constant when the share of the population that is affected by a supply interruption changes. For the first 40 percent of the population, it remains just below 70 thousand €/MWh. It then starts to rise and peaks at around 75 thousand €/MWh when 60 percent of the population is affected. It then starts to decrease again and reaches approximately 65 thousand €/MWh when 100 percent of the population is affected by the supply interruption. This is shown in figure 5.1. The VoLL for a supply interruption of 100 percent is equal to the weighted average VoLL of the total population, which corresponds to a scenario where no load shedding sequence is followed, but all users are treated equally.

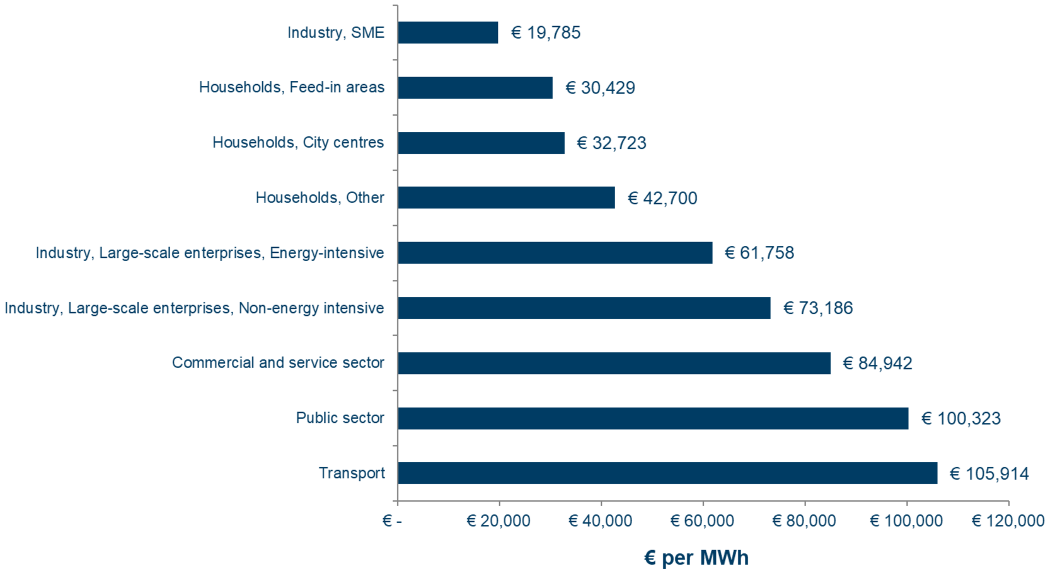
Figure 5.1 The single VoLL for different magnitudes of the supply interruption



The sectoral VoLLs range from 20 to 106 thousand €/MWh.

A sectoral VoLL is the VoLL for a subset of the total number of Dutch electricity users. A set of six user categories is specified in the ACER methodology: households, commercial or service, public service, transport, industrial SMEs (small and medium sized enterprises), and industrial large enterprises. Some subcategories have been added for the purpose of this study. Figure 5.2 shows the values found for the sectoral VoLLs. They range from 19,785 €/MWh for industrial SMEs to 105,914 €/MWh for the transport sector. A more detailed list of VoLLs for more narrowly defined subsectors is provided in Annex II.

Figure 5.2 The sectoral VoLLs per user category



The Dutch VoLL is higher than those in other EU-countries, although the willingness to pay as a percentage of the electricity bill is in line with other studies.

Until now, four other EU Member States have determined a single VoLL. Results range from 7.689 €/MWh in Sweden to 20.000 €/MWh in Italy. These are significantly lower than the Dutch VoLL. Explanations for this difference could be:

- A structurally higher valuation of reliability in the Netherlands compared to other countries.
- The unusually high and volatile electricity price in the Netherlands at the time the survey was held.
- Different choices in the application of the ACER-methodology in other countries, leading to different results.

Based on current information, it is not possible to determine which of the above explanations is the most important factor. However, recent academic studies into the willingness to pay for a reliable electricity supply yield a range of 3 to 14 percent of the annual electricity bill, which is in line with the results of this study. This suggests that the results of this study do not deviate much from other conjoint experiments, but are sensitive to the electricity price level.

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Annex I: Surveys used

Survey for households

[Welcome page]
Welkom bij dit onderzoek.

Over het onderzoek
Ecorys en SEO Economisch Onderzoek doen in opdracht van de Autoriteit Consument & Markt onderzoek naar de economische waarde van het voorkomen van stroomonderbrekingen. In deze vragenlijst vragen we u om te kiezen tussen verschillende mogelijke elektriciteitscontracten waarin onder andere de betrouwbaarheid van de levering verschilt. Uw antwoorden worden uitsluitend gebruikt om te achterhalen welke waarde u hecht aan een betrouwbare levering van elektriciteit, niet om uw elektriciteitsprijzen aan te passen.

Over deelname
Het invullen van de vragenlijst duurt ongeveer 10 minuten. Bij de meeste vragen hoeft u slechts één antwoord aan te vinken. Al uw antwoorden worden volledig anoniem en vertrouwelijk verwerkt.

Namens de Autoriteit Consument & Markt willen wij u alvast bedanken voor uw deelname.

Klik op 'Volgende' om de vragenlijst te starten.

