STUDY ON THE ESTIMATION OF THE COST OF DISRUPTION OF GAS SUPPLY IN EUROPE

Task A: Review and assess existing methods for the valuation of security of gas supply and recommend a method to estimate the value of CoDG

Task B: Application of the recommended method for the valuation of the CoDG

Final Report

November 2018

Final Report

***Date*:**

19 November 2018

Client name:

Agency for the Cooperation of European Regulators (ACER)

Project title:

STUDY ON THE ESTIMATION OF THE COST OF DISRUPTION OF GAS SUPPLY IN EUROPE

Final Report

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EXECUTIVE SUMMARY

KANTOR MANAGEMENT CONSULTANTS (KMC, GR) and Economic Consulting Associates (ECA, UK) were commissioned by the Agency for the Cooperation of Energy Regulators (ACER) to conduct a study on the **estimation of the Cost of Disruption of Gas supply** (CoDG) in Europe.

STUDY SCOPE, INTENDED USE AND STRUCTURE

The study aims to improve the existing methodology regarding the monetisation of the CoDG. In particular, the study aims to provide:

- Clearly structured, documented and practical methods for estimating the CoDG
- Estimates (figures) of the value of CoDG
    - per Member State,
    - per type of consumer, including value patterns according to the level of involuntary curtailment (1-100%) for industrial consumers, the duration of the involuntary curtailment/disruption, and the way in which a prior notice (e.g. 24 hours ahead of the disruption) may impact the cost of disruption.
- Insights on a possible methodology for the solidarity price.

In this regard, the study has two main intended uses:

- Provide input to the European Network Transmission System Operations for Gas (ENTSOG) in further quantifying the monetary impact of a disruption in the context of the application of the Cost-Benefit Analysis methodology (CBA) and in the Ten-Year Network Development plan (TYNDP).
- Provide insights to national regulatory authorities (NRAs), and the Agency if involved, towards calculating compensation costs in the context of the solidarity mechanism as per Commission Recommendation (EU) 2018/177.

The study includes two distinct tasks:

- Task A:
    - Review and assess existing methods for the valuation of security of gas supply
    - Recommend a method to estimate the value of CoDG
- Task B:
    - Apply the recommended method of Task A by using publicly available data to estimate the value of CoDG
    - Discuss a possible approach for the estimation of the solidarity price

The output from the above two tasks is outlined in the six chapters of this report, with further details and findings provided in 30 Appendices.

REVIEW AND ASSESSMENT OF EXISTING PRACTICES AND SCIENTIFIC APPROACHES FOR THE CALCULATION OF THE CODG

To identify the approaches used to monetise the value of security of supply, we reviewed the corresponding literature. In addition, we conducted a survey addressed to NRAs to identify current practices of estimating CoDG in the EU.

Review of possible approaches for the calculation of CoDG

Past practices and scientific approaches can be grouped in three categories corresponding to the underlying concept used to monetise CoDG (Table 1). The cost-function approaches aim at estimating the monetary cost of measures taken to mitigate or adapt to a supply disruption. The demand-function approaches reflect the idea that the consumers derive a welfare surplus, which is lost when there is a disruption of supply. Finally, the production-function category contains approaches that quantify the loss of revenue due to the interruption of production caused by a disruption.

The cost-function approaches may be based on historic precedents of a supply disruption, in which case they use actual costs, as observed in past events of disruption or use hypothetical cost estimates provided through consumer surveys, desk research on fuel costs, or via more sophisticated economic modelling techniques.

The demand-function approaches aim to quantify consumer welfare losses caused by energy supply disruptions. The key difference between the four demand-function approaches that we identified lies in the type of data used. The revealed-preference approach uses market data of prices and quantities. The other three approaches rely on various surveying techniques to collect data on consumer willingness to pay (WTP) in order to avoid a supply disruption or willingness to accept (WTA) a compensation in case such a disruption occurs.

The production-function approaches aim to quantify the value of production output at risk of loss due to energy supply disruptions. We identified eight approaches that fall under this category.

NRA Survey

In addition to our literature review, we carried out an online survey addressed to NRAs in order to define a baseline of currently available and applicable approaches to the determination of CoDG values at Member State level. Through this survey, we sought to collect information on (a) known implications of past gas supply disruptions (including ex-post cost estimates if available) and (b) existing measures (including demand-side management and compensation mechanisms) already in place.

The survey confirmed the initial understanding that methodologies for the estimation of CoDG are in general not available in Member States. With the exception ofthe NRA of Great Britain, all other respondents to the questionnaire acknowledged that such methodologies (and related values) do not exist at national level.

In the survey, voluntary demand response measures were recognised as a key mechanism to address disruptions before administrative measures are invoked, such as the solidarity mechanism of Article 13 of Regulation (EU) 2017/1938. Nevertheless, less than half the NRAs that participated in the study (7 out of 16) commented that such mechanisms are in place with only 3 NRAs, also acknowledging the existence of a compensation mechanism. It is understood that such mechanisms, where they exist, are in their majority market-based.

Less than half of the NRAs that took part in the survey (7 out of 16) confirmed the existence of an obligation for power plants in their counties to maintain the ability to switch to an alternative fuel.

It is noted that only 3 out of 16 NRAs are competent authorities for issues related to the security of gas supply in their countries. Thus it appears that more detailed information should be sourced from the respective competent authorities, if needed.

Possible approaches to the estimation of CoDG

We evaluated the approaches identified above with a view to select those that are most suitable to form the base of our methodology (Table 1). The assessment exercise revealed that a number of approaches may be utilised (independently or in combination with each other) for the purpose of estimating CoDG.

Table 1: Summary of the assessment of the CoDG estimation approaches

Review		Assessment				
Practice/Approach		Granularity	Applicability to natural gas disruptions	Data availability, accessibility, homogeneity, robustness	Estimation practicality and replicability	Public acceptability
Cost-function approach assessment	Case studies	− −	+ + +	−	−	+ + +
	Fuel Switch	+	+ + +	+	+ +	+ +
	Hypothetical estimates of costs	+ + +	+ + +	− −	+	+
	EIB	− − −	+ + +	− − −	− − −	− −
Demand-function approach assessment	Revealed preferences	−	+ + +	+	− −	− − −
	Contingent valuation	+	+ + +	− − −	+	−
	Contingent ranking	+ +	+ + +	− − −	− − −	− −
	Choice experiment	+ +	+ + +	− − −	− − −	− −
Production-function approach assessment	GDP-at-risk	− − −	+ +	+ + +	+ + +	− −
	GVA-at-risk	− −	+ +	+ + +	+ + +	− −
	Adjusted GVA-at-risk	+	+ +	−	+ + +	+ +
	Input-output	− −	+	+ + +	− − −	− −
	Producer surplus	−	+ + +	+	+	+
	Real options	−	+ + +	− − −	− −	+
	Tax-at-risk	− − −	+ +	+ + +	+ + +	− −
	Leisure-at-risk	−	− − −	+ + +	+ +	− − −

The fuel-switch approach can provide a base for calculating the CoDG in the residential and services sectors, as well as in industrial and power generation sector facilities which use natural gas. These estimates can be supplemented with findings from case studies (where applicable and available), so as to provide a form of ex-post assessment of the methodology and the calculated CoDG values.

The adjusted gross value added (GVA) at-risk approach seems to be best suited to monetise CoDG in sectors that rely critically on the use of natural gas for their production as feedstock. To ensure that CoDG estimates are of sufficient granularity, the hypothetical-cost approach based on surveying can provide useful supplementary input.

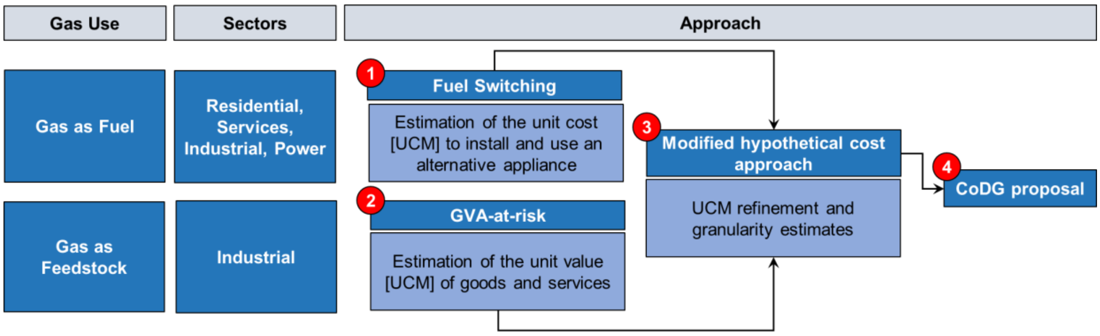
RECOMMENDED APPROACH FOR THE MONETISATION OF THE CODG

In this section, we develop and present a consistent methodology for estimating CoDG, covering all consumer types and all European Member States (MS).

