Determination of Reliability Standard Indicator for Portugal

A report to Entidade Reguladora dos Serviços Energéticos (ERSE)

DECEMBER 2025

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TABLE OF CONTENTS

1   Introduction

1.1   Background

Security of supply is a key objective of EU energy policy. When it comes to security of electricity supply, in particular, that is defined as 'the ability of an electricity system to guarantee the supply of electricity to customers with a clearly established level of performance, as determined by the member states concerned[1]'. To ensure there are adequate generation resources, Member States have been using capacity mechanisms. These help incentivise capacity, rather than energy, effectively ensuring there is sufficient capacity to meet a desired 'security standard'.

There is a set of parameters used for this 'security standard' and for the design of capacity mechanisms developed in in European Union (EU) Member States (MS) as per the agreed guidelines. These are:

— **Value Of Lost Load (VOLL)** – this reflects the cost to consumers from supply interruptions, expressed in EUR/MWh.

— **Cost Of New Entry (CONE)** – this refers to the annualised cost for commissioning and retaining new generation capacity.

— **Cost of Renewal/Prolongation (CORP)** – this is the annual avoidable fixed cost for keeping an existing generator in operation or prolonging its lifetime by a set period of time.

— **Reliability Standard (RS)** – this is the target level of adequacy or acceptable level of risk in terms of unserved energy, often expressed in terms such as Loss Of Load Expectation (LOLE) or Expected Energy Not Served (EENS).

The LOLE for each reference technology can be estimated based on the following formula:

$$LOLE_{Technology} = \frac{CONE/CORP\ fixed_{Technology}}{VOLL - CONE/CORP\ variable_{Technology}}$$

These parameters are defined in Regulation (EU) 2019/943. Article 25 of this Regulation requires MS to have set a RS when requesting the introduction of a capacity mechanism.

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[1] https://eur-lex.europa.eu/eli/reg/2019/941/oj/eng

This RS should be calculated based on VOLL and CONE/CORP, and in accordance with a specific methodology developed by the European Network of Transmission System Operators for Electricity (ENTSO-E) and approved by the Agency for the Cooperation of Energy Regulators (ACER). These three parameters are described in more detail in ACER Decision No 23/2020, which provides guidance on the methodologies for their calculation and how these should be used.

There is a desire for harmonising the methodology to calculate the parameters (i.e., VOLL, CONE/CORP and RS) for capacity mechanisms to be approved under EU State Aid rules. ensuring that such mechanisms are justified, proportionate and do not distort cross-border competition.

This report analyses on the one hand how various EU MS have defined and applied these parameters in their adequacy assessments, highlighting methodological approaches, and potential implications for the design/approval of capacity mechanisms. On the other hand, AFRY has carried out an independent assessment of the key parameters needed to define the RS according to the Portuguese context, which has been presented as well alongside AFRY's critical view.

1.2   Objectives

The objective of this report is to present the study of several national indicators regarding the security of supply of the Portuguese electricity system (Sistema Elétrico Nacional, SEN), with the purpose of determining a proposal for the RS indicator for mainland Portugal, to be calculated according to the guidelines contained in the methodology approved by ACER – hereinafter referred to as the 'ACER methodology' in this document. These indicators have been compared to the ones derived from other MS to provide some context around them.

The results and conclusions of the study will contribute to the assessment of the adequacy of existing resources in the SEN to meet the current and expected future demand for electricity. The possible identification of resource adequacy problems in the SEN will lead to consideration of the need to introduce a capacity mechanism in Portugal, provided for in article 21 et seq. of the aforementioned European regulation.

1.3 Structure of this report

This study consists of four different work streams.

1.3.1 WS1: Initial VOLL & CONE estimates

AFRY has performed an initial analysis to review the VOLL, CONE and RS from the approved parameters from other MS. From this review, AFRY has provided a critical view on the values that could be applicable for the Portuguese market.

1.3.2 WS2: CONE estimates

The CONE is estimated for different reference technologies.

Choice of reference technologies

ACER methodology suggests that all technologies that contribute to generation adequacy should be considered. The starting point is the capacity mix portfolio included in the revised National Energy and Climate Plan 2021-2030 (Plano Nacional de Energia e Clima, PNEC 2030). The technologies should cover existing, new build and renovated generating units.

Additional capacity potential

For each reference technology identified, the potential for additional capacity is determined by calculating the additional capacity that could be installed or renewed through investments in the SEN over the period considered (between 2025 and 2030). The additional capacity corresponds to the difference between the planned installed capacity in 2030 and that as of 31st December 2024. In cases of generating unit extension/renewal, the additional capacity is equal to the entire installed capacity of plants that between 2025 and 2030 will reach the end of their useful life.

Estimating the CONE

The last step corresponds to the calculation of the CONE, which includes the determination the investment costs (CAPEX) and the Annual Fixed Costs (AFC). Both are expressed in EUR/MW, and reflect as much as possible the prices, requirements and characteristics of the reference technologies for mainland Portugal, based on verifiable sources, referenced in the study. In addition to the fixed CONE, the Weighted Average Cost of Capital (WACC) applied to mainland Portugal, which represents the minimum rate of return required by investors to finance the reference technology, has been calculated.

1.3.3 WS3: Determination of the VOLL

In accordance with the ACER methodology, AFRY has analysed the data collected from the VOLL survey performed for ERSE by QMETRICS. For each supply interruption scenario, appropriate statistical methodologies have been applied to convert the unprocessed data into EUR per MWh values for the Domestic and Non-domestic segments. These two sectoral VOLL have then been used to determine a single VOLL for mainland Portugal.

1.3.4 WS4: Determination of the Reliability Standard

AFRY has calculated the RS to be applicable in the Portuguese market based on the CONE and VOLL findings from WS3 and WS4. This RS is the result of the selection of the technology with the highest LOLE that is required to assure the security of supply coverage.

1.4 Conventions

The analysis presented in this report has been prepared based on information publicly available as of November 2025. The report does not consider any developments that occurred after mid-November 2025.

Unless otherwise indicated, monetary values are expressed in real Jan 2025 Euros. For the sake of simplicity, values are sometimes calculated as averages, approximations or groupings without loss of accuracy for the purposes of the analysis.

Unless otherwise stated, the source of all tables and figures is AFRY.

2 Preliminary study of VOLL and CONE

2.1 Summary

AFRY has analysed publicly available information on VOLL, CONE, CORP and RS prepared by different EU MS and ACER. This information is summarised in Exhibit 1:

— There is a wide variation in **VOLL**, ranging from EUR 68,887/MWh in the Netherlands to EUR 6,838/MWh in Greece, with an average of EUR 19,292/MWh.

— Depending on the market, three different options for **CONE/CORP** can be observed, depending on the reference technology used by MS to obtain the final RS:

— OCGT[2]: 46% of MS selected this option, with values ranging from EUR 115,990/MW-year to EUR 55,000/MW-year, with an average value of EUR 71,173/MW-year.

— DSR[3]: 54% of MS selected this option, with values ranging from EUR 60,000/MW-year to EUR 7,873/MW-year, with an average value of EUR 32,230/MW-year.

— Extension of CCGT[4]: 15% of MS selected this option, with two observations of EUR 34,401/MW-year and EUR 17,000/MW-year.

— The combination of the above values leads to an **RS** ranging from 8.00 h/year to 1.00 h/year depending on the MS, with an average of 3.29 h/year.

In general, the above observations are volatile and therefore difficult to apply to the Portuguese context, even at a high level. In the following subsections, AFRY has explored the different components in more detail in order to analyse the main differences between MS; in addition, the analysis presented proves to be useful for the results corresponding to WS2, 3 and 4.

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[2] Open Cycle Gas Turbine (OCGT).
[3] Demand Side Response (DSR).
[4] Combined cycle gas turbine (CCGT).

Exhibit 1 – VOLL, CONE/CORP, RS for the different MS

Wide VOLL range, which leads to a varied definition of the RS, depending on the selection of the reference technology and the resulting value of CONE/CORP.

MS	Date	VOLL (EUR/MWh)	CONE/CORP (EUR/MW-yr)	Reference technology for CONE/CORP	RS (h/year)
Belgium	2022	12,832	30,000	DSR	3.00
Cyprus					3.00
Czech Republic	2022	16,003[5]	105,800	OCGT	6.70
Estonia	2020	9,206	72,859	OCGT	8.00
Finland	2022	8,000	17,000	CCGT extension	2.10
France	2022	33,000	60,000	DSR	2.00
Germany & Luxembourg	2021	12,240	57,067	DSR/OCGT	2.77
Greece	2021	6,838	18,735	DSR	3.01
Ireland	2023	17,909	115,990	OCGT	3.00[6]
Italy	2021	20,000[7]	53,000	OCGT	3.00
Netherlands	2022	68,887			4.00
Poland[8]	2023	17,194	30,183	DSR/OCGT	3.00
Slovenia	2022	17,233	21,753	DSR	
Spain[9]	2024	22,879	34,401	CCGT extension	1.50
Sweden[10]	2021	7,870	7,873	DSR	1.00

Notes: Some specificities of each market are commented on where applicable, later in the report.
Values are in nominal money.
Sources: ACER and MS.

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[5] According to ACER, the figures obtained for VOLL have been increased by four, although this information is not public.

[6] Initially set at 6.50 hours/year, but subsequently amended by the Irish MS.

[7] Italy has published different parameters for each price zone and a single value for Italy, which is shown in the table.

[8] Assumed exchange rate of 1 Esloti per EUR 0.2133, consulted at _the European Central Bank_ (ECB) on 14 March 2023, the date of approval of the MS. This exchange rate may differ from that used by ACER in its annual monitoring report.

[9] The Spanish parameters have not been officially accepted.

[10] Assumed exchange rate of 1 SEK per EUR 0.0954, consulted at _the European Central Bank_ (ECB) for the year 2020, date of approval of the MS. This exchange rate may differ from that used by ACER in its annual monitoring report.

2.2 VOLL

ACER defines a set of criteria for estimating the VOLL:

— **Criterion 1, customer segmentation:** segmentation of consumers according to households, tertiary, public services, small and medium-sized industry, large industry and transport.

— **Criterion 2, definition of VOLL parameters**: definition of loss of load events, including duration, periods of occurrence or pre-notification period.

— **Criterion 3, quality of surveys:** ACER states that the surveys shall be statistically representative, divided into two sections, measuring at least willingness to pay (WTP). Some sensitivity or macroeconomic checks are recommended.

— **Criterion 4, single VOLL calculation:** to derive a unique VOLL value from the different customer segments, survey results shall be weighted, excluding price-sensitive consumers.

— **Criterion 5, transparency:** ACER recommends transparency in WTP parameters, survey and respondents, WTP by sector, weightings by sector and single WTP calculation.

AFRY's review of the approach taken by other MS, shown in Exhibit 2, suggests that:

— most MS segment their consumers, although not necessarily in line with ACER guidelines and without justifying the selection;

— the selection of consumers surveyed is not always statistically representative (or there is no information to confirm this);

— most MS do not have macroeconomic checks or additional sensitivities, which can be very useful in framing the VOLL provided; and

— there is a lack of transparency in some MS (for example, questionnaires are not made available or analysis references older documents).

AFRY's analysis shown in Exhibit 2 reflect AFRY's best understanding of the criteria to be followed in VOLL surveys, in accordance with ACER; however, AFRY's view shall be regarded as an independent but subjective one.

Exhibit 2 – Qualitative assessment of the VOLL calculation by MS

MS	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
Belgium	🟡	✓	✓	✓	✓
Czech Republic	✓			✓	**X**
Estonia	✓	**X**	**X**	**X**	**X**
Finland	🟡	✓	🟡	✓	✓
France	✓	✓	🟡	✓	🟡
Germany & Luxembourg	**X**	**X**	**X**	**X**	**X**
Greece	✓	✓	🟡	✓	🟡
Ireland	🟡	✓	✓	✓	✓
Italy	🟡	✓	✓	✓	✓
Netherlands	✓	✓	✓	✓	✓
Poland	✓	✓	✓	✓	✓
Slovenia	🟡			**X**	**X**
Spain	🟡	✓	**X**	✓	🟡
Sweden	🟡	✓	✓	✓	🟡

Legend: ✓ for compliant, 🟡 for partially compliant and **X** for non-compliant.
Source: AFRY.

The VOLL in the different MS AFRY has analysed, ranges from EUR 6,838/MWh to EUR 68,887/MWh, with an average value of EUR 19,292/MWh; additional information about the VOLL surveys is presented in Annex A. VOLL variability can be considered to be high on statistical terms. As a result, AFRY has carried out additional analysis presented in the following subsections to understand the differences per MS.

2.2.1 Research guidelines

ACER guidelines are not being strictly followed by MS, as has already been identified by some studies commissioned by ACER, which can lead to different results depending on the questionnaire used, the focus of the questions (e.g. willingness to pay vs. willingness to accept), etc. Furthermore, some markets, such as Germany, Spain or Estonia, do not even follow ACER guidelines on surveys for calculating VOLL.

As shown in Exhibit 2 above, some MS have produced 'high quality' surveys for the calculation of VOLL, meeting most of the criteria defined by ACER. These are the Netherlands, Italy, Poland, Ireland and Belgium.

2.2.2   Date of assessment

The VOLL assessments from the different MS have been carried out over the period 2020 to 2024; as a result, in a period of high variability of inflation, monetary values may not be directly comparable. AFRY has inflated the VOLL values according to average inflation figures obtained from Bloomberg for the European harmonized index of consumer prices.

The inflation adjusted VOLL for the different MS, ranges from EUR 8,176/MWh to EUR 75,982/MWh, with an average value of EUR 21,451/MWh. Inflation-adjusted values are in AFRY's views more relevant to potentially extrapolate them to the Portuguese context, and as a result they will be used in the following subsections.

2.2.3   Weighting methodology

ACER does not propose a specific approach for 'weighting' the VOLL for the different customer segments. In general, most MS apply a weighting per customer group in line with their overall consumption.

Other markets, such as the Netherlands or Sweden, follow a different approach. They establish a specific predefined 'reduction' order, which directly affects the VOLL, according to the selected order and the assumed depth of load shedding.

2.2.4   Economic fundamentals

This subsection explores the relationship in the MS analysed between their Gross Domestic Product (GDP) in 2024 and their electricity demand in the same year; the main analysis is presented in Exhibit 3 and Exhibit 4. The ratio between GDP and electricity demand could be used, to a certain extent, as an indicator of VOLL, since it relates the economic output of a given MS (in EUR/USD) to the input in electricity demand (in MWh).

The following can be gleaned from the analysis:

— There is a positive relationship between VOLL and GDP/demand ratio, but the correlation can be considered statistically weak, with a value of 35%.

— There are some MS where the selected VOLL and the GDP/demand ratio differ significantly (e.g. Netherlands), while for other MS the values are reasonably close (e.g., Ireland).

— Two different trends can be observed: to establish the mathematical relationship, the dataset is cleaned and outliers are eliminated until the resulting Pearson's coefficient or R^2 is greater than 80%, which normally indicates a strong positive linear relationship between two variables[11]. AFRY wishes to reiterate that this is an illustrative calculation and cannot in any way be considered representative, due, among other factors, to

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[11] The methodology applied is an iterative process, as follows: 1) R^2 is calculated; 2) if R^2 is less than 80%, the MS with the greatest Euclidean distance from the regression function is eliminated from the data set; and 3) return to step 1.

the small size of the data set or the failure to consider potential non-linear relationships between variables.