Afbakening [new page]

1. Uit hoeveel personen bestaat uw huishouden inclusief kinderen? [verplicht, één antwoord]
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5 of meer
2. Wie maakt in uw huishouden de keuze voor een energieleverancier? [verplicht, één antwoord][45]
   a. Uzelf (al dan niet in overleg met partner/huisgenoten)
   b. Uw partner/huisgenoten
   c. Iemand anders

[Programmer -> Screenout if Q2 = b or Q2=c]

[Programmer -> Respondent cannot go back in survey]
Op basis van de door u ingevulde kenmerken valt u buiten de doelgroep van het onderzoek. Wij danken u hartelijk voor uw interesse in deelname. Klik op 'Volgende' om terug te keren naar de website van PanelClix.

[Programmer -> Dependent on Q1]

3. Het gemiddelde elektriciteitsverbruik voor uw type huishouden is [*expected average based on* Q2] kWh per jaar. U kunt hieronder invullen wat het afgelopen jaar uw werkelijke verbruik was, als u dat weet of kunt zien op uw jaarnota.
   Als u beschikt over eigen opwekking, zoals zonnepanelen, vult u het verbruik vóór saldering in.
   [numeric between 0 and 10,000]

4. De gemiddelde elektriciteitskosten voor uw type huishouden zijn [*expected average based on Q2*] euro per jaar. U kunt hieronder invullen wat het afgelopen jaar uw werkelijke kosten waren, als u dat kunt zien op uw jaaroverzicht.
   [numeric between 0 and 1,000]

Achtergrondkenmerken respondenten [new page]

5. Wat is uw geboortejaar? (*Graag antwoorden met 4 cijfers: bijvoorbeeld: 1982)*
   [numeric four digit response between 1920 and 2003]
6. Wat is uw geslacht?
   a. Man
   b. Vrouw
   c. Non-binair/wil ik niet zeggen
7. Wat is de hoogste opleiding die u heeft afgerond?
   d. Basisonderwijs
   e. VMBO
   f. MBO
   g. HBO
   h. WO of hoger
8. Wat zijn de vier cijfers van uw postcode?
   [numeric four digit response between 1000 and 9999]
9. Hoe regelmatig werkt er iemand in uw huishouden vanuit huis?
   a. Dagelijks of bijna dagelijks
   b. Eén a twee dagen per week
   c. Een enkele keer of een paar keer per maand
   d. Minder dan eens per maand
   e. Nooit
10. Beschikt u thuis over eigen elektriciteitsopwekking (bijvoorbeeld zonnepanelen)?
   f. Ja
   g. Nee

Informatieblok [new page]

Vervolg van het onderzoek

U krijgt zo meteen tien keer de keuze uit drie elektriciteitscontracten. Stelt u zich voor dat u op dit moment op zoek bent naar een nieuw elektriciteitscontract voor het komende jaar en dat de drie aangeboden contracten de enige beschikbare opties zijn.

Elk elektriciteitscontract heeft andere kenmerken met betrekking tot de stroomonderbrekingen die plaatsvinden en heeft een andere prijs. In alle andere opzichten zijn de contracten gelijk. Ook uw elektriciteitsverbruik is dus bij elk contract hetzelfde. Gaat u er verder vanuit dat bij een stroomonderbreking uw gehele wijk zonder stroom zit. U kunt dus niet naar de buren of het café om de hoek voor stroom.

De getoonde elektriciteitscontracten en stroomonderbrekingen hoeven niet overeen te komen met in werkelijkheid bestaande contracten en onderbrekingen. Het gaat erom welke keuze u zou maken als dit de enige opties zouden zijn om een elektriciteitscontract af te sluiten.

Uitleg kenmerken

U krijgt telkens drie elektriciteitscontracten te zien die kunnen verschillen op de volgende punten:

- Frequentie van stroomonderbrekingen: Dit kenmerk geeft aan hoe vaak de stroomonderbreking plaatsvindt.
- Duur van de onderbreking: Dit kenmerk geeft aan hoe lang de stroomonderbreking duurt.
- Dag van de week: Dit kenmerk geeft aan of de stroomonderbreking op een werkdag plaatsvindt, tijdens het weekend of op een feestdag.

- Deel van de dag: Dit kenmerk geeft aan op welk deel van de dag de stroomonderbreking plaatsvindt.
- Seizoen: Dit kenmerk geeft aan in welk seizoen de stroomonderbreking plaatsvindt.
- Waarschuwing: Dit kenmerk omschrijft of en wanneer u van tevoren een waarschuwing krijgt dat er een stroomonderbreking zal plaatsvinden.
- Kosten per jaar: Dit kenmerk omschrijft uw jaarlijkse elektriciteitskosten (in euro's), uitgaand van een gelijkblijvend elektriciteitsverbruik.

Discrete choice experiment

The respondents are asked to 10 times make a choice between three electricity contracts.

At each choice, seven attributes of the electricity contracts are presented to the respondents. These attributes vary and possibly influence the choice of respondents.