Our recommended approach for the monetisation of the CoDG is summarized in the following four steps:

1. Estimate a cost measure per unit of energy (UCM in €/MWh) when natural gas firing equipment is substituted by alternative appliances/equipment and fuels, for all sectors where natural gas is used as a fuel. A fuel-switching approach is used as the base for this part of the methodology. In essence, the CoDG is assessed by looking at the cost of the measures which have to be undertaken in order to ensure that gas interruptions have no effect on the activity of the relevant entity or person ("how much do I have to spend to avoid damage when gas is not available").
2. Estimate a UCM in the industrial sub-sectors where natural gas is used as feedstock. An adjusted GVA-at-risk approach is used for this part of the methodology. In this case, the CoDG is assessed by looking at the value of the lost output due to the absence of gas ("what damage will I sustain if there's no gas").
3. Use a modified hypothetical-cost approach with a view to obtain views from stakeholders as to whether the above UCM estimates can be used to represent the CoDG and if further refinements in the methodology maybe necessary (carry out a "reality check"). The approach involves sectoral surveys asking consumers about their estimates of CoDG under hypothetical scenarios with several granularity options (time of day, day of week, month, disruption duration, early warning).
4. Use the results from steps 1, 2 and 3 above to calculate sectoral CoDG values for each Member State.

Figure 1: Overview of the CoDG methodology and approach



STEP 1: Fuel Switching (UCM for natural gas-as-fuel)

For each Member State, sector, sub-sector and type of end use, a fuel UCM is estimated at appliance or equipment type level. By appliance type, we refer to the specific appliances that may be used in the residential and services sectors to substitute other types of energy for natural gas, such as use an electric stove or an electric water heater or an oil or pellet boiler for space heating instead of gas-burning equipment. By equipment type, we refer to a dual-fired turbine burning either gas or light fuel oil (LFO) or an LFO or liquefied petroleum gas (LPG) boiler for industrial uses. For simplicity, in the remaining parts of this document we chose to use the word "appliance" to also refer to alternative equipment for power generation and industrial uses.

UCM values are then evaluated at more aggregate levels (end-use type, subsector, sector and Member State), using appropriate weighting factors.

In detail:

- The appliance-based fuel UCM is a function of the capital cost, the utilisation time and the end-use price difference between the alternative fuel and natural gas.
- The end-use type fuel UCM is computed as the average of the UCM values of each representative alternative appliance relative to the specific end-use.
- The sub-sector and sector fuel UCM values are calculated as a weighted average of the end-use type UCM values, where applicable. For example, for the residential sectors such end-use weights refer to the share of gas used for cooking, water heating (or production of steam), and space heating. Weighting factors were derived from own assumptions and EUROSTAT data on gas consumption by Member State and end-use type.

STEP 2: GVA-at-risk (UCM for natural gas-as-feedstock)

For gas-as-feedstock, we looked into the types of products and industries using natural gas in a production process.

We found that such industries are almost invariably within the chemical and petrochemical sub-sectors where natural gas is used for the production of hydrogen (for hydrocracking, hydro-desulfurization, and ammonia production). Methanol is also produced from natural gas and can become a feedstock for manufacturing other chemical substances, such as formaldehyde, insulation materials, varnishes, paints, glues, fuel additives, acetic acid and MTBE (methyl tert-butyl ether). Furthermore, fertilizers (e.g. urea) are produced from natural gas through a series of chemical conversions.

We thus assigned a feedstock UCM value solely to the chemical and petrochemical industry. This value was computed as a function of the chemical and petrochemical industry GVA for the Member States where such industrial sectors exist, the respective natural gas and total fuel consumption, and the portion of natural gas consumed as feedstock.

STEP 3: Implementation of the modified hypothetical cost approach

Three sectoral questionnaires were prepared, targeting the residential, services and industry and power sectors. Interviews with industrial and power sector stakeholders and associations willing to provide additional comments were also carried out.

The questionnaires were used to assess public acceptance of the proposed methodology, get feedback from stakeholders for the proposed UCM values as proxies of the CoDG, and for obtaining further insights on including value patterns according to the level of involuntary curtailment (1-100%) of gas supply for industrial consumers in cases of gas supply disrutions, the duration of the involuntary curtailment/disruption, and the way in which a prior notice (e.g. 24 hours ahead of the disruption) may impact the cost of the disruption. Based on the results, parametric adjustments of the UCM values calculated under STEP 1 of the methodology were carried out with a view of determining the relative sensitivity of the UCM values to input parameters and assumptions.

STEP 4: Calculation of CoDG values per Member State.

A cross-sectoral aggregated CoDG value per Member State is calculated in two steps:

(1) First, a total industry UCM is evaluated as the weighted average of the fuel-based UCM and the feedstock-based UCM. Two weighting factors are defined. The first factor is the ratio of the natural gas consumption as fuel in the industrial sector to the natural gas final consumption, including non-energy uses in the industrial sector. The second factor is equal to the ratio of the natural gas consumption for non-energy uses to the natural gas final consumption, including non-energy uses.

(2) Next, a Member State-specific UCM is evaluated as the weighted average of the residential, services, power and industry UCM values for that MS. Weighting factors are defined as the ratio of the sector-specific natural gas consumption to the total natural gas final consumption (including non-energy uses) in the MS.

All values used in the calculation of the weighting factors are available from EUROSTAT.

Assessment of the recommended methodology

Table 2 presents the assessment of our recommended approach.

Table 2: Assessment of the proposed approach for the estimation of the CoDG

Gas Use	Applied Approaches	Steps of the Methodology	Granularity	Applicability to natural gas disruptions	Data availability, accessibility, homogeneity and robustness	Estimation practicality and replicability	Public acceptability
Fuel	Modified fuel switch & Modified hypothetical cost	1,3,4	⊕⊕	⊕⊕⊕	⊕	⊕⊕	⊕⊕
Feedstock	Adjusted GVA-at-risk & Modified hypothetical cost	2,3,4	⊕⊕	⊕⊕⊕	⊕	⊕⊕	⊕⊕

The proposed UCM approach provides numerical values by country, sector and type of end-use of gas. A modified fuel switch approach is used which takes into account the utilisation of alternative equipment (hours per day, days per week and weeks per year). The modified hypothetical-cost (MHC) approach allows for further assessment of parameters that may influence the value of the CoDG, such as gas supply disruption duration and curtailment magnitude.

The approach faces some challenges in terms of data availability, accessibility, homogeneity and robustness. For example, the UCM estimation in the case when natural gas is used as a fuel requires an extensive amount of data, both from regularly available public sources and from ad-hoc sources. In particular, there is a risk that the values of alternative appliances collected from web sites may be sample-biased due to limited number of data sources and skew caused by large international firms quoting appliance prices which tend to be lower than the actual average price paid by customers who buy such appliances.

In addition, the modified hypothetical-cost (MHC) approach introduces a subjective element as its outcome depends on the input provided by respondents which is, at least partially, based on expectations. Nevertheless, the MHC is less subjective compared to the contingent valuation approach (direct willingness-to-pay and willingness-to-accept questions), as the respondents in the MHC are asked to provide a quantitative assessment of specific CoDG values based on prior UCM calculations, rather than entirely hypothetical WTP and WTA assessments.

Limited size samples and geographic bias may also contribute to the uncertainties of the adopted approach. To ensure that uncertainties are minimized, we used subjective input (the e-Survey results of a poll) only to determine the sensitivity of the model output parameters to the input data. We would recommend that for a further evaluation of the sensitivity of the model to the input parameters and their granularity, a larger scale, more targeted survey is carried out for each Member State.

We note that the questionnaires distributed as part of this study were made available only in English and were web-based via e-Survey. Although language is not expected to be a substantial barrier for the European industrial and power sectors, considerable sample bias is acknowledged for the residential and services sectors, as the English language is not equally accessible across all EU countries and social groups.