— **Subset 1:** Ireland, Belgium, Germany/Luxembourg, Slovenia, Finland, Sweden, Estonia and Greece; the resulting relationship is described by the function $0.73 \times \frac{GDP}{Demand} + 6,510$. As an illustrative analysis, using the Portuguese GDP/demand ratio (i.e. EUR 6,003/MWh) on the relationships observed in this group of MS, the VOLL that could be expected would be EUR 10,898/MWh.

— **Subset 2:** Netherlands, France, Italy, Spain, Poland, Czech Republic, Slovenia, Finland, Sweden, Estonia and Greece; the resulting relationship is described by the function $8.86 \times \frac{GDP}{Demand} - 33,936$. As an illustrative analysis, using the Portuguese GDP/demand ratio (i.e. EUR 6,003/MWh) on the relationships observed in this group of MS, the VOLL that could be expected would be EUR 19,272/MWh.

— **Subset 3:** includes data from all MS; the resulting relationship is described by the function $1.73 \times \frac{GDP}{Demand} + 7,837$. As an illustrative analysis, using the Portuguese GDP/demand ratio (i.e. EUR 6,003/MWh) on the relationships observed in this group of MS, the VOLL that could be expected would be EUR 18,191/MWh.

Exhibit 3 – GDP & electricity demand in 2024 and VOLL for selected MS

MS	Demand (TWh)	GDP (bn USD)	VOLL (EUR/MWh)	GDP/demand (USD/MWh)
Belgium	81.0	665.0	14,154	8,209
Czech Republic	60.9	344.9	17,653	5,664
Estonia	8.0	42.8	11,293	5,344
Finland	82.0	298.8	8,824	3,644
France	429.2	3,162.0	36,399	7,367
Ireland	32.3	577.2	18,724	17,870
Italy	279.1	2,372.1	23,914	8,499
Germany & Luxembourg	464.7	4,658.5	14,635	10,025
Greece	50.4	257.1	8,176	5,101
Netherlands	115.0	1,227.2	75,982	10,671
Poland	163.5	908.6	17,976	5,557
Slovenia	12.4	72.5	19,009	5,844
Spain	232.3	1,722.2	23,920	7,414
Sweden	131.9	610.1	9,654	4,626

Note: All prices are in nominal money.
Sources: ENTSO-E, International Monetary Fund (IMF) and MS.

Exhibit 4 – Relationship between GDP/demand in 2024 and VOLL by MS[12]

Two different trends can be observed, depending on the sub-selection of MS
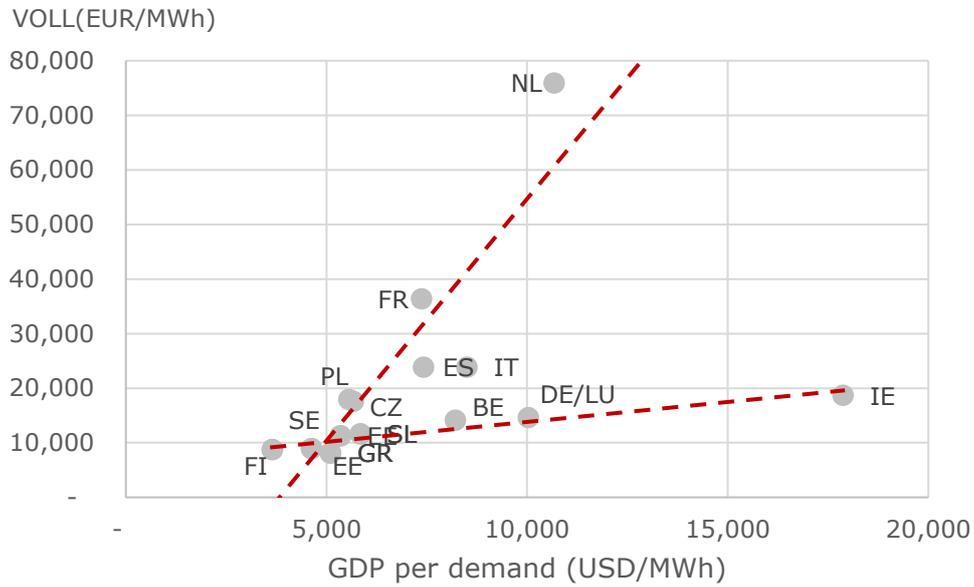
Sources: ENTSO-E, IMF, MS and AFRY.

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[12] Two-letter codes for the EU, in accordance with ISO 3166-1 alpha-2.

2.3 CONE/CORP

This section provides further details on the calculated CONE/CORP for the different MS. Specifically, AFRY has analysed the results in more detail to understand the main differences between the different MS in order to make a critical assessment at this stage of which could be used as a proxy for the Portuguese context and why. In addition, all the analysis and data collection resulting from this assessment are valuable for some of the tasks to be carried out later in the project for WS2.

— ACER defines criteria that must be met in the calculation of CONE/CORP, as described below. AFRY has analysed the information from the different MS and classified it, as presented in Exhibit 5. This assessment is illustrative, subjective and based on AFRY's best understanding of the principles presented by ACER:

— **Criterion 1:** selection of reference technologies and estimation of their potential.

— **Criterion 2:** definition of technical characteristics based on reference technologies.

— **Criterion 3:** estimation of capital and fixed costs for each technology.

— **Criterion 4:** estimation of WACC.

— **Criterion 5:** calculation of CONE/CORP (fixed and variable).

— **Criterion 6:** transparency, reliability and objectivity.

In general, AFRY has identified that there is not much consistency among MS in the application of the principles defined by ACER. Some examples where MS are not being consistent are:

— Regarding the selection of reference technologies, a large percentage of MS do not estimate the potential of each technology. In addition, only two MS (i.e. Spain and Finland) consider, in the selection of reference technologies, existing assets whose useful life can be extended (i.e. CORP).

— Most MS do not provide technical information on the reference technologies considered, such as (but not limited to): fuel type, efficiency, emission factor, etc.

— In general, all MS comply with the provision on WACC. However, in a large proportion of cases, the approach taken is to simplify, i.e. top-down, rather than building the WACC bottom-up from the different components of the Capital Asset Pricing Model (CAPM), as suggested by the ACER methodology.

— It has been noted that some MS do not provide a calculation of the CONE/CORP variable. In the methodology defined by ACER, it is indicated that the CONE/CORP variable can be ignored for the sake of simplicity when its magnitude is insignificant compared to VOLL. However, a large percentage of MS directly ignore this parameter, rather than producing it and concluding that it can be ignored.

— In general, contrary to what has been observed in the VOLL section, most MS do not provide all the data or are not sufficiently transparent about the information used to calculate CONE/CORP.

Exhibit 5 – Qualitative assessment of CONE/CORP calculation by MS

MS	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6
Belgium	🟡	✓	✓	🟡	✓	🟡
Czech Republic						
Estonia	🟡	✗	🟡	🟡	🟡	✗
Finland	✓	🟡	✓	🟡	✓	🟡
France	🟡	✗	✓	🟡	🟡	✗
Germany & Luxembourg	✓	✗	✗	✗	✓	✗
Greece	✓	✗	✓	🟡	✓	🟡
Ireland	🟡	✗	✓	✓	🟡	🟡
Italy	✓	✗	✓	🟡	🟡	🟡
Netherlands						
Poland	🟡	✗	🟡	🟡	✓	✗
Slovenia	🟡	✗	✗	✗	✓	✗
Spain	✓	✗	✓	🟡	🟡	🟡
Sweden	✓	✓	✓	✓	✓	✓

Legend: ✓ for compliant, 🟡 for partially compliant and ✗ for non-compliant.
Source: AFRY.

Exhibit 6 shows the selection of reference technologies, as noted in the documents published by the different MS; the Netherlands and the Czech Republic have not published anything on this topic. In general, the technologies selected for the Portuguese case, which are the technologies to be implemented by 2030 in PNEC, as presented in Exhibit 6, are well covered by the technologies selected by the different MS; this will be useful later in the project to inform the analysis carried out in WS2.

However, the Portuguese PNEC does not include a position on DSR or OCGT. As illustrated in Exhibit B.1 and Exhibit B.2, these technologies are considered by most MS: they are technologies with lower CONE/CORP and usually have high potential, making them the best candidate for a low LOLE. As a result, AFRY has considered these technologies in the CONE assessment later introduced in the report.

Analysing Exhibit B.1 and Exhibit B.2, the following conclusions can be observed:

— The technologies with the lowest CONE/CORP and therefore likely to be of great importance in the calculation of RS are DSR, CCGTs, OCGTs and storage.

— The variable CONE/CORP for all technologies except DSR can be considered insignificant compared to a reasonably expected VOLL; as a result, as explained later in Section 2.4, it is not considered in the RS calculation. However, the variable cost of DSR is, on average, EUR 1,084/MWh, which can be considered comparable and therefore requires further investigation.

— There is some dispersion in certain technologies, namely storage and DSR. AFRY believes that the volatility results from:

  — In the case of storage, investment costs, especially for battery cells, have fallen rapidly in the period 2020-2023, directly affecting CONE/CORP.

  — In the case of DSR, implementation costs depend on the consumer and the solutions to be implemented, which as far as AFRY understands is not standardized.

Exhibit 6 – Reference technologies in Portugal and CONE/CORP in different MS

Existing capacity	New capacity	Compliance with other MS	Average fixed CONE/CORP (EUR/kW-yr)	Average variable CONE/CORP (EUR/MWh)
CCGT	CCGT	✓	93/35	73
Cogeneration	Cogeneration	✓	256/315	52
Hydroelectric	Hydroelectric	✓	225	3
Onshore wind	Onshore wind power	✓	671	2
Offshore wind	Offshore wind	✓	2,227	3
Municipal solid waste	Municipal solid waste			
Biomass	Biomass	✓	275	29
Biogas	Biogas			
Solar	Solar	✓	553	0
	Storage	✓	277	54
	DSR	✓	27	1,084
	OCGT	✓	77	128

Note: Values are in nominal money.
Sources: MS and AFRY.

2.4 Reliability Standard

This section provides further details on the RS for the different MS. Specifically, AFRY has analysed the results in more detail to understand the main differences between the MS in order to make a critical assessment at this stage of which could be used as a proxy for the Portuguese context and why. In addition, all the analysis and data collection resulting from this assessment are valuable for some of the tasks to be carried out later in the project for WS4.

ACER defines the criteria that must be met when calculating the RS, as described below. AFRY has analysed the information from the different MS and classified it, as presented in Exhibit 7. This assessment is illustrative, subjective and based on AFRY's best understanding of the principles presented by ACER:

— **Criterion 1:** it is necessary to calculate a different LOLE for each technology.

— **Criterion 2:** the MS shall verify the validity of the LOLE for each technology through: 1) a decrease in EENS with an increase in capacity; and 2) EENS is only reduced in the MS.

— **Criterion 3:** transparency requirements, including the calculation of LOLE for each technology, verification of compliance with the conditions of Criterion 2, potential capacity per technology, minimum capacity required for the RS, and the RS itself.

After analysing the information published by the different MS, AFRY has identified some gaps in the approaches followed compared to the ACER methodology:

— None of the MS, except for Sweden, verifies all the conditions that must be met to validate the LOLE by technology.

— In general, the level of transparency is low, especially in comparison with the CONE/CORP and VOLL calculations: some of the MS that have been aligned with ACER on these parameters, such as France, Poland, Ireland and Belgium, do not provide the corresponding information for the RS. AFRY has not classified them as red, as it may be that AFRY has not been able to identify the correct documents.

Exhibit 7 – Qualitative assessment of the RS calculation by MS

MS	Criterion 1	Criterion 2	Criterion 3	Reference technology for CONE/CORP	RS (h/year)
Belgium				DSR	3.0
Czech Republic	✓	X	X	OCGT	6.7
Estonia	X	X	X	OCGT	8.6
Finland	🟡	X	🟡	Extension of CCGT	2.1
France				DSR	2.0
Germany & Luxembourg	✓	X	✓	DSR/OCGT	2.8
Greece	✓	X	✓	DSR	3.0
Ireland				OCGT	3.0
Italy	✓	X	✓	OCGT	2.0
Netherlands					4.0
Poland				DSR/OCGT	3.0
Slovenia	X	X	X	DSR	
Spain	✓	X	✓	Extension of CCGT	1.5
Sweden	✓	✓	✓	DSR	1.0

Legend: ✓ for compliant, 🟡 for partially compliant and X for non-compliant.
Source: AFRY.

Exhibit 1 and Exhibit C.1 show the LOLE for the different reference technologies selected by the MS and their corresponding estimate in terms of capacity potential. The following conclusions can be drawn, together with the resulting RS observed in Exhibit 7:

— The technologies with the lowest LOLE are typically storage, DSR, OCGT and CCGT, with an average value of:

  — **DSR:** 3.3 h/year.

  — **CCGT:** 5.2 hours/year.

  — **OCGT:** 4.6 hours/year.

  — **Storage:** 10.5 hours/year.

— The potential capacity for DSR and storage is typically considered limited, between 800 MW and 3,000 MW, while for CCGT and OCGT the values are higher.

— As a result of the above, the technologies with the lowest LOLE and sufficient capacity to achieve RS are typically DSR, CCGT and OCGT.

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3 CONE/CORP calculations

3.1 Reference technologies

This section presents a review of the potential technology choices for new entry and for extensions that could be considered for the calculation of the RS in Portugal. Based on Article 10 of ACER methodology, the criteria to be met by the potential reference technologies are:

— being a 'standard' technology; and

— having a demonstrable potential for new entry.

3.1.1 Selection of 'standard' technologies

A technology is 'standard' if the following criteria apply:

— reliable and generic cost data are available;

— construction and operating costs of units are of the same order of magnitude across projects; and

— development of projects is not significantly constrained by technical limits.

The assessment of existing and new technologies against these three factors is shown in Exhibit 8.

Note that for CCGTs, AFRY has included as alternatives to be considered the development of a new unit or the extension of CCGTs, as the latter can be a competitive alternative versus the construction of a greenfield unit.

In the case of DSR, it is important to note that it is not a 'single' technology as it can vary significantly depending on the solution and/or consumer – this means that it may not fit the standard technology framework. However, DSR is likely to be a cost competitive and efficient solution and a proven one, given a non-negligible amount of consumers are already qualified to provide ancillary services in Portugal. As a result, AFRY has decided to consider DSR within the list of selected standard technologies.

Exhibit 8 – Definition of 'standard' technologies for the Portuguese market

Candidate technology	Reliable & generic cost data available	Costs similar across projects	Development limited by technical constraints	Standard technology
Battery storage	Yes	Yes	No	Yes
Bioenergy/Waste	Yes	Yes	No	Yes
CCGT (new build)	Yes	Yes	No	Yes
CCGT (extension)	Yes	Yes	No	Yes
CHP[13]	No	No	No	No
DSR	No	No	No	**Yes**
Engines	Yes	Yes	No	Yes
Geothermal	No	No	Yes	No
Hydroelectric power	Yes	Yes	No	Yes
OCGT	Yes	Yes	No	Yes
Offshore wind	Yes	Yes	No	Yes
Onshore wind	Yes	Yes	No	Yes
Solar PV	Yes	Yes	No	Yes
Tidal	No	No	Yes	No

Notes: For Bioenergy/Waste, AFRY considers a reference project based on biomass.
Sources: Based on Portuguese PNEC and AFRY analysis.