The attributes are:

1. Frequency of supply interruption [range: 1 time in 10 years, 1 time in 5 years, 1 time in 2 years, 1 time per year, 2 times per year, 4 times per year]
2. Duration of interruption [range: Less than 1 minute, 5 minutes, 15 minutes, 30 minutes, 60 minutes, 2 hours, 4 hours, 6 hours]
3. Day of the week [range: working day, weekend, public holiday]
4. Part of the day [range: morning (6:00 to 12:00), afternoon (12:00 to 18:00), evening (18:00 to 00:00) and night (00:00 to 6:00]
5. Season [range: spring, summer, autumn, winter]
6. Advance warning [range: none, 1 working day in advance, 3 working days in advance, 1 week in advance, 2 weeks in advance]
7. Cost per year [range: 0.8 to 1.2 times the current estimated annual cost]

[Programmer -> Respondents cannot go back in the survey after this]

WTP direct uitvragen

11. Hoeveel zou u maximaal bereid zijn om te betalen om een stroomonderbreking met onderstaande kenmerken te voorkomen?
NB: Het gaat hierbij alleen om de extra kosten voor het voorkomen van een eenmalige stroomonderbreking, niet om de totale kosten van het elektriciteitscontract.
[numeric]

    - Duur van de onderbreking: 1 uur.
    - Dag van de week: werkdag.
    - Deel van de dag: avond.
    - Seizoen: winter.
    - Waarschuwing vooraf: 1 werkdag van tevoren.

Risk attitude

12. Hoe ziet u zichzelf: bent u over het algemeen een persoon die bereid is om risico's te nemen of probeert u risico's zoveel mogelijk te mijden? (*Toelichting: 1 betekent ik ben totaal niet bereid om risico's te nemen, 10 betekent ik ben volledig bereid om risicos's te nemen)* [grid, 1-10]

13. Hoe schat u uw houding tegenover risico's in op de volgende gebieden? (*Toelichting: 1 betekent ik ben totaal niet bereid om risico's te nemen, 10 betekent ik ben volledig bereid om risicos's te nemen*).

Bij het maken van financiële beslissingen?	[grid, 1 – 10]
Met uw carrière?	[grid, 1 – 10]

Overig

14. Bent u tevreden met de betrouwbaarheid van de levering van uw elektriciteitsvoorziening? *(Toelichting: 1 betekent zeer ontevreden, 3 betekent neutraal, 5 betekent zeer tevreden)* [five point scale]
15. Heeft uw huishouden te maken gehad met stroomonderbrekingen in de afgelopen 2 jaar?
    a. Ja, 1 keer
    b. Ja, meer dan 1 keer. *Geef hiernaast aan hoeveel keer?* [open field with required response]
    c. Nee
    d. Weet ik niet meer

Afsluiting van de vragenlijst

Dit is het einde van de vragenlijst. Mede namens de Autoriteit Consument & Markt danken wij u hartelijk voor uw deelname.

16. Heeft u naar aanleiding van dit onderzoek nog vragen en/of opmerkingen? [niet verplicht, open invulveld]

Klik op 'Volgende' om terug te keren naar de website van PanelClix.

Survey for small and medium sized enterprises

[Welcome page]
Welkom bij dit onderzoek.

Over het onderzoek
Ecorys en SEO Economisch Onderzoek doen in opdracht van de Autoriteit Consument & Markt onderzoek naar de economische waarde van het voorkomen van stroomonderbrekingen. In deze vragenlijst vragen we u om te kiezen tussen verschillende mogelijke elektriciteitscontracten waarin onder andere de betrouwbaarheid van de levering verschilt. Uw antwoorden worden uitsluitend gebruikt om te achterhalen welke waarde u hecht aan een betrouwbare levering van elektriciteit, niet om uw elektriciteitsprijzen aan te passen.

Over deelname
Het invullen van de vragenlijst duurt ongeveer 10 minuten. Bij de meeste vragen hoeft u slechts één antwoord aan te vinken. Al uw antwoorden worden volledig anoniem en vertrouwelijk verwerkt.

Namens de Autoriteit Consument & Markt willen wij u alvast bedanken voor uw deelname.

Klik op ‘Volgende’ om de vragenlijst te starten.

Afbakening [new page]

1. Tot welke sector behoort uw organisatie? [only one response]
   (Als uw organisatie in meerdere sectoren actief is: kies de sector die het beste aansluit bij uw hoofdactiviteit)
   a) Landbouw, bosbouw en visserij
   b) Winning van delfstoffen
   c) Industrie
   d) Productie en distributie van en handel in elektriciteit, aardgas, stoom en gekoelde lucht
   e) Winning en distributie van water; afval- en afvalwaterbeheer en sanering
   f) Bouwnijverheid
   g) Groot- en detailhandel; reparatie van auto’s
   h) Vervoer en opslag
   i) Logies-, maaltijd- en drankverstrekking
   j) Informatie en communicatie
   k) Financiële instellingen
   l) Verhuur van en handel in onroerend goed
   m) Advisering, onderzoek en overige specialistische zakelijke dienstverlening
   n) Verhuur van roerende goederen en overige zakelijke dienstverlening
   o) Openbaar bestuur, overheidsdiensten en verplichte sociale verzekeringen
   p) Onderwijs
   q) Gezondheids- en welzijnszorg
   r) Cultuur, sport en recreatie
   s) Overige dienstverlening

[Programmer -> skip to Q6 if not Q1=c, Q1=j, Q1=o or Q1=q]

2. Is de ononderbroken voortgang van uw bedrijfsproces, bijvoorbeeld tijdens een landelijke stroomonderbreking, van vitaal belang voor de Nederlandse samenleving? [only if Q1=c]
   Dit is bijvoorbeeld het geval als de stroomonderbreking leidt tot ernstige milieuschade of onherstelbare schade aan productiefaciliteiten.