. We also note that the UCM methodology for gas-as-fuel depends to some extent on CAPEX data for alternative equipment and - to a larger extent - on fuel costs. These values will change over time and the input data would have to be revisited on a regular basis.

To put it simply, the UCM values in this document should not be regarded as "static", but as the result of the application of the chosen methodology at a particular point in time. Accordingly, the UCM values calculated by using the same methodology at a different moment in time could change due to changes in prices of fuels, appliances, share of gas in energy use, value of output in sectors which use gas as feedstock, and other variables. However, the methodology itself is considered to be sufficiently robust and able to provide meaningful results. The methodology is implemented in e-format (as an xls) file) and those who wish to assess UCMs with its help may do so by varying the inputs according the particular circumstances which they face.

The approach is mathematically simple, does not require sophisticated software and estimation techniques and is thus practical and easily reproducible. Finally, the recommended approach was assessed positively by the public acceptability criterion, as the survey respondents found the proposed approach generally acceptable.

FINDINGS

Natural gas-as-fuel

UCM values by sector for EU-26 are shown in Table 3. As Cyprus and Malta do not have access to natural gas, neither country is included in the list.

Our analysis yields an EU-26 average residential sector UCM value of 96€/MWh. Estimates are in the lowest range of 60-70 €/MWh for Bulgaria, Hungary, the Czech Republic, the Netherlands and Sweden and in the highest range of 140-160 €/MWh for Germany, Belgium and Denmark. Residential sector UCM values are generally directly correlated to the GDP of the country, meaning that richer Member States tend to show higher UCM values. Other parameters such as the price difference between the alternative fuel and natural gas and the capital cost of the alternative appliances in each Member State also have an influence on the UCM values.

For the services sector, the UCM EU-26 average value is estimated to be of the order of 80-90 €/MWh. Bulgaria, the Czech Republic, Lithuania, the Netherlands and Sweden are in the lowest range of 40-60 €/MWh. Denmark, Italy, Spain, Germany, Belgium, the United Kingdom and Ireland are in the highest range with UCM values from 100 to 145 €/MWh.

For the industrial sector, the EU-26 average fuel UCM is at 45 €/MWh. Values in the lowest range (30-40 €/MWh) were calculated for Sweden, Finland, Estonia, Lithuania, Bulgaria, Romania, Poland, Slovenia, Hungary, Czech Republic, Austria and Luxembourg. Values in the highest range (60-75 €/MWh) were calculated for Italy, Portugal, Germany and the United Kingdom.

For the power sector, the EU-26 average UCM is calculated at 60 €/MWh. Lithuania, Latvia and Estonia are in the lowest range of 40-50 €/MWh, while Portugal, Finland, the Netherlands, Sweden and Denmark are in the highest range of 70-90 €/MWh.

Table 3: Natural gas-as-fuel: UCM Values at Sector levels per MS [€/MWh]

MS	Residential	Services (P)	Services (NP)	Industrial	Power
Austria	82	75	71	38	51
Belgium	147	136	127	53	52
Bulgaria	62	53	53	37	59
Croatia	76	68	65	47	66
Czech Republic	64	57	54	30	53
Denmark	157	145	133	53	87
Estonia	71	61	61	34	47
Finland	80	71	66	30	75
France	75	68	64	48	62
Germany	146	140	127	73	60
Greece	104	97	94	50	58
Hungary	70	63	65	33	57
Ireland	118	107	98	57	58
Italy	119	109	105	70	57
Latvia	91	81	77	51	48
Lithuania	84	68	56	36	50
Luxembourg	107	95	82	34	57
Netherlands	62	52	51	44	75
Poland	83	74	66	38	54
Portugal	105	94	90	60	72
Romania	84	74	70	33	56
Slovakia	118	96	87	56	63
Slovenia	87	77	72	38	65
Spain	111	102	94	45	51
Sweden	66	44	41	36	80
United Kingdom	118	107	101	60	52
EU-26 average value	**96**	**85**	**80**	**45**	**60**

MS	Residential	Services (P)	Services (NP)	Industrial	Power
EU-26 min value	62 (NL)	44 (SE)	41 (SE)	30 (FI)	47 (EE)
EU-26 max value	157 (DK)	145 (DK)	133 (DK)	73 (DE)	87 (DK)

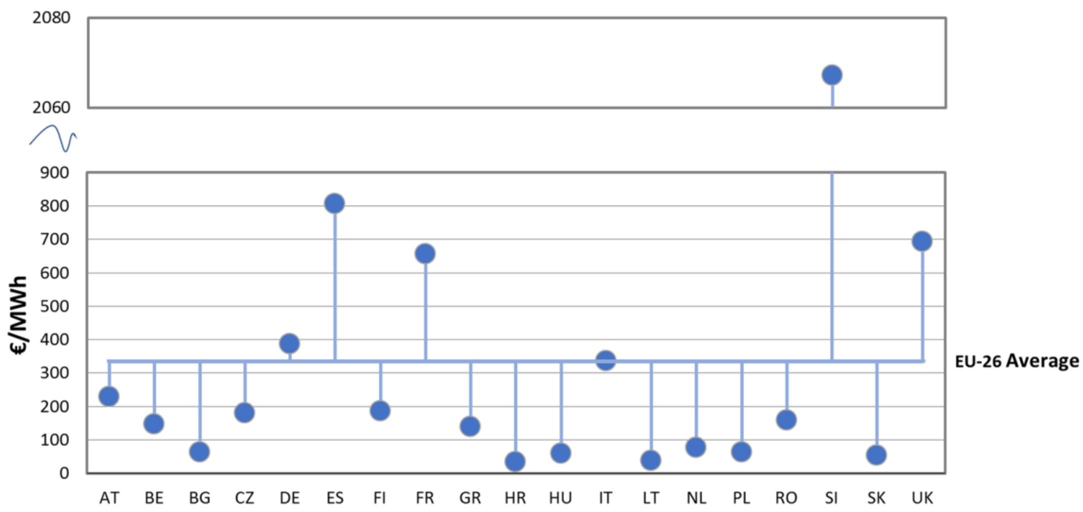
Natural gas-as-feedstock

The EU-26 average feedstock UCM value was estimated at 336 €/MWh[1].

Lithuania, Croatia, Bulgaria, Poland, Slovakia, Hungary and the Netherlands are in the lowest range with values from 35 to 100 €/MWh. Feedstock UCM values of 650 to 810 €/MWh were calculated for Spain, France and the United Kingdom.

Slovenia is an outlier with a value exceeding 2000 €/MWh. For all remaining countries UCM values are in the range 140-390 €/MWh (Figure 2).

Figure 2: Industrial Sector (Gas as a feedstock) – Member State level UCM_{MS}^{CP}



Findings from the Modified Hypothetical Cost Approach

Questionnaires were made available on-line for a period of approximately 5 weeks. Unfortunately, participation was rather limited. Twenty-six (26) responses from 9 MS were received for the questionnaire targeting the residential sector. Almost no responses were received for the services sector. Forty-eight (48) respondents from 18 MS completed the industrial/power sector questionnaire.

Despite the limited participation, responses to the survey confirmed:

[1] Average reported herein is based on the average of 19 countries with Chemical-Petrochemical industry. The remaining countries have no chemical/petrochemical industry and thus have no gas consumption for non-energy use.

- Increased natural gas consumption of the residential sector from October to March mainly due to heating requirements impacts the UCM value.

  Within the day, gas consumption peaks from 06:00 to 10:00 and from 16:00 and 23:00, Monday to Friday. Proposed CoDG values for the residential sector ranged from 100 to 1100 €/MWh. Participants did not respond to questions in relation to early warning and curtailment levels.

- Increased consumption of the power sector from October to March potentially to meet increased residential demand impacts the UCM value.

  Within the day, gas consumption peaks from 06:00 to 10:00, Monday to Friday. Proposed CoDG values ranged from 70 to 530 €/MWh. The majority of respondents indicated that they do not have fuel switching capabilities. For those with dual firing equipment, light oil is used as alternative to natural gas. Storage capacity of light oil is of the order of 1-5 days of operation at full load. The operating cost per annum for maintaining fuel switching facilities (not including the cost of the alternative fuel) is of the order of, or less than 5-10% of the overall OPEX of the facility. The additional operating cost for replacing alternative fuel fired during a planned maintenance is of the order of 5-15%. In the absence of dual-fuel burners, a disruption in the gas supply naturally leads to a complete halt of production, regardless of early warning. Curtailments of the order of 30-70% were acknowledged to lead to almost proportional reductions in electricity produced, regardless of early warning.