3.1.2 Selection of potential new entrants

As a second step, AFRY has assessed which of these 'standard' technologies are likely new entrants in the Portuguese market. AFRY's starting point is to assume a technology is a potential new entry if it is included in the PNEC.

Additionally, AFRY has included both CCGTs and OCGTs as potential new entrants, even though there is no new gas-fired capacity considered in the PNEC, as they remain a reliable solution for ensuring generation adequacy. AFRY recognises that Article 40 of the Portuguese Climate Framework Law bans the use of fossil gas after 2040, pushing for the use of low-carbon fuels, such as biogas or hydrogen. OCGTs and CCGTs can be developed to be 'hydrogen-ready'. Some controllable capacity with no energy limitations may be needed for ensuring generation adequacy; therefore, AFRY believes this type of capacity should be part of the short list.

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[13] Combined Heat and Power.

The PNEC does not include any new bioenergy, waste or hydro either. These technologies align the with wider decarbonisation agenda, and thus, AFRY has considered them in the short list of technologies.

Exhibit 9 – Potential new entrant capacity in the Portuguese market

Technology Candidate	Capacity developed in recent years	Capacity under development	Planned installation within the contractable period	Allowed under Portuguese regulation	Allowed under European regulation	Potential new entrant
Battery storage	No	Yes	Yes	Yes	Yes	Yes
Bioenergy/Waste	No	No	No	Yes	Yes	Yes
CCGT (new build)	No	No	No	Yes	Yes	Yes
CCGT (extension)	No	No	No	Yes	Yes	Yes
CHP	No	No	No	Yes	Yes	No
DSR	Yes	No	No	Yes	Yes	Yes
Engines	No	No	No	Yes	No	No
Geothermal	No	No	No	Yes	Yes	No
Hydroelectric power	Yes	No	No	Yes	Yes	Yes
OCGT	Yes	No	No	Yes	Yes	Yes
Offshore wind	No	No	Yes	Yes	Yes	Yes
Onshore wind	Yes	Yes	Yes	Yes	Yes	Yes
Solar PV	Yes	Yes	Yes	Yes	Yes	Yes
Tidal	No	Yes	Yes	Yes	Yes	No

Sources: Based on Portuguese PNEC and AFRY analysis.

3.1.3   Shortlist of reference technologies

Following the analysis performed based on the two criteria shown in Exhibit 8 and Exhibit 9, AFRY has defined the short list of reference technologies for Portugal as shown in Exhibit 10.

Exhibit 10 – Final reference technology selection

Candidate technology	Standard technology	Potential new entrant	Reference technology
Battery storage	Yes	Yes	Yes
Bioenergy/Waste	Yes	Yes	Yes
CCGT (new build)	Yes	Yes	Yes
CCGT (extension)	Yes	Yes	Yes
CHP	No	No	No
DSR	Yes	Yes	Yes
Engines	Yes	No	No
Geothermal	No	No	No
Hydroelectric power	Yes	Yes	Yes
OCGT	Yes	Yes	Yes
Offshore wind	Yes	Yes	Yes
Onshore wind	Yes	Yes	Yes
Solar PV	Yes	Yes	Yes
Tidal	No	No	No

Sources: Based on Portuguese PNEC and AFRY analysis.

3.2 Additional capacity potential

Article 10 of the ACER Decision 23/2020 states that the entity calculating CONE/CORP *'shall calculate the potential for additional capacity resource, by estimating how much additional capacity could reasonably be added by rational investors within the considered geographic area for the considered timeframe'.*

To do so, AFRY has based its analysis on the Portuguese PNEC, considering the 'With Existing Measures' scenario. The additional capacity is defined as the difference between installed capacity in 2025 and 2030. The values used in the analysis are presented in Exhibit 11.

In some cases, the PNEC does not provide sufficient disaggregation, and AFRY has assumed the following:

— in 2025, gas capacity is split in 3.8GW of CCGTs and 1GW of CHP;

— for 2030, the assumption is that one 0.99GW CCGT has retired with the remaining being CHP capacity decommissioning;

— the extension in operation of CCGTs considers the refurbishment of the unit assumed to retired, with a capacity of 0.99GW; and

— AFRY considers the extension in operation of the remaining CCGTs without refurbishment, totalling c. 2.8GW.

Exhibit 11 – Capacity additions in Portugal

Technology Candidate	Reference Technology	2025 (GW)	2030 (GW)	Expected capacity (GW)
Battery storage	Yes	0.5	2.0	+1.5 GW
Bioenergy/Waste	Yes	1.3	0.9	-
CCGT	Yes	3.8	2.8	2.8 GW
CCGT (end of lifetime extension)	Yes			Potential of +0.99 GW
CHP	No	1.0	0.6	-
DSR	Yes			Estimated to be 0.7GW
Engines	No	0.6	0.5	-
Geothermal	No	0.1	0.1	-
Hydroelectric power	Yes	4.5	4.2	-
Hydroelectric w/pumped storage	No	3.6	3.9	Retrofit of +0.3 GW
OCGT	Yes	0.0	0.0	-
Offshore Wind	Yes	0.0	2.0	+2.0 GW
Onshore Wind	Yes	6.3	10.4	+4.1 GW
Solar PV	Yes	8.4	20.8	+12.4 GW
Tidal	No	0.0	0.2	+0.2 GW

Notes: For CCGTs, AFRY consider that support payments are likely needed for the capacity that continues operating, whilst for CCGT (end of lifetime extension), AFRY considers the potential refurbishment of the retired CCGT capacity – more details on this can be found in Section 3.2.1.
For DSR, AFRY presents a detailed estimate in Section 3.2.2.
Sources: Based on Portuguese PNEC, and AFRY analysis.

3.2.1 Continuing operation of the CCGT fleet

The current fleet of CCGTs in Portugal consists of four CCGTs: Tapada do Outeiro, Ribatejo, Lares and Pego. An estimate of the historical accumulated running hours for these CCGTs is shown in Exhibit 12.

The typical technical lifetime of a CCGT is around 100,000 running hours before needing some refurbishment work to extend its lifetime. In the case of the reviewed units, only Tapada do Outeiro CCGT is close to needing a refurbishment to extend its operation – this is in line with the information presented in the PNEC, where Tapada do Outeiro is assumed to be decommissioned by the end of this decade.

Exhibit 12 – Historical accumulated running hours of the Portuguese CCGT fleet

Technology Candidate	Commissioning date	Running hours
Tapada do Outeiro	1999	>90,000
Ribatejo	2004	>50,000
Lares	2009	>40,000
Pego	2010	>30,000

Sources: REN, ERSE and AFRY analysis.

AFRY has considered as a result three types of extensions for the current CCGT fleet:

1. **Tapada do Outeiro:** two types of extensions have been included in the analysis: a) 5-year; or b) long term extension. The two scenarios differ in the extension CAPEX required to refurbish the CCGT, as well as the lifetime of the asset. The potential capacity of this power plant is 990MW.

2. **Rest of the CCGTs:** Ribatejo, Lares and Pego are far from reaching their technical lifetime (i.e., c. 100,000 running hours), and as a result they should not require major CAPEX to keep them operating.

   However, according to AFRY's estimates, in a context of increasing renewables, CCGTs in Iberia will be dispatched less frequently, making it difficult for them to cover their fixed operating costs (i.e., OPEX). As a result, they may find it economically challenging to continue operating without a capacity mechanism.

   Therefore, AFRY has included these three CCGTs as candidates to receive contracts for a potential extension. Their CORP is equivalent to the fixed OPEX they need to cover to ensure the continuity of their operation. The potential capacity of Ribatejo, Lares and Pego is c. 2.8GW.

3.2.2 Potential deployment of DSR

Currently there is c. 400MW of DSR participating in the Portuguese ancillary services. The overall volume potential of DSR in Portugal is unclear, and AFRY has not performed a detailed bottom-up analysis of how much capacity could be made available in this study.

As a simplification to assess its potential, AFRY has considered the qualified consumers in the pilot programme organised by REN to incentivise

participation of consumers in ancillary services, which at the moment of writing of this report amounts to c. 1GW. Out of these consumers, a total of c. 0.4GW of capacity are already active in the different ancillary services, which makes the potential for new DSR development c. 0.7GW.

3.3 Technical characteristics of the reference technologies

Article 11 (ACER Decision 23/2020) suggests that technical characteristics of each reference technology must be specified – both those that influence cost estimates (Article 13) and/or de-rating factors (Article 12).

The characterisation of the different technologies should be based on:

— the behaviour of rational private investor estimates from recent/planned projects in Portugal or similar geographies;

— reasonable expectations regarding future business cases, regulation, and infrastructure where there are no existing/planned units;

— relevant assumptions from the latest ERAA[14] or national adequacy studies; and

— the application of the legal and regulatory framework in Portugal.

The technical parameters used in the analysis are based on publicly available information, including academic literature and research institutions. The parameters have also been informed by AFRY's own market knowledge.

AFRY has considered three scenarios to provide a range of values. The Central scenario reflects AFRY's best view while the High and Low provide cases where prices and WACCs are adjusted to a more or less constrained context for the cost drivers. Note that the High and Low should not be considered as upper and lower boundaries, as they do not aim to cover extreme sporadic spikes, but rather long-term trends.

3.3.1 De-rating factor

AFRY has estimated the marginal de-rating factors for a given generation portfolio in Portugal in 2030. These de-rating factors reflect the marginal contribution for different technologies in the periods with the tightest capacity margin.

To do so, AFRY has used its own internal modelling to evaluate the marginal contribution of the capacity existing for the evaluated technologies when adding 1 MWh of demand over the tighter periods of the system. This marginal contribution is reflective of the de-rating expected.

For controllable generation with no energy limitation, the de-rating factor is practically equal to their expected availability. For example, a CCGT has a 93.2% probability of being available in tight periods once AFRY has accounted for forced outages and some maintenance.

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[14] European Resource Adequacy Assessment (ERAA).

For energy-limited units, the de-rating factors drop as more similar energy-limited capacity is added on the system. Given the energy limitations, such technologies cannot contribute to the capacity margin over consecutive tight periods. Their marginal de-rating factors depend significantly on the relative capacity on the system (and the potential cannibalisation) and the amount of renewable generation in the system, which can significantly alter the periods of tightness in a year.

The de-rating factor for renewables is linked to the production of these technologies during tight periods, typically nighttime over winter months.

For DSR, there is high uncertainty over the de-rating to be expected in the market, as the wide variety of technologies and applications make difficult to determine a single representative value. In order to perform this evaluation, AFRY chose to take as a reference value 65%, as it is roughly halfway between firm technologies that are generally available the most (CCGTs) and flexible technologies that are easily cannibalised (BESS). AFRY acknowledges that this value might require further analysis given its relevance.

Additionally, AFRY has evaluated a sensitivity with a de-rating factor of 80% for BESS. The goal is to understand whether BESS would be more cost competitive in this case.

Exhibit 13 – De-rating assumptions for the reference technologies in 2030 (%)

Technology Candidate	Central	High	Low
BESS[15] – 2h	17.4	17.4	25.1
BESS – 4h	28.7	28.7	36.2
BESS – 2h (80% DR[16])	80.0	80.0	80.0
BESS – 4h (80% DR)	80.0	80.0	80.0
Biomass	65.8	65.8	65.8
CCGT (new build and extension)	93.2	93.2	93.3
DSR (HVAC[17])	65.0	65.0	65.0
Hydroelectric power	93.2	93.2	93.3
OCGT	94.1	94.0	94.0
Offshore wind	5.1	5.1	7.7
Onshore wind	9.6	9.6	10.5
Solar PV	0.2	0.2	0.2

Note: In the case of battery storage, AFRY specifically focus on shorter durations, as the Portuguese market remains underdeveloped in the use of storage units thus making them highly competitive in a context of no existing cannibalization of the spread between the cheaper and more expensive hours.
For hydroelectric power AFRY has considered the same level as for CCGT units, to consider a best-case scenario for the technology. This as hydropower is not expected to be within the competitive range of technologies.
Source: AFRY.

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[15] Battery Energy Storage System (BESS).
[16] De-rating (DR).
[17] Heating, Ventilation and Air Conditioning (HVAC).

3.3.2 CAPEX and FOM

For the calculation of the cost components of the CONE/CORP, Article 13 of the ACER Decision 23/2020 suggests that the capital expenditure (CAPEX) and fixed annual O&M[18] (FOM) must be estimated for each reference technology, and include:

— EPC[19] costs (equipment, labour, materials, contractor fees, contractor contingencies);

— investment costs (project development, licensing/permits, pre-commissioning testing, grid interconnection, gas/fuel connection, software/communications, dual-fuel capability, land, etc.); and

— other upfront costs (environmental or local compensation, decommissioning, etc.).

AFRY has researched several sources widely used in the industry to determine the CAPEX and FOM parameters. These include BNEF (2024), ERSE (2025), the IEA (2024), IRENA (2025), Gas Turbine World (2024), NREL (2024) and the UK DESNZ (2025).

3.3.2.1 Extension of CCGTs

As part of the cost alternatives analysed, AFRY has included the expected expenditures to prolong the operation of CCGT, considering as potential alternatives as introduced in Section 3.2.1:

— an OPEX-equivalent payment, which seeks to ensure that CCGTs that have not reached their technical lifetime and that might be retired as their economics are at risk, receive payments to ensure annual avoidable fixed cost recovery;

— a short-term extension of five years, with minor refurbishments of the Tapada do Outeiro power plant that allow to sustain the operation over a limited period of time; and

3.3.2.2 Demand Side Response (DSR)

To estimate the costs for DSR, AFRY has taken the analysis by Bird et al (2022) for the addition of control systems to the HVAC unit of a building. Based on the costs provided, AFRY has estimated a CAPEX of EUR 55.5/kW and an OPEX of EUR 0.1/kW-year for the DSR system. This cost estimate includes a restriction in the HVAC power consumption reduction to no more than 75%. The unit can always operate at a minimum load of 25%, ensuring continuous operation.

AFRY considers these costs to be reflective of the potential DSR for commercial and services buildings, and multi-story residential compounds. However, it is important to note that levels can be uncertain depending on the specific characteristics of installation.

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[18] Operation & Maintenance (O&M).
[19] Engineering, Procurement, and Construction (EPC).

3.3.2.3 Hydroelectric power

The cost of hydroelectric power can be highly uncertain, as it significantly varies depending on specific geographies and regulatory conditions. AFRY has taken for reference the average value for European projects as reported by IRENA. It is important to note that capex can very easily increase for this technology; however, as it is not considered a likely driver of the reliability standard, it has been evaluated as a good-case for costs to show that it is not likely to be competitive.

3.3.2.4 Parameters

As already discussed, the Central scenario figures are based on literature review. For the High and Low scenarios, we assume a 15% premium and discount respectively. The CAPEX assumptions are presented in Exhibit 14, and the FOM assumptions can be found in Exhibit 15.

Exhibit 14 – CAPEX assumptions for the reference technologies (EUR/kW)

Technology Candidate	Central	High	Low
BESS – 2h	580	667	493
BESS – 4h	1,026	1,180	872
Biomass	3,418	3,931	2,905
CCGT (new build)	791	909	672
CCGT (OPEX extension)	0	0	0
CCGT (5-year extension)	93	107	79
CCGT (long-term extension)	626	720	532
DSR (HVAC)	55	64	47
Hydroelectric power	2,020	2,323	1,717
OCGT	717	825	610
Offshore wind	6,374	7,330	5,418
Onshore wind	1,238	1,424	1,052
Solar PV	727	837	618

Sources: Based on BNEF (2024), ERSE (2025), the IEA (2024), IRENA (2025), Gas Turbine World (2024), NREL (2024) and the UK DESNZ (2025), and AFRY analysis.