a) Ja
b) Nee

3. Levert uw organisatie producten of diensten die als nuts- of basisvoorziening gekenmerkt kunnen worden, zoals het verzorgen van telecommunicatie of het uitzenden van radio- en televisieprogramma's? [only if Q1=j]
    a) Ja
    b) Nee
4. Verricht uw organisatie activiteiten die bijdragen aan de openbare orde en veiligheid, zoals de brandweer, de politie, gevangenissen en gemeentehuizen? [only if Q1=o]
    a) Ja
    b) Nee
5. In welke van de onderstaande categorieën valt uw zorgorganisatie? [only if Q1=q]
    a) Intramurale zorg, zoals bijvoorbeeld ziekenhuizen en verpleeghuizen
    b) Extramurale zorg, zoals bijvoorbeeld huisarts- en tandartspraktijken

6. Hoeveel vestigingen met een eigen elektriciteitsaansluiting heeft uw organisatie? [numeric]
7. Hoeveel medewerkers telt uw organisatie in Nederland?
    a) Minder dan 50 medewerkers
    b) Tussen de 50 en 250 medewerkers
    c) Meer dan 250 medewerkers
8. Hoe groot is uw jaaromzet?
    a) Minder dan 2 miljoen euro
    b) Tussen de 2 en 10 miljoen euro
    c) Tussen de 10 en 50 miljoen euro
    d) Meer dan 50 miljoen euro
9. Wat was het elektriciteitsverbruik in 2020 van uw organisatie in Nederland in MWh? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric]
   Toelichting: 1MWh = 1.000 kWh
10. Klopt het dat het door u opgegeven verbruik [insert: answer to Q9] MWh is? Als dit niet klopt geef hieronder nogmaals het correcte verbruik op. [optional, numeric]
11. Hoe hoog schat u de totale kosten van het elektriciteitsverbruik van uw organisatie in Nederland in 2020? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric]

[Programmer -> Screenout if Q11/Q10<60 or Q11/Q10>350
if Q10 is unanswered, screenout if Q11/Q9<60 or Q11/Q9>350]

[Programmer -> Respondent cannot go back in survey]
Op basis van de door u ingevulde kenmerken valt u buiten de doelgroep van het onderzoek. Wij danken u hartelijk voor uw interesse in deelname. Klik op 'Volgende' om terug te keren naar de website van PanelClix.

12. Hoe groot zijn uw elektriciteitskosten als percentage van uw totale productiekosten?
    a) Minder dan 3 procent
    b) Tussen de 3 en 10 procent
    c) Meer dan 10 procent

Informatieblok [new page]

Vervolg van het onderzoek

U krijgt zo meteen tien keer de keuze uit drie elektriciteitscontracten. Stelt u zich voor dat u op dit moment op zoek bent naar een nieuw elektriciteitscontract voor het komende jaar en dat de drie aangeboden contracten de enige beschikbare opties zijn.

Elk elektriciteitscontract heeft andere kenmerken met betrekking tot de stroomonderbrekingen die plaatsvinden en heeft een andere prijs. In alle andere opzichten zijn de contracten gelijk. Ook uw elektriciteitsverbruik is dus bij elk contract hetzelfde. Gaat u er verder vanuit dat bij een stroomonderbreking uw gehele wijk zonder stroom zit. U kunt dus niet naar de buren of het café om de hoek voor stroom.

De getoonde elektriciteitscontracten en stroomonderbrekingen hoeven niet overeen te komen met in werkelijkheid bestaande contracten en onderbrekingen. Het gaat erom welke keuze u zou maken als dit de enige opties zouden zijn om een elektriciteitscontract af te sluiten.

Uitleg kenmerken

U krijgt telkens drie elektriciteitscontracten te zien die kunnen verschillen op de volgende punten:

- Frequentie van stroomonderbrekingen: Dit kenmerk geeft aan hoe vaak de stroomonderbreking plaatsvindt.
- Duur van de onderbreking: Dit kenmerk geeft aan hoe lang de stroomonderbreking duurt.
- Dag van de week: Dit kenmerk geeft aan of de stroomonderbreking op een werkdag plaatsvindt, tijdens het weekend of op een feestdag.
- Deel van de dag: Dit kenmerk geeft aan op welk deel van de dag de stroomonderbreking plaatsvindt.
- Seizoen: Dit kenmerk geeft aan in welk seizoen de stroomonderbreking plaatsvindt.
- Waarschuwing: Dit kenmerk omschrijft of en wanneer u van tevoren een waarschuwing krijgt dat er een stroomonderbreking zal plaatsvinden.
- Kosten per jaar: Dit kenmerk omschrijft uw jaarlijkse elektriciteitskosten (in euro's), uitgaand van een gelijkblijvend elektriciteitsverbruik.

Discrete choice experiment

The respondents are asked to 10 times make a choice between three electricity contracts.

At each choice, seven attributes of the electricity contracts are presented to the respondents. These attributes vary and possibly influence the choice of respondents.

The attributes are:

1. Frequency of supply interruption [range: 1 time in 10 years, 1 time in 5 years, 1 time in 2 years, 1 time per year, 2 times per year, 4 times per year]
2. Duration of interruption [range: Less than 1 minute, 5 minutes, 15 minutes, 30 minutes, 60 minutes, 2 hours, 4 hours, 6 hours]
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5. Season [range: spring, summer, autumn, winter]
6. Advance warning [range: none, 1 working day in advance, 3 working days in advance, 1 week in advance, 2 weeks in advance]
7. Cost per year [range: 0.8 to 1.2 times the current stated annual cost]

[Programmer -> Respondents cannot go back in the survey after this]

WTP direct uitvragen

13. Hoeveel zou uw organisatie maximaal bereid zijn om te betalen om een stroomonderbreking met de onderstaande kenmerken te voorkomen? *Als u het niet precies weet, geef dan uw beste inschatting* [numeric]
 NB: Het gaat hierbij alleen om de extra kosten voor het voorkomen van een eenmalige stroomonderbreking, niet om de totale kosten van het elektriciteitscontract.
    - Duur van de onderbreking: 1 uur.