- A reduced consumption for the industrial sector in August impacts the UCM.

  Respondents indicated a stable gas consumption from 06:00 to 23:00 Monday to Friday. Proposed CoDG values, for gas as fuel, ranged from 10 to 770 €/MWh. Proposed CoDG values for gas as feedstock reached a maximum of approximate 2500 €/MWh. Participants acknowledged substantial reductions in production (over 90%), regardless of the level of curtailment and despite early warning.

We note that the findings summarised above should be treated with caution due to the limited sample size, and also due to geographical bias (more than 50% of responses came from 1-2 MS).

In addition to the online survey, a number of interviews were held with participants from the European industrial and power sectors.

Interviewees agreed that:

- With the exception of East/South East Europe, customers in the EU have enjoyed natural gas supply without significant interruptions for over a decade. The low likelihood of disruptions of gas supply accounts for the fact that there are very few systematic studies and estimates of CoDG.
- Regulatory frameworks attempting to set the CoDG value should be simple and transparent.
- The growing interdependence between the gas and electricity sectors and markets in Europe makes the exercise of estimating the cost of gas disruption more complex.

- The solidarity price of gas supplied during a disruption under Regulation (EU) 2017/1938 is not identical to the CoDG value, as the CoDG looks at the potential cost of damages caused by the absence of gas or the cost of measures needed to ensure that no damage is incurred, while Regulation (EU) 2017/1938 looks at the price of emergency gas supplies. In this context, CoDG is better suited for assessments by using, for example, the cost-benefit analysis (CBA) methodology as applicable to projects listed in the EU-wide 10-year network development plan (TYNDP) or to projects of common interest (PCI). Furthermore, the price under Regulation (EU) 2017/1938 is related to a comparatively short-term incident, while assessing the CoDG values is related to long-term planning and risk management. In all cases, considering the value of CoDG for practical purposes should not interfere with market functioning and should not be substituted for scarcity values in case of a tense gas supply and demand balance.

Interviewees also noted that detailed estimates of the CoDG by sector and country may not be possible. Instead, CoDG estimates may be reported in terms of orders of magnitude rather than defined with a precision down to €1. It was also noted that CoDG values for protected consumers should be in line with the underlying rationale for protecting these consumers. It was argued that this inherently implies that disruption cost estimates for protected customers should be higher than the respective estimates of non-protected customers.

CODG proposals

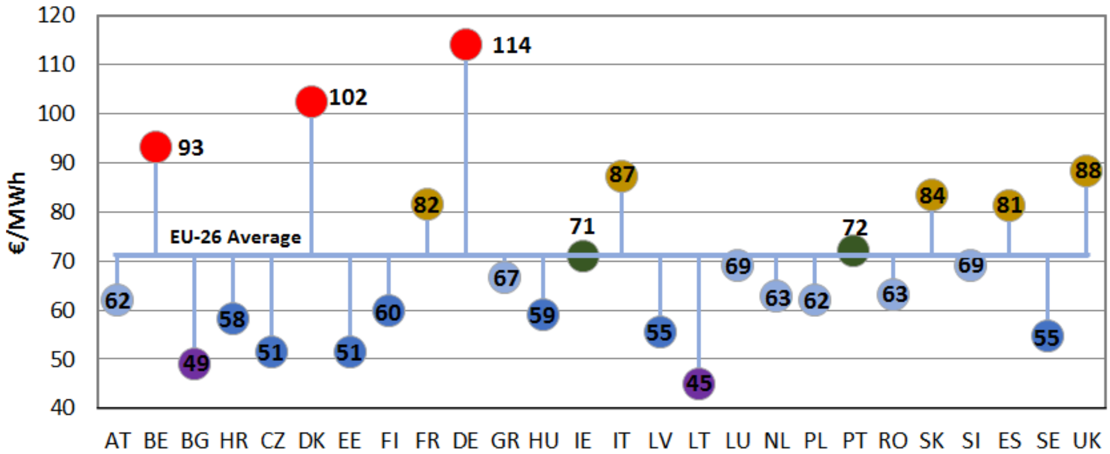
A cross-sectoral UCM value per Member State is finally estimated by taking into account the fuel-specific UCM by sector and the feedstock-specific UCM for the chemical/petrochemical subsectors, Figure 3.

Estimates are:

- In the lowest range of just below 50 €/MWh for Bulgaria and Lithuania.
- Between 50 and 60 €/MWh for the Sweden, Estonia, Croatia, Czech Republic, Hungary, Finland and Latvia
- Between 61 and 70 €/MWh for Austria, Greece, Luxembourg, the Netherlands, Poland, Romania and Slovenia
- Between 71 and 80 €/MWh for Ireland and Portugal
- Between 81 and 90 €/MWh for France, Italy, Slovakia, Spain and the UK
- Between 91 and 114 €/MWh for Belgium (93 €/MWh), Denmark (102 €/MWh) and Germany (114 €/MWh).

The UCM values reported herein may be used as CoDG proxies.

Figure 3 Proposed CoDG values calculated through their UCM proxies at Member State level [€/MWh]

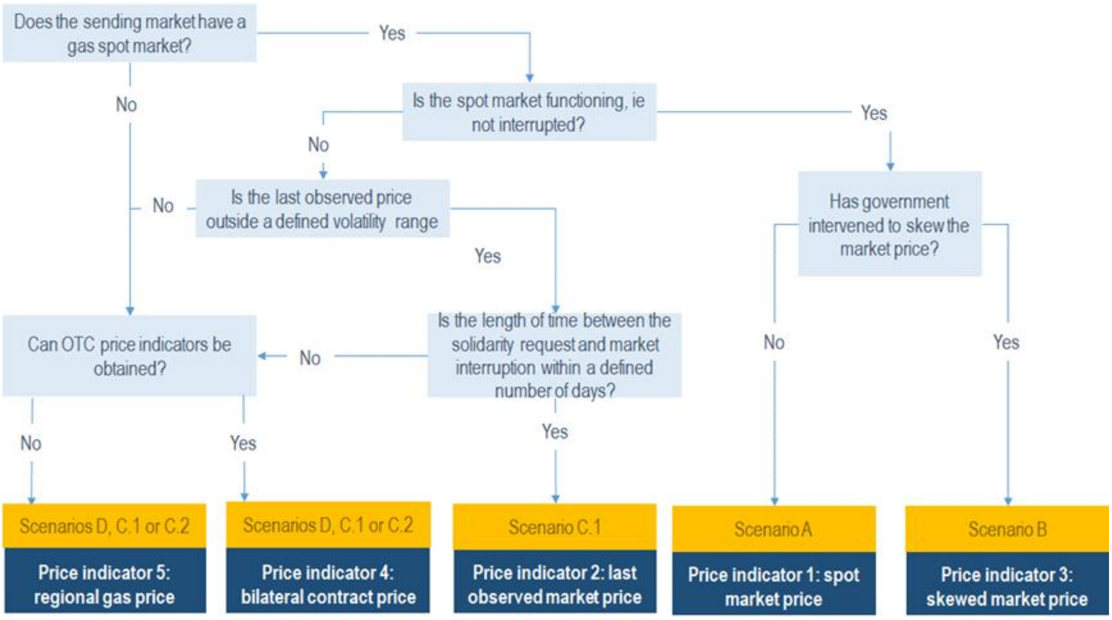


Regarding the potential use of CoDG values as an input to a possible methodology for solidarity gas pricing, we note that_as per the European Commission guidance, solidarity gas prices should be reflective of market conditions. Ideally, this means that the price is determined through a competitive market in the solidarity provider Member State (SP-MS), rather than via CoDG values. However, country-specific factors and circumstances related to the supply disruption may make it difficult to observe gas prices at the time of the solidarity gas request. A variety of different price indicators can be taken as proxies for a competitive spot market.

We reiterate that CoDG values cannot be taken as direct indicator of potential solidarity gas prices, as CoDG refers to cost or damages which users in different sectors may incur when gas supply is cut off, and not to gas prices. However, CoDG values can be considered in the context of elaborating risk management and infrastructure planning strategies, as well as, in a broader sense, when the issue of pricing solidarity gas is at stake. As part of this study, possible ideas have been developed with the general objective to provide Member States with background information that could be applied to select the best proxy for solidarity gas pricing that (i) maintains flexibility to be applied across a range of situations, (ii) can be easily and quickly applied and (iii) is in line with basic economic principles.