Exhibit 15 – FOM assumptions for the reference technologies (EUR/kW-year)

Technology Candidate	Central	High	Low
BESS – 2h	16	18	13
BESS – 4h	28	32	24
Biomass	95	109	81
CCGT (new build)	17	20	15
CCGT (OPEX extension)	17	20	15
CCGT (5-year extension)	17	20	15
CCGT (long-term extension)	17	20	15
DSR (HVAC)	0.1	0.1	0.1
Hydroelectric power	50	58	43
OCGT	14	16	12
Offshore wind	127	147	108
Onshore wind	26	30	22
Solar PV	11	13	9

Sources: Based on BNEF (2024), ERSE (2025), the IEA (2024), IRENA (2025), Gas Turbine World (2024), NREL (2024) and the UK DESNZ (2025), and AFRY analysis.

3.3.3   WACC

The WACC must represent the minimum rate of return required by capital providers to finance the reference technology in Portugal, based on transparent market data (Article 13). If possible, the WACC should be technology specific. If no WACC is available, it should be calculated per Annex 2 of the ACER methodology. Uncertainty ranges may be provided.

AFRY has developed WACC estimates with a bottom-up approach using predominantly publicly available sources for the different WACC parameters. WACC calculations have been performed for three different scenarios, each having specific assumptions on debt premium and betas, reflecting the underlaying uncertainty. The equation used for the calculation is shown in Exhibit 16.

Exhibit 16 – WACC formula

$$WACC_{real} = \left(1 + (Rfr + P_D) * G + (Rfr + P_E * B + P_T) * \frac{(1-G)}{(1-T)}\right) * \frac{1}{(1+inf)} - 1$$

B	Equity Beta
G	Gearing
inf	Inflation
P_D	Debt premium
P_E	Equity premium
P_T	Technology premium
Rfr	Risk-free rate
T	Tax rate

3.3.3.1 Parameters

As previously described, the formula is based on a series of parameters to define the WACC. In order to determine value used for the different parameters, AFRY has taken the following sources:

— the equity beta and equity premium are taken from Damodaran (2025)[20];

— the gearing and debt premium are based on ERSE's input[21];

— the inflation assumption is based on the European Central Bank's 2.0% target[22];

— the risk-free rate is calculated as the average value of the 10-year German government bond yield, over the last 36-months[23]; and

— the tax rate is based on the Portuguese government's target of a corporate tax rate of 17.0% by 2028, with the addition of other local and state taxes that leave it at 27.5%[24].

Technology premiums

As previously mentioned, AFRY has used different technology premiums to account for the risk exposure that could result from the expected capacity mechanism:

— solar and onshore wind are considered mainstream technologies with limited risk attached to them in terms of technological maturity, but also

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[20] https://pages.stern.nyu.edu/~adamodar/
[21] https://www.erse.pt/media/bjdnrr05/par%C3%A2metros-2022-2025.pdf
[22] https://www.ecb.europa.eu/mopo/strategy/pricestab/html/index.en.html
[23] https://fred.stlouisfed.org/series/IRLTLT01DEM156N
[24] https://www.portugal.gov.pt/pt/gc25/comunicacao/comunicado?i=governo-aprova-nova-descida-de-irc-ate-2028

from a regulatory perspective – AFRY considers a 2.0% technology premium;

— even though battery deployment is more limited, the technology is well established and there is currently low risk in terms of development – AFRY considers a 2.0% technology premium;

— hydroelectric power is considered a mainstream technology with limited risk attached to them in terms of technological maturity – AFRY considers a 2.0% technology premium;

— CCGTs and OCGTs are considered transitional in the process of decarbonisation, and may need to operate with low-carbon fuels from 2040 onwards – AFRY considers a 2.5% technology premium;

— for offshore wind, both the lack of deployment in Portugal and the need to use floating (which is far from being a mainstream technology) makes AFRY to consider a higher premium over standard renewables – AFRY considers a 3.5% technology premium;

— for biomass, given the operation with a less standardised fuel and the possibility of challenging access, AFRY considers a 3.5% technology premium;

— for DSR (HVAC), AFRY takes a more limited premium as it is a quick-cycle investment – AFRY considers a 1.0% technology premium; and

— finally, for CCGT extensions, AFRY considers a reduction in risk given the more limited economic lifetime expectation – AFRY considers a 1.0 premium in the case of just supporting OPEX payments, a 1.5% technology premium for a 5-year extension and 2.0% for a long extension.

Exhibit 17 – WACC for CCGT (OPEX extension) and DSR (HVAC)

Element	High	Central	Low
Inflation index	2.00%	2.00%	2.00%
Gearing	50.00%	50.00%	50.00%
Taxation	27.50%	27.50%	27.50%
Risk-free rate	2.38%	2.38%	2.38%
Debt premium	3.12%	2.12%	1.12%
Cost of debt	**5.50%**	**4.50%**	**3.50%**
Equity risk premium	5.98%	5.98%	5.98%
Additional technology premium	1.00%	1.00%	1.00%
Asset beta for energy utilities	0.45	0.34	0.25
Equity Beta	0.78	0.59	0.43
Post-tax Cost of Equity	8.02%	6.89%	5.96%
Pre-tax Cost of Equity	**11.07%**	**9.50%**	**8.22%**
Pre-tax nominal WACC	**8.28%**	**7.00%**	**5.86%**
Post-tax nominal WACC	**6.01%**	**5.08%**	**4.25%**
Pre-tax real WACC	**6.16%**	**4.90%**	**3.78%**
Post-tax real WACC	**3.93%**	**3.02%**	**2.20%**

Sources: Based on Damodaran (2025) and AFRY analysis.

Exhibit 18 – WACC for CCGT (5-year extension)

Element	High	Central	Low
Inflation index	2.00%	2.00%	2.00%
Gearing	50.00%	50.00%	50.00%
Taxation	27.50%	27.50%	27.50%
Risk-free rate	2.38%	2.38%	2.38%
Debt premium	3.12%	2.12%	1.12%
Cost of debt	**5.50%**	**4.50%**	**3.50%**
Equity risk premium	5.98%	5.98%	5.98%
Additional technology premium	1.50%	1.50%	1.50%
Asset beta for energy utilities	0.45	0.34	0.25
Equity Beta	0.78	0.59	0.43
Post-tax Cost of Equity	8.52%	7.39%	6.46%
Pre-tax Cost of Equity	**11.76%**	**10.19%**	**8.91%**
Pre-tax nominal WACC	**8.63%**	**7.35%**	**6.21%**
Post-tax nominal WACC	**6.26%**	**5.33%**	**4.50%**
Pre-tax real WACC	**6.50%**	**5.24%**	**4.12%**
Post-tax real WACC	**4.17%**	**3.26%**	**2.45%**

Sources: Based on Damodaran (2025) and AFRY analysis.

Exhibit 19 – WACC for battery storage, CCGT (long-extension), hydroelectric power, onshore wind and solar PV

Element	High	Central	Low
Inflation index	2.00%	2.00%	2.00%
Gearing	50.00%	50.00%	50.00%
Taxation	27.50%	27.50%	27.50%
Risk-free rate	2.38%	2.38%	2.38%
Debt premium	3.12%	2.12%	1.12%
Cost of debt	**5.50%**	**4.50%**	**3.50%**
Equity risk premium	5.98%	5.98%	5.98%
Additional technology premium	2.00%	2.00%	2.00%
Asset beta for energy utilities	0.45	0.34	0.25
Equity Beta	0.78	0.59	0.43
Post-tax Cost of Equity	9.02%	7.89%	6.96%
Pre-tax Cost of Equity	**12.45%**	**10.88%**	**9.60%**
Pre-tax nominal WACC	**8.97%**	**7.69%**	**6.55%**
Post-tax nominal WACC	**6.51%**	**5.58%**	**4.75%**
Pre-tax real WACC	**6.84%**	**5.58%**	**4.46%**
Post-tax real WACC	**4.42%**	**3.51%**	**2.69%**

Sources: Based on Damodaran (2025) and AFRY analysis.

Exhibit 20 – WACC for new entry CCGTs and OCGTs

Element	High	Central	Low
Inflation index	2.00%	2.00%	2.00%
Gearing	50.00%	50.00%	50.00%
Taxation	27.50%	27.50%	27.50%
Risk-free rate	2.38%	2.38%	2.38%
Debt premium	3.12%	2.12%	1.12%
Cost of debt	**5.50%**	**4.50%**	**3.50%**
Equity risk premium	5.98%	5.98%	5.98%
Additional technology premium	2.50%	2.50%	2.50%
Asset beta for energy utilities	0.45	0.34	0.25
Equity Beta	0.78	0.59	0.43
Post-tax Cost of Equity	9.52%	8.39%	7.46%
Pre-tax Cost of Equity	**13.14%**	**11.57%**	**10.29%**
Pre-tax nominal WACC	**9.32%**	**8.04%**	**6.90%**
Post-tax nominal WACC	**6.76%**	**5.83%**	**5.00%**
Pre-tax real WACC	**7.17%**	**5.92%**	**4.80%**
Post-tax real WACC	**4.66%**	**3.75%**	**2.94%**

Sources: Based on Damodaran (2025) and AFRY analysis.

Exhibit 21 – WACC for biomass and offshore wind

Element	High	Central	Low
Inflation index	2.00%	2.00%	2.00%
Gearing	50.00%	50.00%	50.00%
Taxation	27.50%	27.50%	27.50%
Risk-free rate	2.38%	2.38%	2.38%
Debt premium	3.12%	2.12%	1.12%
Cost of debt	**5.50%**	**4.50%**	**3.50%**
Equity risk premium	5.98%	5.98%	5.98%
Additional technology premium	3.50%	3.50%	3.50%
Asset beta for energy utilities	0.45	0.34	0.25
Equity Beta	0.78	0.59	0.43
Post-tax Cost of Equity	10.52%	9.39%	8.46%
Pre-tax Cost of Equity	**14.51%**	**12.95%**	**11.67%**
Pre-tax nominal WACC	**10.01%**	**8.72%**	**7.58%**
Post-tax nominal WACC	**7.26%**	**6.33%**	**5.50%**
Pre-tax real WACC	**7.85%**	**6.59%**	**5.48%**
Post-tax real WACC	**5.15%**	**4.24%**	**3.43%**

Sources: Based on Damodaran (2025) and AFRY analysis.

3.3.4 Other relevant parameters

Regarding the remaining relevant parameters to determine the CONE/CORP, they can be found in Exhibit 22. AFRY has considered build times of one to two years; however, note that limited changes to this parameter – as e.g., increasing to two years – do not have a major impact on the value of the CONE/CORP.

AFRY has evaluated the CONE/CORP considering as financial lifetimes the standard economic lifetime expected for a project of the specified technology.

Exhibit 22 – Other relevant parameters for the CONE/CORP

Technology Candidate	Build time (years)	Economic lifetime (years)
BESS – 2h	1	15
BESS – 4h	1	15
Biomass	2	20
CCGT (new build)	2	25
CCGT (OPEX extension)	0	5
CCGT (5-year extension)	1	5
CCGT (long-term extension)	1	20
DSR (HVAC)	1	5
Hydroelectric power	2	30
OCGT	1	25
Offshore wind	2	28
Onshore wind	1	28
Solar PV	1	32

Sources: Based on BNEF (2024), the IEA (2024), IRENA (2025), Gas Turbine World (2024), NREL (2024) and the UK DESNZ (2025), and AFRY analysis.

3.4 CONE/CORP

3.4.1 CONE/CORP fixed component

Following all the parameters previously determined, throughout this section AFRY calculates the CONE, based on the ACER methodology. For the fixed component of the CONE, the formula used in the calculation can be found in Exhibit 23.

Exhibit 23 – CONE fixed component formula (EUR/kW)

$$Fixed\ CONE/CORP = \frac{1}{DR} \times \left(\sum_{i=1}^{B} \frac{CAPEX_i}{(1+WACC)^i} + \sum_{i=B+1}^{B+E} \frac{FOM_i}{(1+WACC)^i} \right) \times \frac{WACC \times (1+WACC)^{B+E}}{(1+WACC)^E - 1}$$

B	Build time [years]
DR	De-rating factor (%)
E	Economic lifetime [years]

Source: ACER.

3.4.2 CONE/CORP variable component

The variable component of the CONE should consist of:

— fuel costs (based on efficiency and expected fuel prices);

— CO_2 costs; and

— Variable Other Works Costs (VOWC).

However, according to ACER, if the variable CONE is negligible relative to VOLL, it can be disregarded. There is no official VOLL for Portugal, but in this report, as shown in Chapter 4, AFRY has estimated a value of 12,433 /MWh.

For wind and solar, the variable costs are generally negligible. Battery variable costs are generally expected to be less than EUR 20/MWh – they cover low variable O&M values and potential augmentation costs that AFRY does not expect to be elevated.

For thermal technologies, AFRY can derive the maximum expected level from the peaks seen historically in the wholesale electricity market. In Portugal prices peaked at EUR 650/MWh at the beginning of Ukrainian war (i.e., February 2022) due to the extremely high gas prices, but ever since have decreased to a level closer to EUR 100-150/MWh during the hours where thermal units or hydro (at opportunity costs) set the price.

Regarding DSR, the level seen in current bids in the market is generally below EUR 500/MWh (except for a limited amount of capacity that bids higher). Even though this value is significant, AFRY still sees it as relatively limited compared to the expected VOLL value.

Therefore, AFRY expects the variable CONE to be minor compared to the VOLL, and thus this value can be disregarded in the calculation of the RS.

3.4.3 CONE results considering economic lifetime

Based on the formula shown above, AFRY has calculated the CONE based on the economic lifetime, as defined in Section 3.3.4. The resulting values can be found in Exhibit 24.

Exhibit 24 – CONE at economic lifetime (EUR/kW-year)

Technology Candidate	Central	High	Low
BESS – 2h	423.7	520.0	235.6
BESS – 4h	454.8	557.9	289.4
BESS – 2h (80% DR)	92.3	113.2	73.9
BESS – 4h (80% DR)	163.4	200.5	130.9
Biomass	638.4	794.8	504.9
CCGT (new build)	86.6	109.7	67.4
CCGT (OPEX extension)	18.2	20.9	15.5
CCGT (5-year extension)	41.6	48.8	34.7
CCGT (long-term extension)	75.5	93.7	59.8
DSR (HVAC)	19.8	23.6	16.4
Hydroelectric power	208.2	268.0	160.9
OCGT	74.8	94.3	58.4
Offshore wind	12,906.5	16,416.2	6,541.4
Onshore wind	1,198.7	1,522.7	849.2
Solar PV	30,260.3	38,558.2	21,925.7

Sources: Based on BNEF (2024), the IEA (2024), IRENA (2025), Gas Turbine World (2024), NREL (2024) and the UK DESNZ (2025), and AFRY analysis.

3.5   Discussion

The analysis presented in this chapter shows that extending the operational lifetime of any existing CCGT – be it through payments to cover the fixed OPEX or a refurbishment – are the first and third most cost-competitive options from the CONE perspective. Most of the infrastructure is already in place and there is limited or no CAPEX needed. There are, however, limitations as to how much capacity can be extended and for how long. Thus, using this CORP might not be an appropriate long-term solution.