- Dag van de week: werkdag.
- Deel van de dag: avond.
- Seizoen: winter.
- Waarschuwing vooraf: 1 werkdag van tevoren.

Demand response

Het begrip 'demand response' is een verzamelterm voor een aantal processen en activiteiten waarbij elektriciteitsafnemers hun elektriciteitsverbruik tijdelijk verlagen of verhogen. Dit kan gebeuren 1) op afroep van een andere partij tegen een financiële vergoeding, of 2) op eigen initiatief op basis van de marktprijsontwikkeling voor elektriciteit.

14. Heeft u op dit moment een overeenkomst met een andere partij om uw elektriciteitsverbruik op afroep tijdelijk (maximaal enkele uren) te verlagen tegen een financiële vergoeding?
    a) ja
    b) nee

[Programmer -> Conditional on Q14=a, otherwise skip to Q16]

15. Hoeveel procent van uw elektriciteitsverbruik kunt u op afroep tijdelijk (maximaal enkele uren) afschakelen? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric between 1 and 100]

16. Stuurt u op dit moment uw eigen elektriciteitsverbruik bij op basis van marktprijsontwikkelingen?
    a) ja
    b) nee

[Programmer -> Conditional on Q16=a, otherwise skip to Q18]

17. Hoeveel procent van uw elektriciteitsverbruik kunt u maximaal tijdelijk afschakelen om in te spelen op marktprijsontwikkelingen? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric between 1 and 100]

Maatregelen

18. Heeft uw organisatie maatregelen genomen om de negatieve gevolgen van een stroomonderbreking te verminderen/voorkomen? (*bijvoorbeeld: het aanschaffen van een generator)*
    a) Ja
    b) Nee

[Programmer -> Conditional on Q18=a, otherwise skip to Q24]

19. Welke maatregelen heeft uw organisatie genomen? *Meerdere antwoorden mogelijk* [allow multiple responses]
    a) Aanschaf eigen generator
    b) Aanschaf installatie voor opslag van elektriciteit
    c) Anders, namelijk: [open field]
20. Welk deel van uw verbruik wordt gedekt door uw noodvoorziening? *Probeert u een zo goed mogelijke inschatting te geven.* [numeric between 1 and 100]
21. Hoe hoog schat u de investeringskosten die uw organisatie heeft gemaakt voor deze maatregelen? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric]
    Indien u niet (meer) precies weet wat de kosten waren, probeert u dan een zo goed mogelijke inschatting te geven.
22. Wat is de afschrijvingsduur van deze investering? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric between 1 and 200]
    Indien u niet precies weet wat de afschrijvingsduur is, probeert u dan een zo goed mogelijke inschatting te geven.

23. Hoe hoog schat u de operationele kosten van deze maatregelen, ervan uitgaand dat er geen stroomonderbreking plaatsvindt? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric]

24. Stel dat u niet kunt beschikken over uw noodvoorziening. Hoeveel euro zou uw organisatie dan maximaal bereid zijn om te betalen om een eenmalige stroomonderbreking met de onderstaande kenmerken te voorkomen? *Als u het niet precies weet, geef dan uw beste inschatting.* [numeric]
NB: Het gaat hierbij alleen om de extra kosten voor het voorkomen van een eenmalige stroomonderbreking, niet om de totale kosten van het elektriciteitscontract.
    - Duur van de onderbreking: 1 uur.
    - Dag van de week: werkdag.
    - Deel van de dag: avond.
    - Seizoen: winter.
    - Waarschuwing vooraf: 1 werkdag van tevoren.

Overig

25. Bent u tevreden met de betrouwbaarheid van de levering van uw elektriciteitsvoorziening? *(Toelichting: 1 betekent zeer ontevreden, 3 betekent neutraal, 5 betekent zeer tevreden)* [five point scale]
26. Heeft u te maken gehad met stroomonderbrekingen in de afgelopen 2 jaar?
    a) Ja, 1 keer
    b) Ja, meer dan 1 keer. Geef hiernaast aan hoeveel keer? [open field with required response]
    c) Nee
    d) Weet ik niet meer

Afsluiting van de vragenlijst

27. Heeft u naar aanleiding van dit onderzoek nog vragen en/of opmerkingen? [open field, not required]
28. Mogelijk hebben wij nog enkele vervolgvragen op basis van uw antwoorden. Vindt u het goed dat wij in dat geval contact met u opnemen?
    a) Ja
    b) Nee, liever niet

Dit is het einde van de vragenlijst. Mede namens de Autoriteit Consument & Markt danken wij u hartelijk voor uw deelname. Klik op 'Volgende' om terug te keren naar de website van PanelClix.

Survey for large enterprises

[Welcome page]
Welkom bij dit onderzoek.

Over het onderzoek
Ecorys en SEO Economisch Onderzoek doen in opdracht van de Autoriteit Consument & Markt onderzoek naar de economische waarde van het voorkomen van stroomonderbrekingen. In deze vragenlijst vragen we u om te kiezen tussen verschillende mogelijke elektriciteitscontracten waarin onder andere de betrouwbaarheid van de levering verschilt. Uw antwoorden worden uitsluitend gebruikt om te achterhalen welke waarde u hecht aan een betrouwbare levering van elektriciteit, niet om uw elektriciteitsprijzen aan te passen.