A 'decision tree' shown in Figure 4 presents alternative options for pricing gas under different conditions. The indicators attempt to get as close to an accurate market price as possible. In the best-case scenario, the sending country spot market price is available, but it may be that a recent value, before spot market suspension, or a skewed value, due to government intervention, can be used. If neither of these are applicable, bilateral contract prices can be used (if shared). Since these are not public information, we also suggest ranking the relevance of neighbouring markets, to provide a last resort solidarity gas price indicator.

Figure 4: Decision tree presenting alternative options for the pricing gas



Applying this reasoning during solidarity gas contract negotiations may help Member State's think through eventualities in advance, thereby reducing potential uncertainty in pricing solidarity gas agreements at the time of the request. The principles could also be applied during solidarity gas request, as and when circumstances of a prolonged disruption change.

In addition to the cost of gas, other additional cost factors need to be considered. Transport costs should not differ between solidarity and other gas supplies and many of the administrative costs of the TSO should be considered sunk; these do not require a separate charging methodology. Where strategic storage has been released for solidarity gas supplies, it should be replaced as soon as possible, such that it does not matter whether the receiving or sending member state replaces it. Questions remain around the legality of the interruption and the level of compensation given to non-protected customers, so supplier contracts may need a solidarity clause in future.

Overall conclusions

The methodology proposed in this study for the estimation of a unit cost measure (UCM) as a proxy to the cost of a gas disruption is transparent, straightforward and does not discriminate between sectors and Member States. By applying the proposed methodology, a first attempt to determine CoDG values at pan-European level was made. Given that our analysis represents a first attempt in several areas, we consider that our findings would benefit from possible adjustments and refinements through further research.

In addition to the CoDG estimates, the study provides insight to the use of CoDG values as input to a possible methodology for solidarity gas pricing.

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Abbreviations

Acronyms & Abbreviations	
A/C	Air Conditioner
ACER	Agency for the Cooperation of Energy Regulators
ARERA	the Italian Regulatory Authority for Energy, Networks and Environment
AT	Austria
BE	Belgium
BEIS	Department for Business, Energy and Industrial Strategy
BG	Bulgaria
CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CBCA	Cross Border Cost Allocation
CC	Combined-Cycle
CCGT	Combined Cycle Gas Turbines
CEGH	Central European Gas Hub
CEPA	Cambridge Economic Policy Associates
CERA	Cyprus Energy Regulatory Authority
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CoDG	Cost of Disrupted Gas
CRE	French Energy Regulatory Commission
CZ	Czech Republic
DE	Germany
DK	Denmark
DM	Daily Metered
DRS	Demand Reduction Schedules
DSM	Demand-side management
DSO	Distribution System Operator
DSR	Demand Side Response
E	Emergency
ECA	Economic Consulting Associates
ED	Education
EE	Estonia
EIB	European Investment Bank

Acronyms & Abbreviations	
ENTSOG	European Network of Transmission System Operators for Gas
ES	Spain
ESC	Essential Social Care
EU	European Union
FI	Finland
FID	Final Investment Decision
FR	France
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GR	Greece
GVA	Gross Value Added
H	Healthcare
HFO	Heavy fuel oil
HR	Croatia
HU	Hungary
I&C	Industrial and Commercial
IE	Ireland
IEA	International Energy Agency
IP	Interconnection Point
IRR	Internal Rate of Return
IT	Italy
KMC	Kantor Management Consultants
LFO	Light Fuel Oil
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LT	Lithuania
LU	Luxembourg
LV	Latvia
MHC	Modified Hypothetical Cost
MS	Member State
MTBE	Methyl Tert-Butyl Ether
NBP	National Balancing Point
NDM	Non-Daily Metered
NL	Netherlands
NP	Non-Protected
NRA	National Regulatory Authority
OCGT	Open Cycle Gas Turbines

Acronyms & Abbreviations	
Ofgem	Office of Gas and Electricity Markets (Great Britain)
OPEX	Operating Expenses
P	Protected
PA	Public Administration
PL	Poland
PSOs	Public Service Obligations
PT	Portugal
RAA	Representative Alternative Appliance
RAE	the Greek Regulatory Authority for Energy
REWS	Regulator for Energy & Water Services (Malta)
RO	Romania
S	Security
SAP	System Average Price
SBU	Standard Bundled Unit
SE	Sweden
SI	Slovenia
SK	Slovakia
SMEs	Small and medium-sized enterprises
SoS	Security of Supply
SP-MS	Solidarity provider Member State
SR-MS	the Member State receiving the solidarity
TL	Time-Life
TSO	Transmission System Operator
TTF	Title Transfer Facility
TYNDP	Ten-Year Network Development Plan
UCM	Unit Cost Measure
UK	United Kingdom
VAT	Value Added Tax
VDC	Voluntary Disruption Contract
VoLL	Value of Lost Load
WTA	Willingness to Accept
WTP	Willingness to Pay
ZEE	Belgian Zeebrugge Beach

1 Introduction

KANTOR MANAGEMENT CONSULTANTS (KMC, GR) and Economic Consulting Associates (ECA, UK) were commissioned by the Agency for the Cooperation of Energy Regulators (ACER) to conduct a study on the estimation on the cost of disruption of gas supply in Europe.

This is the first time in the literature that a consistent methodology for estimates of CoDG covering all consumer types and all European Member States (MS) is developed and presented.

1.1 Background to the Study

ENTSOG has quantified the monetary impact of a disruption in the context of the Cost-Benefit Analysis methodology (CBA) and in the Ten-Year Network Development plan (TYNDP) of 2017 by considering a uniform Value of Lost Load (VoLL) for all EU28 Member States. The VoLL is fixed at EUR 600/MWh for the complete time horizon of the project and corresponds to a division of the total EU28 GDP by the gross inland gas consumption in EU28.

In the current (2017-2018) review of the CBA methodology[2], ENTSOG acknowledges that "*while a standardized EU-level VoLL ensures comparability and harmonised assessment of projects, some feedbacks suggest that different values on a country/consumer basis could be considered for the VoLL*".

ACER, in its Opinion No. 15 of 24 October 2017, stresses that projects may provide benefits by mitigating possible demand curtailment and that once volumes of gas supply potentially saved from disruptions are quantified, it is possible to monetise such overall benefits by multiplying those volumes by a unit of value (Euro/MWh). However, the Agency notes that the presentation of the benefit should be:

- *improved* by distinguishing the disrupted demand under normal conditions and the one under stress
- *simplified* by directly presenting the positive benefit of avoided disrupted demand and
- *enhanced* by presenting, for information purposes, the probability of occurrence of disruptions (e.g. in hours per year) and the amount of avoided disrupted gas demand (in energy units)

ACER recommended to ENTSOG to define the Cost of Disruption of gas supply (CoDG) by country and categories of consumers, taking into account available studies and studies which may become available during the adaptation period of the CBA methodology.

In addition, the new Security of Supply Regulation, (EU) 2017/1938 aims to ensure that all necessary measures are taken to safeguard an uninterrupted gas supply to

[2] 2nd ENTSOG methodology for cost-benefit analysis of gas infrastructure projects, draft for ACER and Commission opinions of 24 July 2017, available at: https://www.entsog.eu/public/uploads/files/publications/CBA/2017/INV0256_170724_Draft%202nd%20CBA%20Methodology.pdf

protected customers throughout the Union, in the event of difficult climatic conditions or disruptions of the gas supply. The Regulation stresses that this objective should be achieved through the most cost-effective measures and in such a way that gas markets are not distorted. The Regulation also translates the concept of solidarity into practice and establishes a solidarity mechanism between interconnected Member States. The European Commission, in its 2 February 2018 Recommendation (Commission Recommendation (EU) 2018/177) stresses that the solidarity mechanism is a last resort measure to ensure the flow of gas to those that are the most vulnerable.

Solidarity under the Regulation is provided on the basis of compensation which should cover at least (Article 13, par. 8 of Regulation (EU) 2017/1938):

a) The gas delivered into the territory of the requesting Member State
b) All other relevant and reasonable costs incurred when providing solidarity including where appropriate costs of such measures that may have been established in advance.
c) Reimbursement for any compensation resulting from judicial proceedings, arbitration proceedings or similar proceedings and settlements involving the Member State providing the solidarity vis-à-vis entities providing the solidarity.