The second most cost-competitive alternative corresponds to DSR, also achieving a low CONE. However, this estimate is significantly more uncertain in terms of cost and potential and is only reflective of one type of demand-side response. Given this, AFRY considers that it might not be the most appropriate technology to determine the RS in the long term.

Finally, OCGTs are the mainstream technology with the most competitive CONE with potential for development of new build capacity – AFRY considers this technology to be the most well-grounded technology to be used in the determination of the long-term RS.

It is important to note that the CONE defined through ACER's methodology corresponds to what in literature can be regarded as the gross CONE, as no adjustment is made due to potential revenues from the energy market. This means the analysis cannot capture the actual missing money of the technology (which would correspond to the net CONE), but rather the full cost of new entry for the technology (as previously mentioned, gross CONE). AFRY has followed the methodology as set by ACER, though considers that improvements can be applied to better capture the competitivity of technologies.

Another relevant point not touched upon in this report is the consider is the exclusion of interconnections as a reference technology for CONE/CORP. Currently, none of the MS consider interconnection as part of their analysis, although four of them (i.e. Belgium, France, Italy and Poland) are open to their participation in the capacity mechanism, according to ACER. Future reviews might need to evaluate whether including interconnectors could be a viable alternative.

4 Determination of the single VOLL

The ACER methodology prescribes that a single VOLL, for the purpose of determining the reliability standard, should be calculated, reflecting the maximum electricity price that customers are willing to pay to avoid a supply interruption. The willingness to pay of customers is to be determined based on their responses to a survey, the minimum template for which is provided in the ACER methodology.

In Portugal, the survey has been designed and performed by QMETRICS. In the following sections, AFRY describes the approach taken by QMETRICS, as well as the approach taken by AFRY to the analysis of the survey results. Finally, AFRY presents the sectoral and single VOLL.

4.1 Survey design

As per the ACER methodology, the survey is to contain at least two sections, as follows:

a. a section for collecting information about the interviewee; and

b. a section describing scenarios of interruption of electricity supply and asking for cost estimates.

In the Portuguese survey, Section 1 has been designed to:

— explain the context of the survey;

— ensure the interviewee is sufficiently knowledgeable to be able to respond in an informed way;

— collect the required information regarding the interviewee's consumption;

— collect the necessary information to identify the consumer segment to which the interviewee belonged; and

— identify any consumers that have been price-responsive or protected from load-shedding.

Where customers have been identified as 'protected' in Section 1, the survey terminates, and willingness to pay data has not been collected for them.

Section 2 has been designed to assess the impact of, and willingness to pay to avoid interruptions to supply in 16 different scenarios.

The consumer segmentation and scenarios assessed are detailed further in the sections that follow.

4.2   Consumer segmentation

ACER prescribes that the survey must cover at least the following consumer categories:

— household;

— commerce or service sector;

— public service;

— small-medium enterprise in the industrial sector;

— large enterprise in the industrial sector; and

— transport sector.

According to ACER, these categories may be aggregated where it has not been possible to collect representative data for an individual category, provided that this approach is highlighted and justified.

Section 1 of the Portuguese survey identified consumers by type –domestic or non-domestic– and further classified each into different segments.

4.2.1   Domestic consumers

For domestic consumers, the derived segmentation is shown in Exhibit 25. The classification is based on region, number of inhabitants per household, and number of rooms in the household.

Exhibit 25 – Segmentation of domestic consumers

Region	Number of residents per household	Number of rooms per household
Alentejo and Algarve	2 residents or less	4 rooms or less
		5 or more rooms
	3 residents or more	5 or more rooms
		4 rooms or less
Centre	2 residents or less	5 or more rooms
	3 residents or more	4 rooms or less
		5 or more rooms
Downtown	2 residents or less	4 rooms or less
North	2 residents or less	4 rooms or less
		5 or more rooms
	3 residents or more	4 rooms or less
		5 or more rooms
West and Tagus Valley, Greater Lisbon, Setúbal	2 residents or less	4 rooms or less
		5 or more rooms
	3 residents or more	5 or more rooms
		4 rooms or less

Source: QMETRICS.

4.2.2   Non-domestic consumers

For non-domestic consumers, the segmentation has been done in accordance with the ACER methodology, but with the addition of 'companies in the agriculture, animal production, hunting, forestry and fishing sector' and 'large industrial companies that are not large consumers of electricity'. The full list of non-domestic segments is therefore as follows:

1. companies in the agriculture, animal production, hunting, forestry and fishing sector;

2. industrial small and medium-sized enterprises (SMEs);

3. large industrial companies that are not large consumers of electricity;

4. large industrial electricity consumers;

5. companies in the trade and services sector, including data centres, telecommunications operators and commercial areas;

6. public sector companies; and

7. companies in the transport sector that use electricity for mobility.

4.3   Interruption scenarios

The ACER methodology prescribes that the interruption scenarios that consumers are asked to consider, and state their willingness to pay to avoid, are to be defined in terms of at least the following parameters:

1. duration of the interruption (how long?);

2. timing of interruption (when?); and

3. pre-notification period (how much notice?).

A Central scenario is to be defined for each consumer segment, corresponding to the most likely scenario in which load-shedding is expected to impact that segment. The scenarios for the Portuguese survey are shown in Exhibit 26. They have been defined based on a combination of the following parameters:

— season (winter or summer);

— notice period (with 1 day notice or without notice); and

— interruption durations (2 mins, 1 hour, 4 hours and 1 day).

Exhibit 26 – Interruption parameters of the 16 scenarios included in the VOLL survey

Timing	Notice Period	Duration
winter Peak	Without notice	2 mins
		1 hour
		4 hours
		1 day
	With 1 day notice	2 mins
		1 hour
		4 hours
		1 day
summer Peak	Without notice	2 mins
		1 hour
		4 hours
		1 day
	With 1 day notice	2 mins
		1 hour
		4 hours
		1 day

Source: QMETRICS.

The timing of the historical annual peak demand over the 5-year period corresponds to the winter peak. Furthermore, based on the results of the ERAA, and corroborated by AFRY's internal modelling, the most likely forward-looking interruption duration over this same 5-year period is one hour.

For example, for 2026 the ERAA projects six periods of LOLE of one hour, one period of LOLE of two consecutive hours, and two periods of LOLE of three consecutive hours. For 2028, the ERAA predicts three periods of LOLE of one hour and one period of LOLE of three consecutive hours.

Based on conversations maintained with REN, the most likely scenario in terms of notice period is expected to be the 'without notice' scenario.

The Central scenario is therefore defined as the winter peak, no notice, 1-hour interruption case - indicated in bold text in the table above. The most likely interruption scenario has been assumed to be the same for all consumer segments.

The remaining scenarios serve to illustrate the sensitivity of the single VOLL to the timing and duration of the supply interruption, as well as the associated notice period.

4.4 Sectoral VOLL

The ACER methodology requires that the VOLL for each consumer sector be evaluated for each interruption scenario based on the survey responses. The willingness to pay responses for each interruption scenario are to be converted to a VOLL in EUR/MWh using the electricity consumption of each interviewee, combined with standard load profiles. This individual VOLL data is then used to calculate a VOLL for each consumer sector surveyed, for each scenario considered.

4.4.1 Domestic sector

For the Portuguese domestic survey data, the following steps have been taken to determine the sectoral VOLL:

1. **Data validation:** the response data underwent a rigorous validation process by QMETRICS designed to ensure the internal consistency of the information and the reliability of the results. This procedure involved different stages of cross-checking between variables, allowing inconsistencies to be identified and ensuring that only consistent and representative data have been included in the analysis. The validations focused on different aspects of the information collected, from billing consumption scenarios to the consistency of the amounts declared in the interruption scenarios.

2. **Filtering:** protected customers had already been filtered out at the start of the survey process and have been therefore excluded from the survey data.

3. **Treatment of 'zero' responses:** Many respondents answered 'zero' as their willingness to pay in one or more scenarios. This is shown in Exhibit 27.

Exhibit 27 – Proportion of responses with a zero willingness to pay, per scenario

Season	Duration	Without Notice	With Notice
Summer	2 mins	87%	86%
	1 hour	65%	72%
	4 hours	51%	54%
	1 day	32%	31%
Winter	2 mins	84%	85%
	1 hour	64%	70%
	4 hours	50%	52%
	1 day	30%	31%

Sources: QMETRICS and AFRY analysis.

There is a consistent and rational trend whereby the number of respondents answering 'zero' decreases as the duration of the interruption increases. This seems to indicate that the 'zero' responses have a genuine meaning.

However, there is a considerable proportion of zero responses (about 30%) even in the case of the 1-day interruption. Many of these responses have been accompanied by commentary from the interviewees to the effect that they considered it should not be the consumer who should bear the cost of an interruption to supply. Typical examples of these comments are as follows:

> '*Não concordo que sejam os consumidores a ter de pagar o que quer que seja por um problema que não é de sua responsabilidade. Quem deve suportar esses custos devem ser os comercializadores ou então o próprio estado se for sua a responsabilidade pela falta de energia.*'

> '*Como cliente de um fornecedor de energia, a existir interrupçao nunca será o cliente a pagar para ter energia sim o fornecedor de energia é que terá se arranjar solução repor energia e pagar os prejuizos derivados da falha de fornecimento.*'

These comments imply that the associated 'zero' responses are not a genuine indication of the value the interviewee places on having an uninterrupted supply of electricity but are effectively 'protest' answers motivated by the idea that additional costs should not be placed on customers for security of electricity supply.

In addition to being asked to indicate their willingness to pay in all 16 scenarios, respondents have been also asked to qualitatively rate the impact of an interruption to their supply for the case of the 1-hour duration, with and without notice, in both winter and summer. As a means of determining which 'zero' responses have been genuine, rather than 'protest' responses, these zero responses have been compared against the impact rating the interviewee had given for the 1-hour duration for each given timing and notice period scenario.

The impact rating has been graded on a scale of 1-5, with 1 being the most impactful, and 5 being the least impactful. The question has been phrased as follows:

> '*Imagine que esta interrupção do fornecimento de eletricidade na sua habitação tem a duração de uma hora. Utilizando a escala onde 1 significa 'extremamente problemático' e 5 'nada problemático', como classificaria o impacto desta situação?*'

The willingness to pay responses have been therefore filtered based on their consistency with the corresponding impact rating. Where respondents answered 'zero' as their willingness to pay but rated the impact of an interruption as either a 1, 2 or 3, their 'zero' response has been excluded from the analysis. Where they had answered a 4 or 5, it has been included in the analysis. As the impact rating related to the 1-hour duration scenario, this logic has been applied only to scenarios of 1-hour duration or more. No 'zero' responses have been excluded from the analysis for the 2-min scenario.

4.4.1.1 Calculation of domestic willingness to pay

The average willingness to pay in the 16 interruption scenarios have been calculated for each of the domestic consumer segments listed in Section 4.2.

These values have been then weighted based on the population size for that consumer segment. The population in this case refers to the number of classic family dwellings of habitual residence in each segment. The resulting weighted average represents the willingness to pay data for the domestic sector. This is presented in Exhibit 28 for each of the scenarios.

Exhibit 28 – Domestic average willingness to pay by interruption scenario (EUR/interruption)

Season	Duration	Without Notice	With Notice
Summer	2 mins	0.17	0.18
	1 hour	2.06	1.56
	4 hours	4.17	3.50
	1 day	10.21	9.28
Winter	2 mins	0.25	0.20
	1 hour	**2.21**	1.72
	4 hours	4.28	3.61
	1 day	10.64	9.71

Sources: QMETRICS and AFRY analysis.

For the Central Scenario – a 1-hour interruption during the winter peak, with no notice – the statistical distribution of willingness to pay across all domestic customers is characterised as follows:

— Average: 2.21 EUR.

— Maximum: 50 EUR.

— Minimum: 0 EUR.

— Standard deviation: 5.30 EUR.

The standard deviation is large compared to the average and there is therefore a broad spread to this data, influenced heavily by the 'zero' responses that remain despite the filtering of these where they are inconsistent with the impact rating given by the interviewee for the same scenario.

Exhibit 29 illustrates the sensitivity of the willingness to pay of the domestic sector in Portugal to the various interruption parameters. The longer the interruption, the greater the average willingness to pay. It is also apparent that customers are willing to pay more to avoid an interruption that occurs without notice, than one where notice is given. Finally, the notice period is more important to domestic customers than the timing of the interruption, with the summer and winter interruption scenarios producing reasonably

similar willingness to pay responses. It is, however, the winter scenarios that are associated with the highest willingness to pay of all, across all durations.

Exhibit 29 – Sensitivity of the average willingness to pay of the domestic sector to the interruption parameters (EUR/interruption)
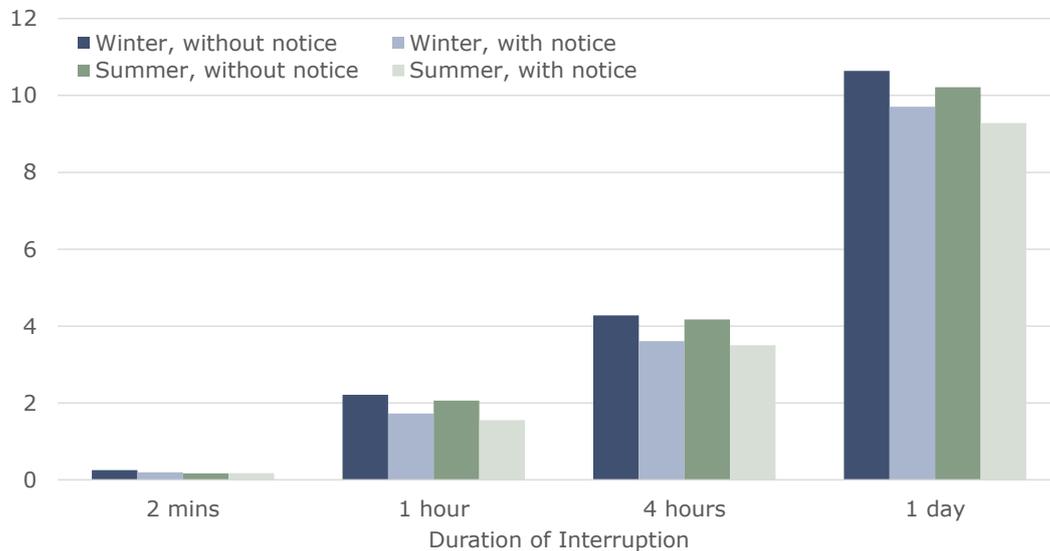
Sources: QMETRICS and AFRY analysis.

4.4.1.2 Calculation of domestic VOLL

To convert the willingness to pay data to the sectoral VOLL, the standard domestic load profile for each interruption scenario has been applied to the annual consumption figures provided by each interviewee to determine the kWh consumption of each interviewee during each interruption. The individual willingness to pay figures have been then divided by the corresponding individual consumption data to produce a VOLL for each interviewee.

As with the willingness to pay data, the average VOLL for each of the 16 consumer segments has been calculated and weighted according to the population of each segment to determine the overall domestic VOLL for each scenario. The resulting figures are presented in Exhibit 30.

Exhibit 30 – Domestic average VOLL by interruption scenario (EUR/MWh)

Season	Duration	Without Notice	With Notice
Summer	2 mins	12,556	12,772
	1 hour	5,327	3,976
	4 hours	2,715	2,267
	1 day	1,438	1,308
Winter	2 mins	11,713	8,573
	1 hour	**3,442**	2,639
	4 hours	1,726	1,439
	1 day	1,113	1,009

Sources: QMETRICS and AFRY analysis.