Over deelname
Het invullen van de vragenlijst duurt ongeveer 10 minuten. Bij de meeste vragen hoeft u slechts één antwoord aan te vinken. Al uw antwoorden worden volledig anoniem en vertrouwelijk verwerkt.

Namens de Autoriteit Consument & Markt willen wij u alvast bedanken voor uw deelname.

Klik op 'Volgende' om de vragenlijst te starten.

Afbakening [new page]

1. Welk van de onderstaande uitspraken is het meest van toepassing op uw situatie bij uw werkgever?
    a) Ik ben niet betrokken geweest bij het afsluiten van het elektriciteitscontract.
    b) Ik ben nauwelijks betrokken geweest bij het afsluiten van het elektriciteitscontract.
    c) Ik heb geadviseerd over het afsluiten van het elektriciteitscontract.
    d) Ik ben (mede)beslisser geweest bij het afsluiten van het elektriciteitscontract.

[Programmer -> Screenout if Q1=a or Q1=b]

[Programmer -> Respondent cannot go back in survey]
Op basis van de door u ingevulde kenmerken valt u buiten de doelgroep van het onderzoek. Wij danken u hartelijk voor uw interesse in deelname. Klik op 'Volgende' om terug te keren naar de website van PanelClix.

2. Tot welke sector behoort uw organisatie? [only one response]
   (Als uw organisatie in meerdere sectoren actief is: kies de sector die het beste aansluit bij uw hoofdactiviteit)
    a) Landbouw, bosbouw en visserij
    b) Winning van delfstoffen
    c) Industrie
    d) Productie en distributie van en handel in elektriciteit, aardgas, stoom en gekoelde lucht
    e) Winning en distributie van water; afval- en afvalwaterbeheer en sanering
    f) Bouwnijverheid
    g) Groot- en detailhandel; reparatie van auto's
    h) Vervoer en opslag
    i) Logies-, maaltijd- en drankverstrekking
    j) Informatie en communicatie
    k) Financiële instellingen
    l) Verhuur van en handel in onroerend goed
    m) Advisering, onderzoek en overige specialistische zakelijke dienstverlening
    n) Verhuur van roerende goederen en overige zakelijke dienstverlening

o) Openbaar bestuur, overheidsdiensten en verplichte sociale verzekeringen
p) Onderwijs
q) Gezondheids- en welzijnszorg
r) Cultuur, sport en recreatie
s) Overige dienstverlening

[Programmer -> skip to Q7 if not Q1=c, Q1=j, Q1=o or Q1=q]

3. Is de ononderbroken voortgang van uw bedrijfsproces, bijvoorbeeld tijdens een landelijke stroomonderbreking, van vitaal belang voor de Nederlandse samenleving? [only if Q1=c]
Dit is bijvoorbeeld het geval als de stroomonderbreking leidt tot ernstige milieuschade of onherstelbare schade aan productiefaciliteiten.
   a) Ja
   b) Nee
4. Levert uw organisatie producten of diensten die als nuts- of basisvoorziening gekenmerkt kunnen worden, zoals het verzorgen van telecommunicatie of het uitzenden van radio- en televisieprogramma's? [only if Q1=j]
   a) Ja
   b) Nee
5. Verricht uw organisatie activiteiten die bijdragen aan de openbare orde en veiligheid, zoals de brandweer, de politie, gevangenissen en gemeentehuizen? [only if Q1=o]
   a) Ja
   b) Nee
6. In welke van de onderstaande categorieën valt uw zorgorganisatie? [only if Q1=q]
   a) Intramurale zorg, zoals bijvoorbeeld ziekenhuizen en verpleeghuizen
   b) Extramurale zorg, zoals bijvoorbeeld huisarts- en tandartspraktijken

7. Hoeveel vestigingen met een eigen elektriciteitsaansluiting heeft uw organisatie? [numeric]
8. Hoeveel van deze elektriciteitsaansluitingen zijn direct aangesloten op het landelijk elektriciteitsnet van TenneT? *Bij een directe aansluiting op het landelijk elektriciteitsnet heeft u voor deze aansluiting een aparte Aansluitings- en Transportovereenkomst (ATO) met TenneT.* [numeric]
NB: Laat deze vraag leeg wanneer u niet weet of uw organisatie directe aansluitingen heeft op het landelijk elektriciteitsnet van TenneT.

[Programmer -> Conditional on Q8>0, otherwise skip to Q10]

9. Hoeveel procent van uw totale elektriciteitsverbruik realiseert u via uw aansluiting(en) op het landelijk elektriciteitsnet? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric between 1 and 100]
10. Hoeveel medewerkers telt uw organisatie in Nederland?
    a) Minder dan 50 medewerkers
    b) Tussen de 50 en 250 medewerkers
    c) Meer dan 250 medewerkers
11. Hoe groot is uw jaaromzet?
    a) Minder dan 2 miljoen euro
    b) Tussen de 2 en 10 miljoen euro
    c) Tussen de 10 en 50 miljoen euro
    d) Meer dan 50 miljoen euro
12. Wat was het elektriciteitsverbruik in 2020 van uw organisatie in Nederland in MWh? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric]
Toelichting: 1MWh = 1.000 kWh
13. Klopt het dat het door u opgegeven verbruik [insert: answer to Q9] MWh is? Als dit niet klopt geef hieronder nogmaals het correcte verbruik op. [optional, numeric]