In the context of the concerns noted above, this study aims to improve the existing methodology regarding the monetisation of the CoDG per Member State and type of consumer, taking into consideration the possibility of varying value patterns according to the level of involuntary curtailment (1-100%) for industrial consumers, the duration of the involuntary curtailment or disruption, and the way in which a prior notice (e.g. 24 hours ahead of the disruption) may impact the cost of disruption. In addition, this study aims to provide methodological insights for the calculation of the compensation provided when solidarity is invoked by a Member State and provided by another Member State pursuant to the revised SoS Regulation.

In the remaining of this Section, we provide further details on the scope of this study, discuss challenges towards achieving the study objectives, highlight our approach and present the structure of this report.

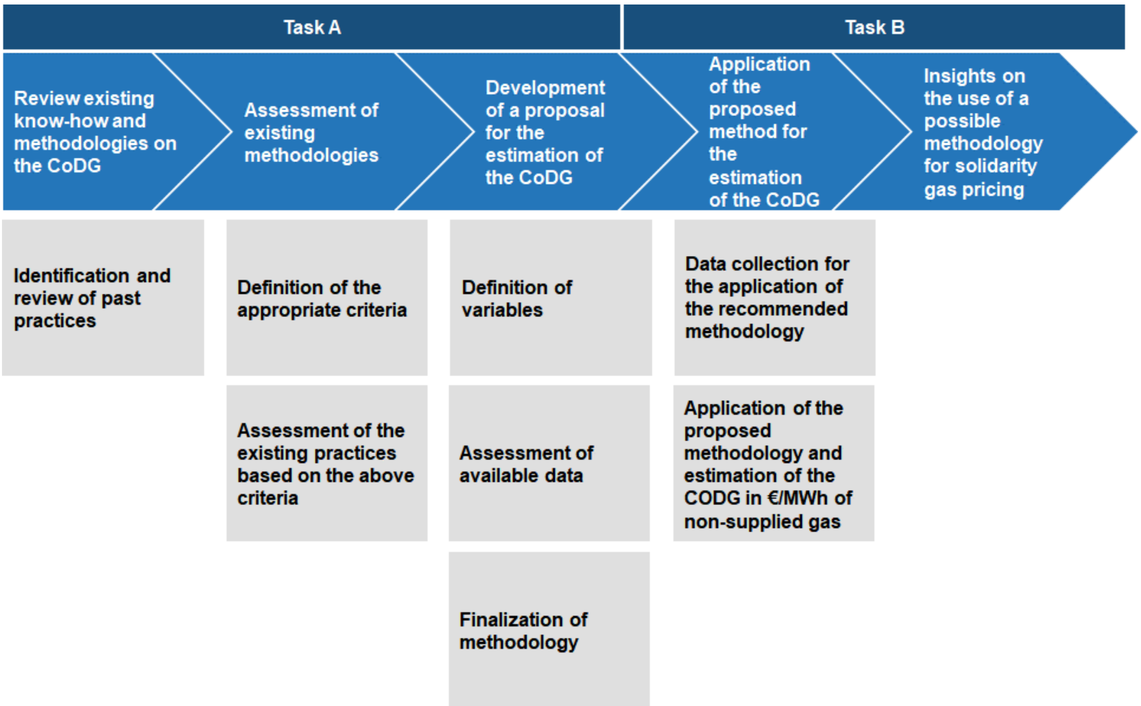
1.2 Our approach

Our work on the CoDG estimation was grouped in two distinct tasks and elementary activities as shown in Figure 5:

Task A: Review and assess existing methods for the valuation of security of gas supply and recommend a method to estimate the value of CoDG.

Task B: Apply the recommended method by using publicly available data to estimate the value of CoDG.

Figure 5: Tasks and activities undertaken in the context of the Study



1.3 The structure of this report

This report is structured as follows:

Chapter 2 includes a detailed review and assessment of **existing practices and approaches**, their key parameters and input data requirements. In addition, it presents findings from a survey addressed to National Regulatory Authorities (NRAs) aiming mainly to collect information on existing practices towards the estimation of CoDG values of any.

Chapter 3 presents the proposed **methodology for the estimation of the CoDG.** It also presents an outline of the data sources used for this estimation, which included a **survey to gas consumers**.

Chapter 4 presents the output of Task B, that is the cost estimates obtained from applying the methodology of Chapter 3. Alongside the figures on the **unit cost measure** of gas supply disruption per member state and gas use, the chapter includes **findings** from **interviews** with industrial and power sectors stakeholders and the gas consumer **survey**.

The **methodological insights** on estimating the **solidarity gas price** are discussed in **Chapter 5.**

The study concludes with **Chapter 6,** which consolidates the findings of the previous chapters and formulates final proposals and key messages.

2 Review and assessment of existing practices and scientific approaches for the calculation of the CoDG

To identify the scientific approaches used to monetize the value of security of supply, we reviewed the literature indicated in the Study Terms of Reference as well as a number of additional studies referred therein. In addition, we performed a more extensive literature search, using the academic reference management tool Mendeley. We also carried out a survey addressed to the National Regulatory Authorities (NRAs) to identify current practices to estimate CoDG in the EU.

2.1 Literature on CoDG estimation

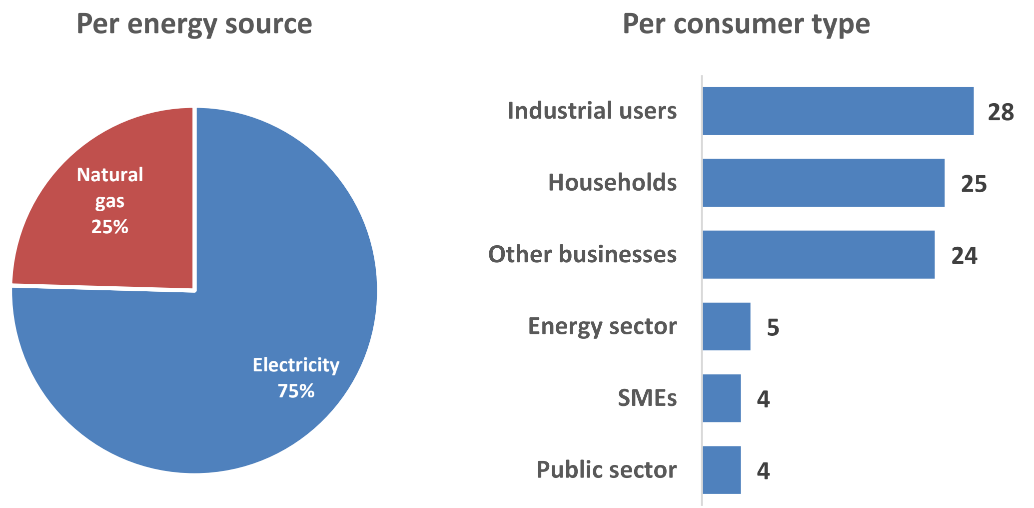
We identified a set of 34 reports, academic publications and working papers that applied approaches to estimate the value of security of supply.[3] Given that often the studies used more than one approach, we identified and reviewed 58 approaches (instances) towards the estimation of the cost of a disruption.

Out of these instances, about 75% concerned estimation of the value of lost load (VoLL) from a disruption in electricity supply, with the remaining 25% pertaining to natural gas supply interruption (Figure 6). This composition reflects the fact that the attempt to monetize the value of security of supply originates from electricity sector planning literature and is less developed in the gas sector.

Note that there are fundamental differences between electricity and gas, both in terms of physics and use. Indicatively, natural gas can be stored whereas storage in electricity remains an uncommon practice. Furthermore, natural gas is a primary energy source used to produce electricity and thermal energy, with fewer applications to the final users compared to electricity (e.g. space and water heating, cooking). Therefore, an approach that pertains to estimating electricity VoLL might not be relevant for natural gas. This was taken into account in the assessment of different approaches below.

[3] A detailed list of the reviewed studies is provided in the Bibliography in Appendix 26 Bibliographic references.

Figure 6: Composition of reviewed instances of past estimation approaches



The approaches also differ with respect to the consumer type or sector they were applied upon. About 44% of the identified cases (24 out of 58) concerned industrial users and other business sectors, with four more concerning industrial users alone. An almost equal share of approaches was found to address the VoLL or CoDG of household users. Significantly fewer cases (4) looked into SMEs as a discreet user category. Five studies looked specifically into the cost of disruption in the energy sector (gas-fired power plants, gas distribution companies, etc.). Finally, four studies also addressed the fact that there might be a loss of tax revenue for the public sector from an energy supply disruption.