For the Central Scenario – a 1-hour interruption during the winter peak, with no notice – the statistical distribution is again very broad and skewed towards the zeros remaining after the filtering process.

— Average: EUR 3,442/MWh.

— Maximum: EUR 102,492/MWh.

— Minimum: EUR 0/MWh.

— Standard deviation: EUR 9,035/MWh.

The sensitivity of the domestic VOLL to the various interruption parameters is shown in Exhibit 31. The trend in the sensitivity to the interruption duration is inverted relative to the willingness to pay trend. This is due to the impact of the consumption figures, which increase by a factor of 440 when the interruption duration increases from 2 mins to 1 day in winter. This is a much more significant gap than the change in customers' willingness to pay, which only increases by a factor of 43 in going from the 2-minute winter interruption scenario to the 1-day scenario. On a per kWh basis therefore, the VOLL falls as the duration of the interruption increases. The highest VOLL for the domestic sector in Portugal is for the 2-minute interruption scenario, in summer and with notice.

The VOLL for the Central scenario for the domestic sector – a 1-hour interruption during the winter peak, with no notice – is **EUR 3,442/MWh**.

Exhibit 31 – Sensitivity of the average VOLL of the domestic sector to the interruption parameters (EUR/MWh)
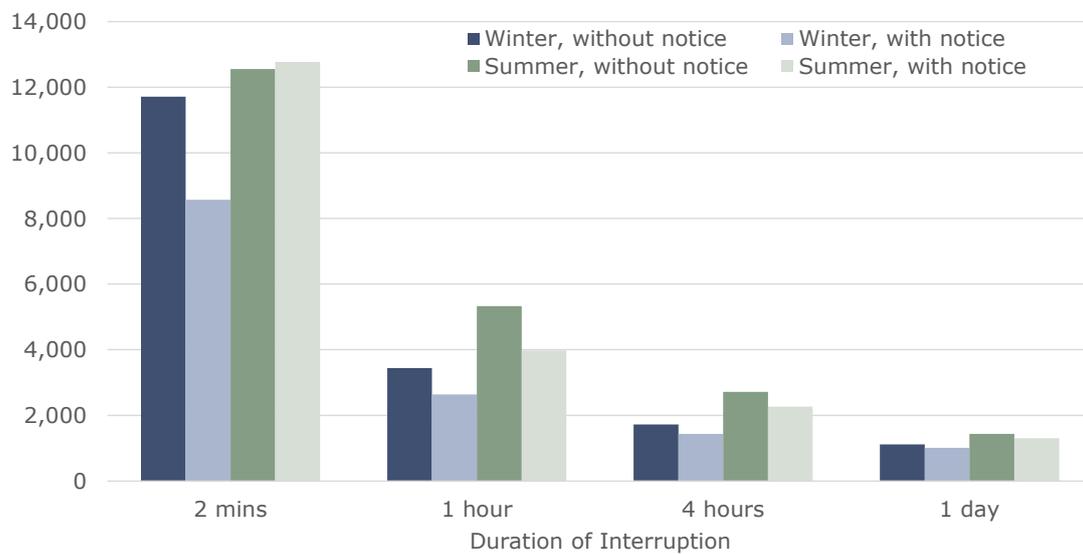
Sources: QMETRICS and AFRY analysis.

4.4.2   Non-domestic sector

It proved challenging to obtain a statistically significant number of responses to the non-domestic survey for some of the non-domestic seven segments. The final dataset comprises 246 responses in total, with many of these respondents not indicating a willingness to pay value for some scenarios.

For the Portuguese non-domestic survey data, the following steps have been taken to determine the sectoral VOLL:

I. **Data validation:** as with the domestic data, the non-domestic response data underwent a rigorous validation by QMETRICS designed to ensure the internal consistency of the information and the reliability of the results. This procedure involved different stages of cross-checking between variables, allowing inconsistencies to be identified and ensuring that only consistent and representative data have been included in the analysis. The validations focused on different aspects of the information collected, from billing consumption scenarios to the consistency of the amounts declared in the interruption scenarios.

II. **Treatment of 'non' responses:** many respondents answered, for some scenarios, that they did not want to respond to the questions regarding their willingness to pay. These responses have been included for scenarios where values have been given and excluded where no value has been given.

III. **Treatment of 'zero' responses:** many respondents answered 'zero' as their willingness to pay in one or more scenarios. As with the domestic data (see Section 4.4.1 for detail), the willingness to pay responses have been filtered based on consistency with their corresponding impact rating response. Where respondents answered 'zero' as their willingness to pay but rated the impact of an interruption as either a 1, 2 or 3, their 'zero'

response has been excluded from the analysis. Where they had answered a 4 or 5, it has been included in the analysis. As the impact rating related to the 1-hour duration scenario, this logic has been applied only to scenarios of 1-hour duration or more. No 'zero' responses have been excluded from the analysis for the 2-min scenario.

IV. **Treatment of responses with backup generation:** whereas only a small proportion of domestic respondents indicated that they had a back-up power source, almost 60% of non-domestic respondents stated that they had some form of back-up power. The sources of backup included uninterruptible power supply, generation, batteries and co-generation. In some cases, these respondents provided commentary to explain how they had considered the presence of their back-up power, but in many cases they did not. There have been two approaches, reflected in respondents' comments, to take into account the presence of back-up power:

a. Where respondents indicated zero willingness to pay on the grounds that they had already invested in a back-up system to mitigate power outages and should not have to pay more, e.g.:

'*Neste tipo de atividade, as infraestruturas encontram-se dimensionadas para assegurar que, sempre que ocorra uma interrupção no fornecimento de energia elétrica, os sistemas alternativos entram de imediato em funcionamento, evitando qualquer quebra de serviço. […] O investimento efetuado permite assegurar uma autonomia de aproximadamente 36 horas em caso de falha no fornecimento público de eletricidade. Assim, atendendo aos recursos já aplicados, a empresa não prevê assumir custos adicionais para evitar interrupções inferiores a um dia, uma vez que os sistemas internos existentes asseguram o funcionamento integral mesmo perante falhas da rede elétrica.*'

b. Where respondents based their willingness to pay on the costs of putting in place a back-up system to mitigate power outages, e.g.:

'*Os custos identificados para os diferentes cenários e durações das interrupções correspondem a valores anuais de CAPEX e OPEX fixo dos equipamentos necessários a tornar as operações imunes aos seus efeitos.*'

Informed by these two approaches, 'zero' responses from respondents who indicated they had back-up generation have been filtered out on the basis that their response likely aligned with the first group of consumers i.e. that they had already invested in their own systems for maintaining security of supply and should therefore not have to pay more.

4.4.2.1 Calculation of non-domestic willingness to pay

The average willingness to pay for the non-domestic sector has been calculated for each of the seven non-domestic segments. These values are shown in Exhibit 32 for the Central scenario. While the coverage of some segments – specifically, Segments 4 and 7 – has been complete or almost complete, the coverage of other segments, post-filtering of the response data as described above, has not been sufficient to be relied upon

statistically. As may be expected however, the highest willingness to pay is seen in the case of large industrial electricity consumers.

Exhibit 32: Average willingness to pay by non-domestic consumer segment for the Central scenario (EUR/interruption)

Consumer segment	Willingness to pay
Companies in the agriculture, animal production, hunting, forestry and fishing sector	18
Industrial small and medium-sized enterprises (SMEs)	2,041
Large industrial companies that are not large consumers of electricity	54,951
Large industrial electricity consumers	864,651
Companies in the trade and services sector, including data centres, telecommunications operators and commercial areas	13,166
Public sector companies	213
Companies in the transport sector that use electricity for mobility	16,278

Sources: QMETRICS and AFRY analysis.

The average non-domestic willingness to pay has been calculated based on the aggregated response data across all consumer segments and is shown in Exhibit 32 for each interruption scenario.

For the Central scenario – a 1-hour interruption during the winter peak, with no notice – the statistical distribution of willingness to pay across all non-domestic customers is characterised as follows:

— Average: 147,620 EUR.

— Maximum: 4,748,418 EUR.

— Minimum: 0 EUR.

— Standard deviation: 705,656 EUR.

The distribution of the data is broad, with the standard deviation being very high relative to the average. This is not entirely unexpected as respondents represented the full range of non-domestic consumers, from micro-enterprises to large energy consumers.

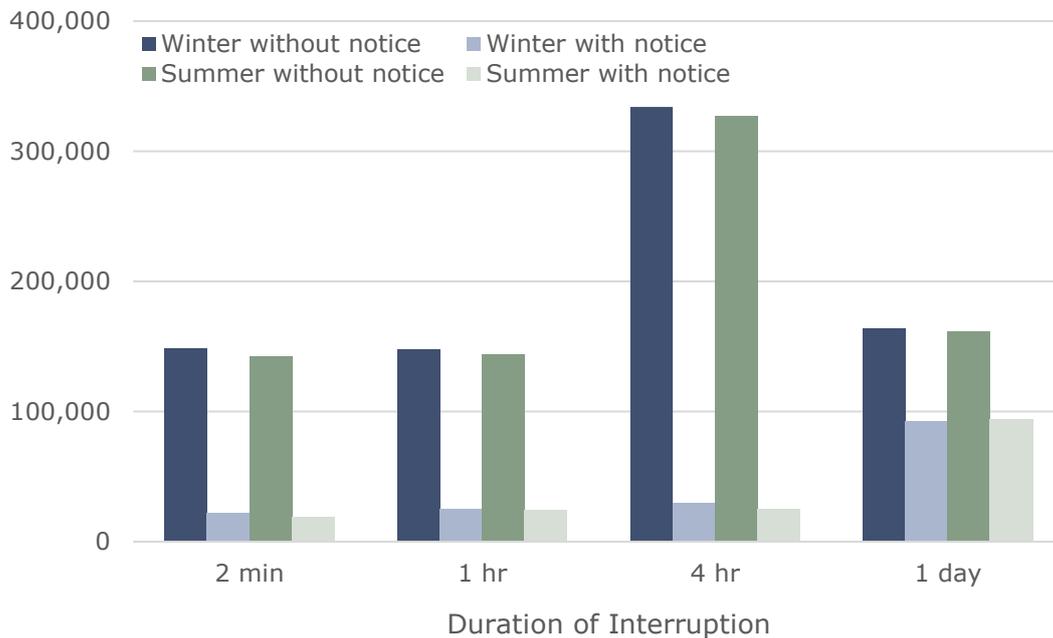**Exhibit 33 – Non-domestic average willingness to pay by interruption scenario (EUR/interruption)**

Season	Duration	Without Notice	With Notice
Summer	2 mins	142,251	19,072
	1 hour	143,620	24,152
	4 hours	327,252	25,156
	1 day	160,977	94,208
Winter	2 mins	148,061	21,772
	1 hour	**147,620**	25,038
	4 hours	333,979	29,668
	1 day	163,348	92,701

Source: QMETRICS and AFRY analysis.

The sensitivity of the non-domestic willingness to pay is illustrated in the exhibit below. As with the domestic sector, it is evident that the longer the duration of the interruption, the more non-domestic customers are willing to pay. In this case however, there is a peak at the 4-hour duration scenario, which is unexpected.

Interrogation of the data shows that this peak arises due to the impact of two specific responses, which give extremely high values for the 4-hour scenario, and no response for the 1-day scenario. These respondents have not provided any rationale to explain why this is. When AFRY re-examined the sensitivity of the non-domestic willingness to pay to the duration of the interruption, excluding these two responses, AFRY found the trend is as would be expected, and the same as that evident in the domestic data, as seem in Exhibit 35. This illustrates the sensitivity of the dataset to individual responses, given the limited number of datapoints.

For non-domestic customers, the value of the notice period is much greater than the timing of the interruption. Though the same trend is evident in the case of domestic customers, it is much more pronounced for non-domestic customers. This is to be expected given that disruption to commercial or industrial activities can be assumed to be far more easily mitigated where notice is given of an interruption. The willingness to pay of non-domestic customers is relatively insensitive to the timing of the interruption i.e. winter or summer.

Exhibit 34 – Non-domestic average willingness to pay by interruption scenario (EUR/interruption)

Sources: QMETRICS and AFRY analysis.

Exhibit 35: Non-domestic average willingness to pay by interruption scenario (EUR/interruption), excluding two responses
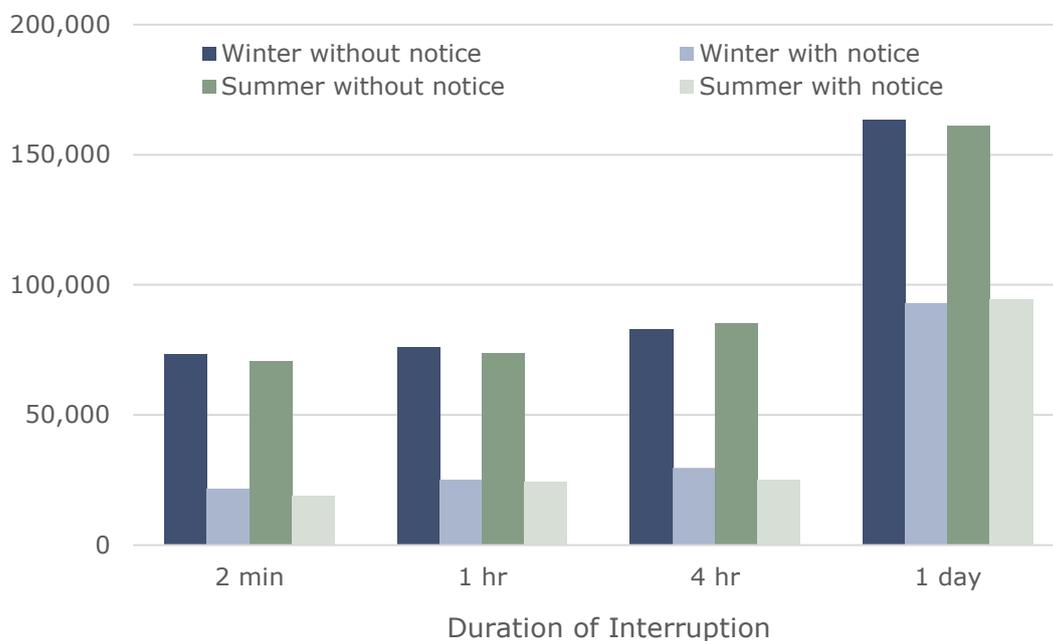
Sources: QMETRICS and AFRY analysis.

4.4.2.1 Calculation of non-domestic VOLL

To convert the willingness to pay data to the sectoral VOLL, the standard load profiles for the commercial, industrial, large energy consumer, public administration, and transportation sectors for each interruption scenario have been applied to the annual consumption figures provided by each interviewee to determine the kWh consumption of each interviewee during each interruption.

The mapping of these load profiles to the seven non-domestic consumer segments identified for the purpose of the survey is shown in Exhibit 36.

Exhibit 36: Mapping of the survey non-domestic consumer segments to the load profiles.

Consumer segment	Load profile applied
Companies in the agriculture, animal production, hunting, forestry and fishing sector	Industrial
Industrial small and medium-sized enterprises (SMEs)	Industrial
Large industrial companies that are not large consumers of electricity	Industrial
Large industrial electricity consumers	Large consumer
Companies in the trade and services sector, including data centres, telecommunications operators and commercial areas	Commercial
Public sector companies	Public administration
Companies in the transport sector that use electricity for mobility	Transportation

Source: AFRY analysis.