14. Hoe hoog schat u de totale kosten van het elektriciteitsverbruik van uw organisatie in Nederland in 2020? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric]
15. Hoe groot zijn uw elektriciteitskosten als percentage van uw totale productiekosten?
    a) Minder dan 3 procent
    b) Tussen de 3 en 10 procent
    c) Meer dan 10 procent

Informatieblok [new page]

Vervolg van het onderzoek

U krijgt zo meteen tien keer de keuze uit drie elektriciteitscontracten. Stelt u zich voor dat u op dit moment op zoek bent naar een nieuw elektriciteitscontract voor het komende jaar en dat de drie aangeboden contracten de enige beschikbare opties zijn.

Elk elektriciteitscontract heeft andere kenmerken met betrekking tot de stroomonderbrekingen die plaatsvinden en heeft een andere prijs. In alle andere opzichten zijn de contracten gelijk. Ook uw elektriciteitsverbruik is dus bij elk contract hetzelfde. Gaat u er verder vanuit dat bij een stroomonderbreking uw gehele wijk zonder stroom zit. U kunt dus niet naar de buren of het café om de hoek voor stroom.

De getoonde elektriciteitscontracten en stroomonderbrekingen hoeven niet overeen te komen met in werkelijkheid bestaande contracten en onderbrekingen. Het gaat erom welke keuze u zou maken als dit de enige opties zouden zijn om een elektriciteitscontract af te sluiten.

Uitleg kenmerken

U krijgt telkens drie elektriciteitscontracten te zien die kunnen verschillen op de volgende punten:

- Frequentie van stroomonderbrekingen: Dit kenmerk geeft aan hoe vaak de stroomonderbreking plaatsvindt.
- Duur van de onderbreking: Dit kenmerk geeft aan hoe lang de stroomonderbreking duurt.
- Dag van de week: Dit kenmerk geeft aan of de stroomonderbreking op een werkdag plaatsvindt, tijdens het weekend of op een feestdag.
- Deel van de dag: Dit kenmerk geeft aan op welk deel van de dag de stroomonderbreking plaatsvindt.
- Seizoen: Dit kenmerk geeft aan in welk seizoen de stroomonderbreking plaatsvindt.
- Waarschuwing: Dit kenmerk omschrijft of en wanneer u van tevoren een waarschuwing krijgt dat er een stroomonderbreking zal plaatsvinden.
- Kosten per jaar: Dit kenmerk omschrijft uw jaarlijkse elektriciteitskosten (in euro's), uitgaand van een gelijkblijvend elektriciteitsverbruik.

Discrete choice experiment

The respondents are asked to 10 times make a choice between three electricity contracts.

At each choice, seven attributes of the electricity contracts are presented to the respondents. These attributes vary and possibly influence the choice of respondents.

The attributes are:

1. Frequency of supply interruption [range: 1 time in 10 years, 1 time in 5 years, 1 time in 2 years, 1 time per year, 2 times per year, 4 times per year]
2. Duration of interruption [range: Less than 1 minute, 5 minutes, 15 minutes, 30 minutes, 60 minutes, 2 hours, 4 hours, 6 hours]
3. Day of the week [range: working day, weekend, public holiday]
4. Part of the day [range: morning (6:00 to 12:00), afternoon (12:00 to 18:00), evening (18:00 to 00:00) and night (00:00 to 6:00]
5. Season [range: spring, summer, autumn, winter]

6. Advance warning [range: none, 1 working day in advance, 3 working days in advance, 1 week in advance, 2 weeks in advance]
7. Cost per year [range: 0.8 to 1.2 times the current stated annual cost]

[Programmer -> Respondents cannot go back in the survey after this]

WTP direct uitvragen

16. Hoeveel zou uw organisatie maximaal bereid zijn om te betalen om een stroomonderbreking met de onderstaande kenmerken te voorkomen? *Als u het niet precies weet, geef dan uw beste inschatting* [numeric] *NB: Het gaat hierbij alleen om de extra kosten voor het voorkomen van een eenmalige stroomonderbreking, niet om de totale kosten van het elektriciteitscontract.*
    - Duur van de onderbreking: 1 uur.
    - Dag van de week: werkdag.
    - Deel van de dag: avond.
    - Seizoen: winter.
    - Waarschuwing vooraf: 1 werkdag van tevoren.

Demand response

Het begrip 'demand response' is een verzamelterm voor een aantal processen en activiteiten waarbij elektriciteitsafnemers hun elektriciteitsverbruik tijdelijk verlagen of verhogen. Dit kan gebeuren 1) op afroep van een andere partij tegen een financiële vergoeding, of 2) op eigen initiatief op basis van de marktprijsontwikkeling voor elektriciteit.