The next subsection provides a detailed presentation of the scientific approaches identified in the literature review.

2.2 Identified scientific approaches

Past practices and scientific approaches of quantifying the value of disrupted energy supply can be grouped in three categories corresponding to the underlying concept they try to monetize (Figure 7).

C**ost-function** approaches aim at estimating the monetary cost of measures taken to mitigate or adapt to a supply disruption.

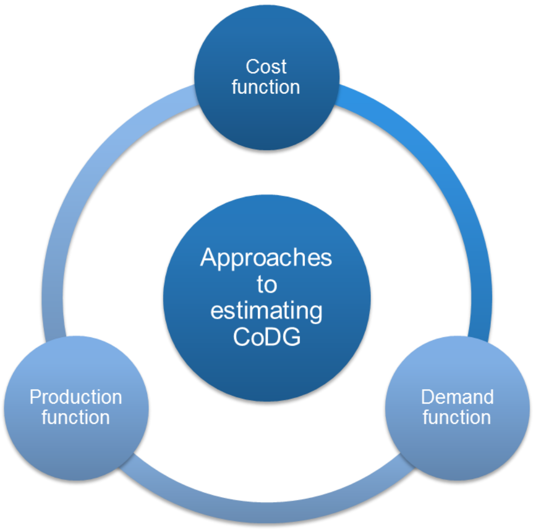
Demand-function approaches reflect the idea that the consumers derive a welfare surplus, which is lost when there is a disruption of supply.

Finally, the **production-function** category contains approaches that quantify the loss of revenue from the interruption of production in case of disruption.

Instances of the above approaches per category are presented in more detail in the remaining part of this section.

We note that the cost approaches may seem more relevant for the CoDG estimates and also for the estimation of the solidarity price for customers that can change to another fuel if gas delivers in their country are diverted to another country. On the other hand, demand and production function approaches, which look into the loss of welfare and revenue from the interruption, are more suited for the residential and industrial sector respectively, when fuel switching is not feasible. It is thus clear that the selection of appropriate methodology for the evaluation of disruption costs, can well depend on sector (such as industrial, residential or services) and type of use (such as feedstock or fuel).

Figure 7: Categories of past approaches to estimating CoDG

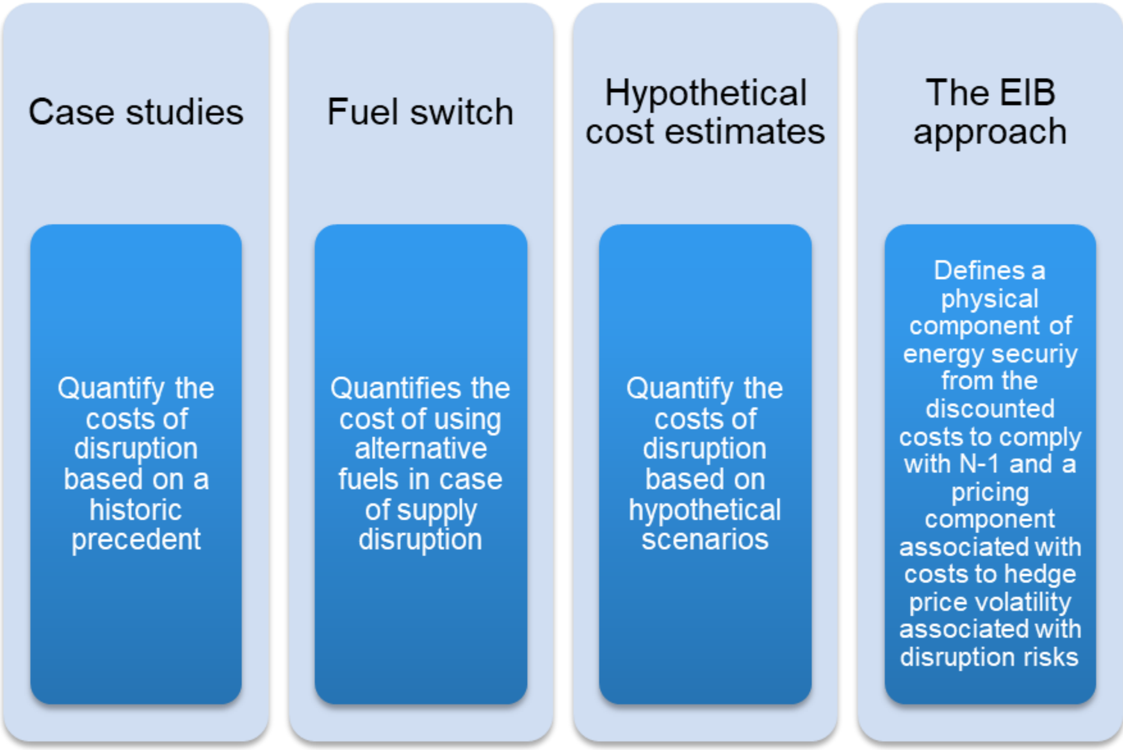


2.2.1 Cost-function approaches

The cost-function approaches aim to quantify the cost of measures that can be taken to mitigate or adapt to an energy supply disruption.

These approaches may be based on historic precedents of a supply disruption, in which case they use actual costs incurred in the past, or use hypothetical cost estimates, provided through consumer surveys, desk research on fuel costs or from more sophisticated economic modelling techniques, as the approach developed by researchers of the European Investment Bank (Figure 8).

Figure 8: Cost-function approaches



2.2.1.1 Case studies

We identified three Case Studies that use historical supply disruption precedents to quantify the cost of disruption.[4] Corwin & Miles (1977) is a seminal, frequently quoted, study that collected estimates from secondary sources on various costs that occurred to businesses, electricity generation companies and the public sector, because of severe electricity network failures in the city of New York in the 1970s.

Serra & Fierro (1997) looked at the actual cost that industrial users of electricity incurred in Chile in 1989 and 1990, when a severe draught led to the need to curtail the supply of electricity by 10% for approximately 45 days. The study collected data on actual costs of the users, together with cost estimates under hypothetical curtailment scenarios.[5]

Following a major incident in a military base in the island of Cyprus which resulted in the loss of a substantial part of the island's electricity generation capacity, Zachariadis & Poullikkas (2012) looked into the costs incurred. To meet demand, the incumbent

[4] More details on the reviewed studies and their key findings are presented in Appendix 1 Examples of current approaches to estimating CoDG and VoLL and Appendix 2 VoLL and CoDG estimates from the literature respectively.

[5] The results from this study are discussed in more detail in the subsection on the hypothetical cost estimates.

utility hired emergency capacity. The rental cost led to a substantially higher cost of electricity generation. [6]

While the case-studies approach provides the most direct estimation of the cost of energy supply disruption, its major shortfall is that its results are hard to generalise to a degree that would enable their use in a comprehensive CBA methodology. This problem is exacerbated by the fact that the cost incurred by consumers reflects the particular circumstances of each incident. Note that all three studies presented herein were focused on outages solely in the electricity sector.

Despite its shortcomings as indicated above, the Case Studies approach can be proven useful if actual data, from gas supply disruptions in the EU over the last decade can be collected (i.e. estimates of the cost of gas supply disruptions in EU MS over the Russian-Ukrainian crisis incidents in 2006, 2009 and 2012). Such figures, if collected, can provide a useful ground for the validation of any proposed CoDG methodology. Naturally, such comparisons need to be treated with caution as costs can be very circumstance-dependent, as outlined above.

2.2.1.2 Fuel switch

This cost-function approach relates to the estimation of the cost of alternative solutions employed to address supply disruptions. We identified one such example (Mandelli, Brivio, Colombo, & Merlo, 2016), which looked at the potential cost that off-grid electricity consumers can incur when the intermittent supply from renewable energy sources fails to cover demand. The study looked into the cost of alternative fuels (such as diesel and kerosene) and services (e.g. mobile charging) to arrive at estimates of VoLL (€/kWh) for different back-up energy supply solutions (diesel generator, kerosene lamps and recharging mobile service).

The method has notable advantages as its application is straightforward and transparent. It takes into account the additional capital cost for purchasing alternative equipment, the operational cost related to the maintenance of the alternative equipment and the additional cost of purchasing the alternative fuel (minus the cost of the fuel substituted).