The individual willingness to pay figures have been then divided by the corresponding individual consumption data to produce a VOLL for each interviewee, reflecting the load profile of the non-domestic load profile segment to which they belong.

The individual VOLL figures have been weighted by the annual consumption of each respondent to produce a weighted average non-domestic VOLL. This has been calculated as an aggregate value across all seven non-domestic segments. This approach was taken as the survey response data is insufficient to be representative at the level of each segment individually, but at the aggregate level should provide a representative indication of the overall non-domestic VOLL. The non-domestic VOLL for each interruption scenario is shown in Exhibit 37.

For the Central Scenario – a 1-hour interruption during the winter peak, and with no notice – the statistical distribution of the VOLL across all non-domestic customers is characterised as follows:

— Average: EUR 16,105/MWh.

— Maximum: EUR 380,448/MWh.

— Minimum: EUR 0/MWh.

— Standard Deviation: EUR 43,272/MWh.

As with the willingness to pay data, the distribution is very broad.

**Exhibit 37 – Non-domestic average VOLL by interruption scenario (EUR/MWh)**

Season	Duration	Without Notice	With Notice
Summer	2 mins	479,485	55,730
	1 hour	16,775	2,439
	4 hours	10,595	666
	1 day	1,061	583
Winter	2 mins	451,291	59,816
	1 hour	**16,105**	2,410
	4 hours	9,826	771
	1 day	1,047	573

Sources: QMETRICS and AFRY analysis.

The sensitivity of the non-domestic VOLL to the various interruption parameters is shown in the graph below. As with the domestic data, the trend in the sensitivity to the interruption duration is inverted relative to the willingness to pay trend, due to the impact of the consumption figures. The highest VOLL for the non-domestic sector in Portugal is for the 2-minute interruption scenario, in summer and without notice.

The average non-domestic VOLL for the Central scenario is **EUR 16,105/MWh.**

Exhibit 38 – Non-domestic average VOLL by interruption scenario (EUR/MWh)
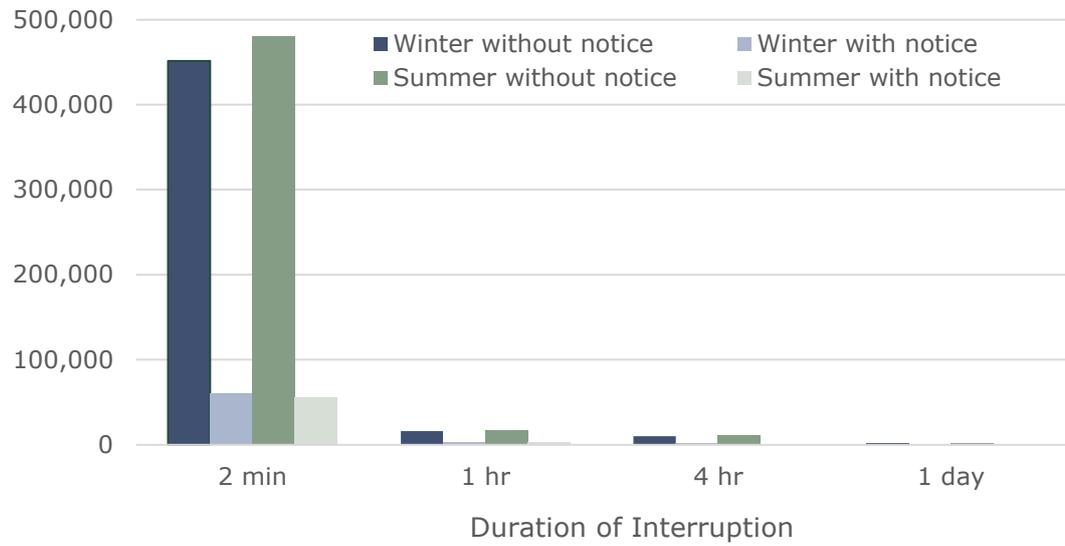
Sources: QMETRICS and AFRY analysis.

4.5 Single VOLL

The ACER methodology determines that based on the sectoral VOLL, a single VOLL is to be calculated. This single VOLL should represent the most likely cost of supply interruptions implemented by the system operators.

The calculation of the single VOLL should exclude consumers who are price-responsive (for the proportion of their demand that is price-responsive) or expected to receive special protection against disconnection.

The sectoral VOLL is to be combined in a way that reflects the EENS that additional capacity resources would avoid. That is, the sectoral VOLL should be weighted appropriately to reflect the avoided EENS for each sector due to the addition of capacity resource. As a simplification, the sectoral weights may instead reflect the average share of load-shedding (rather than avoided EENS) borne by each consumer sector for each central scenario.

4.5.1 Weighting of the sectoral VOLL

AFRY has made use of the simplification envisaged in the ACER methodology whereby the sectoral weights may reflect the average share of load-shedding borne by each consumer sector. AFRY understands from ERSE that sectors are not prioritised or differentiated for load-shedding purposes, and as a result AFRY assumes that load is shed from the different customer sectors in proportion to their consumption at the time. AFRY has therefore weighted the domestic and non-domestic sectoral VOLL in proportion to the consumption of these sectors.

The non-domestic sector constitutes 71% of the total national consumption, with the domestic sector accounting for 29%. On this basis and using a domestic sectoral VOLL of EUR 3,442/MWh and a non-domestic sectoral VOLL of EUR 16,105/MWh, AFRY calculates a **single VOLL** for Portugal of **EUR 12,433/MWh**.

4.5.2 Discussion

The value of the single VOLL produced from this survey is at the lower end of the range of values calculated for other MS. In this context, AFRY notes the challenges encountered in carrying out the survey, specifically with:

— achieving the target response rate from the different sectors;

— 'protest' responses of 'zero' willingness to pay and the difficulty in identifying these;

— differences in the way non-domestic consumers reflected their back-up generation in their willingness to pay; and

— 'non' responses from non-domestic consumers likely due to nuances in how respondents both interpreted the survey questions and intended to answer them.

A key lesson learned from this process is the importance of clearly communicating to respondents how their answers are used and what the significance of a 'zero' response is. This is not an easy task and is likely to be an ongoing challenge with ACER's survey-based methodology.

One concrete change to the survey approach that could support improved data quality would be to specifically provide guidance in the non-domestic questionnaire that willingness to pay should be a value that reflects the cost of provision of back-up power, where the respondent has this backup in place.

Implementation challenges appear to have arisen in other MS also, based on the recently published report from the European Commission on possibilities for streamlining and simplifying the process of applying a capacity mechanism[25], which states the following:

> '*The implementation of the ACER methodology at national level significantly differs between Member States. A recent ACER consultancy study found that the significant divergences in the VOLL (assessed using a survey-based approach) and CONE between the Member States can likely not be fully explained by national specificities reflecting structural differences in their economy. It points to possible implementation difficulties and the diversity of outcomes linked to a survey-based approach. These implementation issues can lead to deviations, potentially giving rise to over- or underinvestment in security of supply.*'

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[25] eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52025DC0065

5 Reliability Standard determination

This chapter introduces the calculation of the RS according to the information presented in Chapters 3 and 4, in alignment with the ACER methodology. The Chapter is structured as follows:

— In the first section, AFRY presents the LOLE per the reference technologies previously selected, taking into account the CONE/CORP and the VOLL obtained.

— In the second section, AFRY checks the validity of the LOLE values obtained, and amendments are made to in case it is deemed necessary.

— Finally, AFRY calculates the RS according to the abovementioned findings, the estimated potential for each reference technology and the capacity requirements according to the latest ERAA.

5.1   LOLE threshold per reference technology

The LOLE reflects, for each selected reference technology, the economic optimisation between the marginal cost of a new entrant (CONE) or the extension/renewal of an existing facility (CORP) and the marginal reduction in the estimated energy not supplied ($EENS = LOLE \times VOLL$). The optimum occurs when both quantities are equal.

ACER's methodology states that for every potential new entry and extension of existing units, with a variable cost lower than the calculated VOLL —which in the case of the reference technologies selected for Portugal means all technologies— a LOLE value must be calculated for all reference technologies according to the following formula:

$$LOLE_{Reference\ Technology} = \frac{CONE/CORP_{Fixed}}{VOLL - CONE/CORP_{Variable}}$$

As discussed in Chapter 3, ACER's methodology allows to simplify the formula from above by disregarding the $CONE/CORP_{Variable}$ if its value is negligible in comparison to the VOLL calculated in Chapter 4. AFRY has demonstrated that this is the applicable case for all the reference technologies considered for the Portuguese market, and thus the applicable formula followed to estimate the LOLE is:

$$LOLE_{Reference\ Technology} = \frac{CONE/CORP_{Fixed}}{VOLL}$$

The results of the LOLE per technology, alongside the estimated potential for each technology –which is relevant for the calculation of the RS in Section 5.3– can be seen in Exhibit 39. This exhibit shows the LOLE for the Central scenario and the CONE computed with the economic lifetime of the projects.

Exhibit 39 – LOLE per technology

Technology Candidate	Expected capacity (GW)	LOLE (hrs)
BESS (2-hr)	+1.5 GW	34.08
BESS (4-hr)		36.58
Bioenergy/Waste	-	51.35
CCGT (new build)	-	6.97
CCGT (OPEX extension)	2.8 GW	1.46
CCGT (5-year extension)	Potential of +0.99 GW	3.34
DSR (HVAC)	Estimated to be 0.7GW	1.60
Hydroelectric power	-	16.75
OCGT	-	6.01
Offshore Wind	+2.0 GW	1038.08
Onshore Wind	+4.1 GW	96.41
Solar PV	+12.4 GW	2433.87

Sources: Based on Portuguese PNEC, and AFRY analysis.

5.2 Conditions of validity of the LOLE threshold

According to ACER, for the LOLE introduced in Section 5.1 to be valid, the following must be met:

1. **The marginal reduction of EENS can be expressed in terms of LOLE**, i.e. the following formula holds:

$$\frac{dEENS(Q)}{dQ} = -LOLE$$

Where Q is the installed capacity of the reference technology. This effectively means:

— no energy constraint affects capacities of the electric system during hours of EENS; or

— energy constraints are properly represented through the de-rating capacity factor, and the installed capacity mentioned in the formula above (Q) represents firm quantities (i.e. installed capacity multiplied by the de-rating capacity factor).

As introduced in Chapter 3, de-ratings have been calculated considering the energy resource availability per technology in the future according to AFRY's modelling capabilities, thus assuring no energy constraints during stress periods. As a result, AFRY considers this validity condition to be met.

2. **Additional capacity resource is required in order to reduce EENS.**

3. **EENS is only reduced in the concerned geographic area.**

AFRY do not have access to the modelling tools required to estimate how EENS changes with changes in firm capacity, including neighbouring countries, so it cannot be confirmed.

However, it can be considered as expectable that in the case of a shortfall of firm capacity that leads to potential future EENS, the addition of the technologies selected as reference leads to a reduction of EENS, specially as energy constraints have been considered in the calculation of the de-rating factor used for the CONE. Furthermore, AFRY expects that during hours of stress with positive EENS, Portugal does not contribute towards security in neighbouring markets, meeting the third requirement.

5.3 Minimum firm capacity required to achieve the RS

One of the key steps for determining the RS is estimating the minimum firm capacity that could eventually be required to achieve the target RS. ACER's methodology determines that the capacity required to achieve the RS must be based on the results of the latest ERAA[26], based on the relationship between the number of hours observed with EENS and the capacity margins for the electricity system. The ACER methodology specifies that the minimum capacity to achieve the reliability standard must be less than (or equal to) the maximum hourly energy not supplied EENS observed in the ERAA or, where applicable, in the regional or national coverage study (i.e., RMSA[27]). The latest available version of the RMSA for 2024 does not assess security of supply according to ACER's guidelines and AFRY understands that as such is not an eligible methodology to justify the RS; however, this judgement is out of AFRY's scope and not part of the analysis presented in this report.

A summary of the EENS and LOLE for Portugal according to the ERAA 2024 is shown in Exhibit 40. The values observed in this table for LOLE and EENS have been derived by aggregating the hourly results from ENTSO-E and dividing them by the 540 scenarios modelled (i.e., 36 weather patterns times 15 forced outage series). The minimum capacity required to reach RS has been derived from the maximum EENS observed in any given hour and scenario, as per ACER's guidelines explained above.

From the information shown, it can be concluded that according to ACER's methodology, there is a shortfall of 446 MW of firm capacity based on the ERAA 2024 in Portugal for 2026, increasing to 557 MW by 2028. However, in 2030 and 2035, the adequacy assessment in Portugal shows a surplus of firm capacity that results in LOLE and EENS equal to zero in all scenarios. This oversupply situation is the result of the capacity mix assumed in the ERAA 2024, as provided by the relevant Portuguese authorities: PNEC.

Given the vintage of the ERAA 2024 report, AFRY recommends ERSE to update the values shown in Exhibit 40 once the ERAA 2025 is published or

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[26] At the moment of writing of this report, latest version is ERAA 2024: https://www.entsoe.eu/eraa/2024/
[27] Relatório de Monitorização da Segurança de Abastecimento (RMSA).

the RMSA 2025 is made available, if its security of supply assessment complies with ACER's methodology.

Exhibit 40 – ERAA 2024 results for Portugal

Year	LOLE (h)	EENS (MWh)	Minimum capacity required to reach RS (MW)
2026	0.13	9.68	446
2028	0.12	10.36	557
2030	0	0	0
2035	0	0	0

Sources: ENTSO-E.

5.4 Calculation of the RS

The target RS is defined in the ACER methodology as the lowest LOLE for a given technology that has additional capacity greater than the minimum capacity required to meet the reliability standard. If the potential of a single reference technology is not capable of covering the minimum capacity, then the target LOLE would be that of the reference technology whose potential (added to the potential of the previous reference technology or technologies) allows the minimum capacity to be covered in order to achieve the reliability standard, as shown in Exhibit 41.

Exhibit 41 – Illustrative capacity requirement and aggregated firm capacity supply curve for the RS calculation (hours)

For a capacity requirement of 4.0 GW, it is necessary to accumulate the total supply of technologies 1, 2 and part of 3 to fulfil the need of the system. The LOLE is set at 5.18 hrs, corresponding to the level set by technology 3.
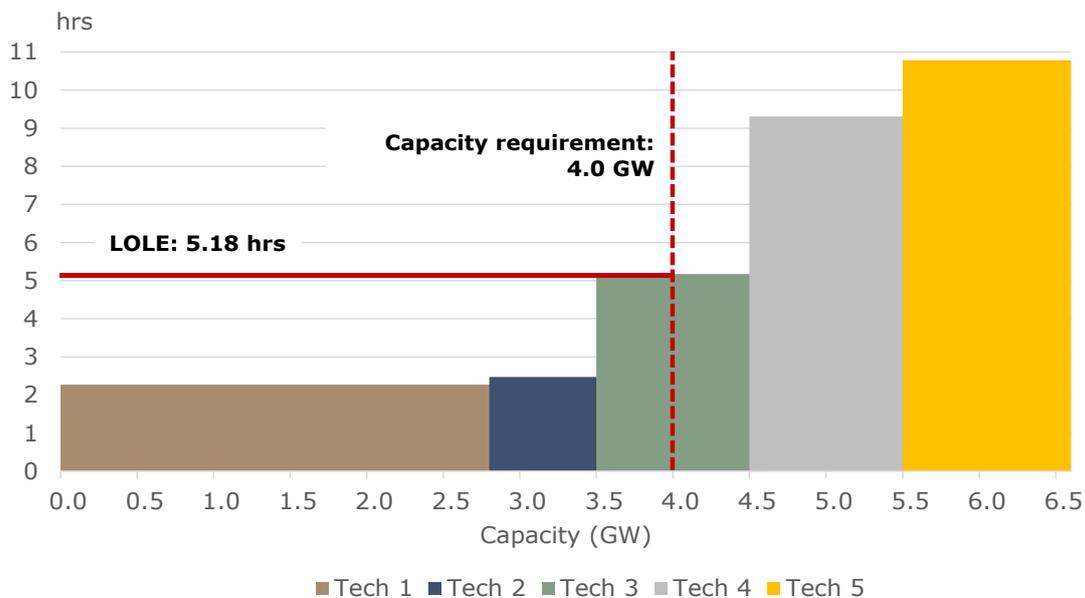
Sources: AFRY analysis.