17. Heeft u op dit moment een overeenkomst met een andere partij om uw elektriciteitsverbruik op afroep tijdelijk (maximaal enkele uren) te verlagen tegen een financiële vergoeding?
    a) ja
    b) nee

[Programmer -> Conditional on Q17=a, otherwise skip to Q19]

18. Hoeveel procent van uw elektriciteitsverbruik kunt u op afroep tijdelijk (maximaal enkele uren) afschakelen? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric between 1 and 100]

19. Stuurt u op dit moment uw eigen elektriciteitsverbruik bij op basis van marktprijsontwikkelingen?
    a) ja
    b) nee

[Programmer -> Conditional on Q19=a, otherwise skip to Q21]

20. Hoeveel procent van uw elektriciteitsverbruik kunt u maximaal tijdelijk afschakelen om in te spelen op marktprijsontwikkelingen? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric between 1 and 100]

Maatregelen

21. Heeft uw organisatie maatregelen genomen om de negatieve gevolgen van een stroomonderbreking te verminderen/voorkomen? (*bijvoorbeeld: het aanschaffen van een generator)*
    a) Ja
    b) Nee

[Programmer -> Conditional on Q21=a, otherwise skip to Q27]

22. Welke maatregelen heeft uw organisatie genomen? *Meerdere antwoorden mogelijk* [allow multiple responses]
    a) Aanschaf eigen generator
    b) Aanschaf installatie voor opslag van elektriciteit
    c) Anders, namelijk: [open field]
23. Welk deel van uw verbruik wordt gedekt door uw noodvoorziening? *Probeert u een zo goed mogelijke inschatting te geven.* [numeric between 1 and 100]
24. Hoe hoog schat u de investeringskosten die uw organisatie heeft gemaakt voor deze maatregelen? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric]
    Indien u niet (meer) precies weet wat de kosten waren, probeert u dan een zo goed mogelijke inschatting te geven.
25. Wat is de afschrijvingsduur van deze investering? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric between 1 and 200]
    Indien u niet precies weet wat de afschrijvingsduur is, probeert u dan een zo goed mogelijke inschatting te geven.
26. Hoe hoog schat u de operationele kosten van deze maatregelen, ervan uitgaand dat er geen stroomonderbreking plaatsvindt? *Rond uw antwoord af op een geheel getal en gebruik geen punten of komma's.* [numeric]

27. Stel dat u niet kunt beschikken over uw noodvoorziening. Hoeveel euro zou uw organisatie dan maximaal bereid zijn om te betalen om een eenmalige stroomonderbreking met de onderstaande kenmerken te voorkomen? *Als u het niet precies weet, geef dan uw beste inschatting.* [numeric]
    NB: Het gaat hierbij alleen om de extra kosten voor het voorkomen van een eenmalige stroomonderbreking, niet om de totale kosten van het elektriciteitscontract.
    - Duur van de onderbreking: 1 uur.
    - Dag van de week: werkdag.
    - Deel van de dag: avond.
    - Seizoen: winter.
    - Waarschuwing vooraf: 1 werkdag van tevoren.

Overig

28. Bent u tevreden met de betrouwbaarheid van de levering van uw elektriciteitsvoorziening? *(Toelichting: 1 betekent zeer ontevreden, 3 betekent neutraal, 5 betekent zeer tevreden)* [five point scale]
29. Heeft u te maken gehad met stroomonderbrekingen in de afgelopen 2 jaar?
    a) Ja, 1 keer
    b) Ja, meer dan 1 keer. Geef hiernaast aan hoeveel keer? [open field with required response]
    c) Nee
    d) Weet ik niet meer

Afsluiting van de vragenlijst

30. Heeft u naar aanleiding van dit onderzoek nog vragen en/of opmerkingen? [open field, not required]
31. Mogelijk hebben wij nog enkele vervolgvragen op basis van uw antwoorden. Vindt u het goed dat wij in dat geval contact met u opnemen? Zo ja, vul dan uw e-mailadres in. [open field, not required]

Dit is het einde van de vragenlijst. Mede namens de Autoriteit Consument & Markt danken wij u hartelijk voor uw deelname. Klik op 'Volgende' om terug te keren naar de website van PanelClix.

Annex II: Detailed characteristics of the survey sample

Subsector	N	Total hourly electricity consumption on country level* (MWh)	VoLL (€/MWh)
Commercial and utilities sector, Critical process industry, utilities and basic services, Regional grid	10	101	€ 119,061
Commercial and service sector, Other, Regional grid	120	1,584	€ 82,755
Industry, Large-scale consumers, Energy intensive, National grid	10	1,368	€ 56,091
Industry, Large-scale consumers, Energy intensive, Critical process industry, utilities and basic services, Regional grid	9	1,796	€ 106,119
Industry, Large-scale consumers, Energy intensive, Other, Regional grid	4	348	€ 92,390
Industry, Large-scale consumers, Non-energy intensive, Critical process industry, utilities and basic services, Regional grid	3	469	€ 64,502
Industry, Large-scale consumers, Non-energy intensive, Other, Regional grid	4	191	€ 94,480
Industry, SME, National grid	6	147	€ 17,642
Industry, SME, Critical process industry, utilities and basic services, Regional grid	16	244	€ 20,416
Industry, SME, Other, Regional grid	41	118	€ 49,579
Public sector, National grid	1	9	X**
Public sector, Public order, safety and health, Regional grid	24	1,015	€ 99,825
Public sector, Other, Regional grid	37	22	€ 123,589
Transport, Other, Regional grid	15	544	€ 105,914
Households, City center, Regional grid	503	2,614	€ 32,723
Households, Feed-in area, Regional grid	260	1,001	€ 30,429
Households, Other, Regional grid	248	1,122	€ 42,700

* = after applying the profile correction factors, correcting for demand-side responsivity and balancing sectoral volumes so that they match the distribution of sectoral volumes for the Netherlands as a whole.

** = to safeguard the privacy of our respondents, this VoLL is not shown in the report.

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