Exhibit 42 shows the reference technologies sorted in ascending order of LOLE, as presented in Section 5.1. It also includes the accumulated firm capacity potential for each technology. The following must be commented about the information shown:

— Only five technologies are shown, showing a range of LOLE between one to 10h approximately. The rationale is that for newly built OCGTs and CCGTs, there is not a theoretical maximum potential that can be applied, as this technology is scalable, so an infinite amount could be eventually commissioned. This means that from the academical perspective, maximum RS in Portugal is capped by the LOLE of the new built CCGT.

— Capacity requirements for 2030 and 2035 have been omitted, as per the ERAA 2024 they are null.

**Exhibit 42 – Reference technologies ordered by LOLE and potential capacity**

Technology	LOLE (h)	Accumulated potential (GW)	2026 capacity requirement (GW)	2028 capacity requirement (GW)
CCGT (OPEX extension)	1.46	2.8	0.4	0.6
DSR	1.60	3.5		
CCGT (5 year-extension)	3.34	4.5		
OCGT	6.01			
CCGT (new build)	6.97			

Note: Both new build CCGT and OCGTs can be added to the system as needed in order to fulfil the capacity requirement.
Sources: AFRY analysis.

Following these results, AFRY initially expects the technology setting the RS in 2026 and 2028 to be CCGT (through OPEX extension), with a value of 1.46h. AFRY has graphically shown this in Exhibit 43.

AFRY initially expects the technology setting the RS in 2026 and 2028 to be CCGT (through OPEX extension) with a value of 1.46h

Exhibit 43 – Expected clearing of the LOLE for the set capacity requirement (hrs)
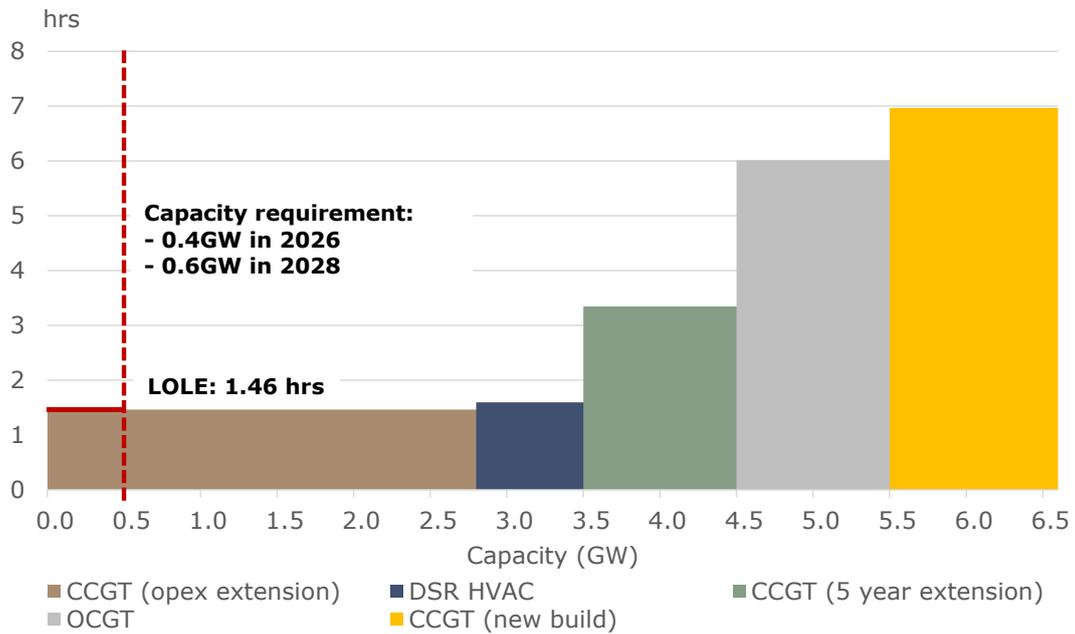
Note: The chart shows 1GW of availability for OCGT and 1GW for CCGT (new build) for demonstrative purposes; capacity for both technologies can be added as required by the system.
Sources: AFRY analysis.

Annex A   Detailed evaluation of VOLL[28]

Exhibit A.1 – Detailed evaluation of VOLL per country

MS	Date	In line with ACER?	Survey approach	Scope of the survey	Interruption period	Domestic VOLL (EUR/MWh)	Industrial VOLL (EUR/MWh)	Commercial VOLL (EUR/MWh)	Other VOLL (EUR/MWh)	Approach to calculating the single VOLL	Total VOLL (EUR/MWh)	Total VOLL (EUR/MWh, nominal value)[29]
Netherlands	2022	Yes	WTP	1,011 households and 301 businesses	1 hour, winter working days, notification one day in advance	35,284	51,576	84,942	103,119	Power cut order	68,887	75,982
France	2022	Yes	WTP, WTA[30], direct value	4,000 consumers	1 a.m. to 6 a.m., winter weekdays, with and without notification	25,000	19,000	50,000	41,000	Weighted by consumption	33,000	36,399

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[28] Information compiled during the first semester of 2025; there is some divergences with the information presented by ACER in its annual monitoring report presumably because changes in the MS surveys or interpretation. AFRY has not been able to validate ACER's latest results.
[29] Inflation in the EU of 2.6% between 2020 and 2021, 8.4% between 2021 and 2022, 5.5% between 2022 and 2023, 2.4% between 2023 and 2024, and 2.1% between 2024 and 2025, source: Bloomberg.
[30] *Willingness To Accept* (WTA).

Italy	2021	Yes	WTP, WTA	1,200 households, 600 commercial and 125 industrials	Two minutes to one hour, summer and winter peaks, with and without notification	37,700	136,100	28,700		Weighted by consumption	28,400	33,958
Spain	2023	No	Macroeconomic, WTP, WTA	5,350 households	Two minutes a day, with and without notification	24,635	22,879	24,635		Weighted by consumption	22,879	23,920
Poland[8]	2023	Yes	WTP, WTA	1,007 households, 329 commercial, 466 industrial and 600 others	1 hour to one day, summer and winter peaks, with and without notification	6,612	16,147	30,769	17,800	Weighted by consumption	17,194	17,976
Ireland	2023	Yes	WTP	590 consumers	1 hour, winter night-time peak, no prior notice	19,199	682	67,288		Weighted by consumption	16,464	17,213
Czech Republic[5]	2022	Yes	WTP			3,073	2,244	13,283	9,310	Weighted by consumption	4,016	4,430

Belgium	2022	Yes	WTP, WTA, direct value	1,026 households and 457 commercial & industrial	1-hour, night-time peak in winter, with one day's notice	3,507	19,050			Weighted by consumption	12,832	14,154
Germany/ Luxembourg	2021	No	Macroeconomic								12,240	14,635
Slovenia	2022	Yes				18,475	8,900	12,019			10,577	11,667
Finland	2022	Yes	WTP, WTA	1,700 consumers	1 hour, winter night peak, with and without notification	2,742	22,810	9,885	9,053	Weighted by consumption	8,000	8,824
Sweden[10]	2021	Yes	WTP, direct value	1,500 households, 750 industrial, 400 commercial and 800 others	1 to 2 hours, without notification	804	23,820	19,911	7,679	Power cut order	7,870	9,654

Estonia	2020	No	Macroeconomic								7,300	8,955
Greece	2021	Yes	WTP, WTA	1,500 consumers	1.5 hours and no notification	11,800	920	4,510	1,999	Weighted by consumption	6,838	8,176

Sources: ACER and MS.

Annex B — Detailed assessment by CONE/CORP[28]

Exhibit B.1 – Selection of reference technologies for CONE/CORP calculations by MS and CONE/CORP obtained

MS	Storage	DSR	CCGT	OCGT	Engines	Cogeneration	Nuclear	Hydraulic	Biomass	Solar	Offshore wind	Onshore wind
Netherlands												
France	✓	✓							✓			✓
Italy	✓		✓	✓				✓		✓		✓
Spain	✓			✓		✓		✓		✓		✓
Poland		✓	✓			✓						
Ireland	✓		✓	✓	✓	✓						
Czech Republic												
Belgium	✓	✓	✓	✓	✓	✓				✓	✓	✓
Germany & Luxembourg		✓										
Slovenia	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓
Finland	✓	✓	✓		✓		✓		✓	✓		✓
Sweden	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Estonia	✓	✓	✓	✓	✓	✓						
Greece	✓	✓	✓	✓		✓			✓	✓	✓	✓
Average fixed CONE/CORP (EUR/kW-year)	**277**	**27**	**77**	**84**	**192**	**266**	**806**	**225**	**275**	**3,625**	**2,227**	**1,059**
Average variable CONE/CORP (EUR/MWh)	**54**	**1,084**	**128**	**73**	**105**	**52**	**4**	**3**	**29**	**0**	**3**	**2**

Sources: MS and AFRY.

Exhibit B.2 – CONE/CORP fixed (EUR/MW-year) by MS and technology

MS	Storage	DSR	OCGT	CCGT	Engines	Cogeneration	Nuclear	Hydraulics	Biomass	Solar	Offshore wind	Onshore wind
Netherlands												
France	193,000	80,000							265,000	1,485,000	1,290,000	750,000
Italy	179,000		57,500	74,500				202,000		525,000		399,000
Spain	283,000			34,500[31]		315,000[32]		145,000		1,460,000	1,496,000	644,000
Poland		32,576	128,710			262,466				3,891,753	1,870,396	1,413,311
Ireland	572,000		190,000	147,000	366,000							
Czech												
Belgium	140,000	30,000	67,000	96,000	93,000	152,000				8,823,000	2,774,000	1,814,000
Germany /Luxembourg		10,884	57,067									
Slovenia	263,000	29,000	74,000	118,000		46,000	960,000	337,000		580,000		613,000
Finland	694,000	18,000	60,000		114,000		651,000		321,000	6,280,000	2,462,000	1,583,000
Sweden	132,884	6,097	24,769	70,198	193,708	515,867						1,366,560
Estonia			62,000									
Greece	33,990	12,626	45,000	50,000		302,077		215,000	238,428	5,956,000	3,468,000	949,165
Average	**276,764**	**27,398**	**76,605**	**84,314**	**191,677**	**265,568**	**805,500**	**224,750**	**274,667**	**3,625,094**	**2,226,733**	**1,059,115**
Median	**193,000**	**23,500**	**61,000**	**74,500**	**153,854**	**282,272**	**805,500**	**208,500**	**265,000**	**2,688,390**	**2,166,198**	**949,170**

Notes: The above figures were calculated based on averages or approximations from the original sources, where relevant.
Sources: MS and AFRY.

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[32] Corresponding to the CORP of existing assets.

Exhibit B.3 – CONE/CORP variable (EUR/MWh) per MS and technology

MS	Storage	DSR	OCGT	CCGT	Engines	Cogeneration	Nuclear	Hydraulics	Biomass	Solar	Offshore wind	Onshore wind
Netherlands												
France												
Italy												
Spain												
Poland		4,933										
Ireland												
Czech Republic												
Belgium		737	80	50	94	53				0	0	0
Germany /Luxembourg		155	80									
Slovenia	40	147	240	60		50	0	3		0		0
Finland	0	9	86		67		7		29	0	5	5
Sweden	122	155	155	110	153	52						2
Estonia												
Greece		1,450										
Average	**54**	**1,084**	**128**	**73**	**105**	**52**	**4**	**3**	**29**	**0**	**3**	**2**
Median	**40**	**155**	**86**	**60**	**94**	**52**	**4**	**3**	**29**	**0**	**3**	**1**

Notes: the above figures have been calculated based on averages or approximations from the original sources, where relevant.
Sources: MS and AFRY.

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Annex C

Detailed assessment of RS[28]

Exhibit C.1 – LOLE (h/year) by MS and technology

MS	Storage	DSR	OCGT	CCGT	Engines	Cogeneration	Nuclear	Hydraulics	Biomass	Solar	Offshore wind	Onshore wind
Netherlands												
France												
Italy	5.8		2.1							18.5		14.1
Spain	12.4			1.5		13.8		6.4		63.8	65.4	28.1
Poland												
Ireland												
Czech Republic		8.3	4.1	6.5	12.8		54.8				231.5	158.8
Belgium												
Germany /Luxembourg		0.9	4.7									
Slovenia												
Finland												
Sweden	18.0	0.8	5.3		26	69.0						181.0
Estonia												
Greece	5.8	2.5	6.6	7.5		44.2		31.5	34.9	809.7	479.1	138.8
Average	**10.5**	**3.3**	**4.6**	**5.2**	**19.4**	**42.3**	**54.8**	**19.0**	**34.9**	**297.3**	**258.7**	**104.2**
Median	**9.1**	**1.7**	**4.7**	**6.5**	**19.4**	**44.2**	**54.8**	**19.0**	**34.9**	**63.8**	**231.5**	**138.8**

Notes: the above figures have been calculated based on the average or approximated from the original sources, where relevant
Sources: MS and AFRY

Exhibit C.2 – Available capacity after reduction of nominal power (MW) by MS and technology

MS	Storage	DSR	OCGT	CCGT	Engines	Cogeneration	Nuclear	Hydraulics	Biomass	Solar	Offshore wind	Onshore wind
Netherlands												
France												
Italy	400		12,880[33]					0		1,400		1,200
Spain[34]	2,935			10,415		485		2,710		2,080	370	4,405
Poland												
Ireland												
Czech Republic												
Belgium												
Germany /Luxembourg		865	Unlimited									
Slovenia												
Finland[35]												
Sweden	Unlimited	2,610	Unlimited		Unlimited	Unlimited						Unlimited
Estonia												
Greece	1,045	1,684	0	2,502		4		868	105	47	12	318

Notes: the above figures have been calculated based on averages or approximations from the original sources, where relevant.
Sources: MS and AFRY.

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[33] Joint potential for CCGT and OCGT.
[34] The values for CCGT and cogeneration represent the extent of existing assets.
[35] No clarity is provided on the different categories selected.

TABLE OF EXHIBITS

Quality control

Roles	Name	Date
Authors	Joaquin Amenabar Grainne Black Ignacio Cobo Kostas Theodoropoulos	12-Dec-2025
Approver	Ignacio Cobo Kostas Theodoropoulos	15-Dec-2025
QC Review	Kostas Theodoropoulos	15-Dec-2025

Document control

Report Identifier: 2025/807000324-001

Version	Date	Comments
V200	17-Dec-2025	Review of ERSE comments
V100	15-Dec-2025	Initial client release

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