It is worth noting that fuel switching is one of the demand side measures named in Annex VIII of Regulation 2017/1938 to be taken into account by the competent authority of the Member State in the development of the preventive and emergency action plans.

An example of the use of the alternative fuel cost estimate in practice can be found in the case of Greece. Following the Russian-Ukrainian disputes which resulted in substantial disruptions of pipeline gas, the Greek regulator RAE developed a compensation mechanism for gas-fired power plants with fuel-switching capabilities (switch to diesel oil in case of emergency). The compensation received by each plant

[6] The paper provides only a qualitative description of the additional costs incurred, stating that "these emergency measures posed a substantial economic burden on the state-owned utility company; to tackle its liquidity problems the company received state aid, and the national energy regulator allowed the utility to increase its retail electricity prices in order to account for the higher generating costs—but this happened many months after the accident." Nevertheless Zachariadis & Poullikkas (2012) employed also other methods to derive a cost of the disruption (e.g. based on lost welfare and production function), which are presented in the corresponding sub-sections below.

that can burn diesel oil in case of disruption in natural gas supply is equal to the capital cost of installing a fuel switching equipment (e.g. gas turbine with duel fuel capabilities) estimated from 1200 to 1988 euros/MW/annum depending on the installation date of the CCGT unit (with lower values corresponding to units installed before 2005). The capital cost of maintaining diesel oil reserves was estimated to be equal to the sum of: (a) the value 87,55€/klt of fuel stored per annum (e.g. cost incurred due to the installation of storage tanks), and (b) the price difference between diesel oil and natural gas multiplied by the amount of fuel used during regular maintenance of the fuel switching installations. In all calculations an internal rate of return (IRR) of 8.5% and a lifetime of 25 years was assumed.

As a second measure, RAE introduced the concept of an "Interruptible Consumer" and urged industrial gas consumers to conclude an annual voluntary disruption contract (VDC) with their Supplier. In the case of a Level 2 crisis (Alert Level as per Annex VII of Regulation (EU) 2007/1938), Interruptible Customers who have signed such a VDC undertake an obligation to at least reduce their demand for natural gas within six (6) hours to no more than forty (40%) of their daily peak demand at any time. Should the crisis continue for a prolonged period of time, these customers maintain reduced gas consumption levels of a period of up to 30 days per annum. The compensation of the industrial users for every MWh of non-received gas, following a decision of the Greek Regulator RAE, is equal to 10 euros/MWh. The cost is calculated by considering the following. A standard combined cycle power plant is operated daily for 16 hours at maximum load and 8 hours at minimum load. In case of emergency as defined above it is anticipated that the plant will only operate 16 hours daily resulting in a reduction of the gas consumption of about 4200 MWh (GCV). The cost of switching on and off the combined cycle is estimated of the order of 20,000 to 40,000 euros. Taking the maximum value (of 40,000 euros) and dividing by 4200 MWh, an amount of the order of 10 euros/MWh is calculated.

2.2.1.3 Hypothetical cost estimates

One more alternative within the broader cost-function category is to quantify the potential cost of energy supply disruption by asking consumers about their estimates of this cost under a number of hypothetical scenarios. Sometimes, this approach is grouped with demand-function approaches, which also rely on surveys to collect the necessary data, such as contingent valuation, contingent ranking and choice experiment approaches, reviewed further below. Naturally this approach can be largely subjective, lacking both a concrete methodology and a scientific base.

The difference between the hypothetical-cost and demand-function approaches (e.g. contingent valuation) lies in the underlying concept consumers are asked to quantify. Here, the consumers are asked to provide estimates on various expenses they would incur in case of an energy supply disruption. In the contingent valuation approach, reviewed below, survey participants are asked to provide an estimate of a compensation they would accept in case of a disruption.

We identified seven studies that employ the hypothetical cost estimate (Table 53). Again, however, with the exception of a single study looking into gas supply disruptions the rest are focused on electricity.

A prominent example is the study carried out by Serra & Fierro (1997). The paper includes detailed estimates of the outage cost in the industrial sector – obtained mostly through interviews carried out with power-restricted parties. The average outage cost per unit of energy at the firm level was estimated by adding up seven cost items (such as changes in uses of production factors, inventory variations, capital costs of purchased equipment and welfare costs), divided by the amount of energy not supplied. The sector level estimates were obtained as an average of the average outage costs of the firms in each sector, weighted by their volume of purchased electricity. The outage cost for the total of Chilean industry was then estimated for 10%, 20% and 30% restrictions, assuming that the sector with the lowest outage cost are the first to have their supply restricted, thus setting the cost for the whole industry. The exercise was carried out for restrictions lasting one, two and ten months, with the results shown in Table 64 in the Appendix 2. It is worth noting the cost dependency to capacity restriction is highly non-linear. Capacity restriction from 10 to 20% results in an increase in the outage cost of about 60%. With a further increase from 20 to 30%, the cost increases by over 200%.

The method has been used for both household and business consumers, large enterprises and SMEs, in industry and services. One notable strength of this approach is its capacity to provide estimates along many dimensions and at significant level of granularity. Its major shortfall is that it relies on surveys, which may require substantial resources. For example, Kim & Cho (2017) collected survey responses from 430 companies, with broad geographical and sectoral coverage within the Republic of Korea. Compared with other survey-based methods, the hypothetical-cost approach has the advantage that it aims at quantifying an objective magnitude, thus it is ideal for techniques such as the Delphi method, which relies on structured questionnaires and answers from expert panels, rather than large-scale surveys.

2.2.1.4 The EIB approach (Paoli, Sacco, & Pochettino, 2010)

The final approach under the cost-function category that we identified and reviewed relates to a number of papers, developed by researchers associated with the European Investment Bank (EIB). The EIB approach aims to evaluate the security of energy supply externalities as part of the economic analysis of energy projects. Such analysis involves the appraisal of the project contribution to the economic welfare of a region or country, assessing whether the project improves, worsens, or does not affect the initial level of security of supply.

The methodology considers that the value of uninterrupted supply of gas is the sum of two components – physical and pricing:

$$\textit{External cost} = \textit{Physical availability component} + \textit{Price increase component}$$

The physical component is quantified by taking the discounted costs of measures to comply with the N-1 standard of energy security (as for example N-1 is defined in Regulation (EU) 2017/1938). This calculation relies on estimating the levelised cost of the least cost backup solution, divided by the present value of total energy supplied by the examined project. The pricing component reflects the cost to hedge against the price volatility associated with risks of gas supply interruptions. The calculation involves estimating GDP loss, as a function of price changes introduced by the project. The GDP loss function feeds into an estimation of expected welfare loss with and without risk aversion. This calculation is supplemented by estimating the risk premium on call options, as a hedging instrument to price changes resulting from disruption, with the use of the Black-Scholes formula.

In addition, the EIB study proposes two alternative methods for estimating the price risk component. The first method utilises estimates, data and assumptions on the risk premium, gas imports and price elasticity of gas demand to compute acceptable monetary surcharge on imported gas, paid to hedge against price increases. The second method sets a cap on GDP loss, derives the corresponding maximum acceptable price change and evaluates the cost of a call option that ensures gas prices do not exceed the maximum gas price level.

The key strength of this approach, which however can also be seen as a weakness in a non-academic setting, is its strong routing in economic theory and finance. Apart from the high level of sophistication, which can hamper the acceptability of this approach for a wider audience and make it less suitable in practice, another major weakness is its inflexibility to provide CoDG figures per various dimensions and levels of granularity.

2.2.2 Demand-function approaches

The demand-function approaches aim to quantify consumer welfare losses from energy supply disruptions. They are less intuitively appealing, as they are based on the economic theory concept of utility or welfare.

The key idea here is that the value the consumers receive, in terms of utility or satisfaction, when they buy a good exceeds or at worst equals the price that they pay for that good. This is proven by the fact that when the price of a good increases, the demand for it in principle falls. This implies that the consumers that buy the good under the new higher price value that good by more than the old lower price and thus were enjoying a surplus before the price change.

Generalising this result, we can think of the area below the demand function and above the price level for the equilibrium quantity of a good sold in the market as a measure of the welfare or the surplus that the consumers receive for that good (Figure 9). When the supply of gas is interrupted, the consumers can no longer enjoy that surplus. The methods presented here attempt to monetise this aspect of the supply disruption cost.

Figure 9: Illustration of the consumer surplus concept

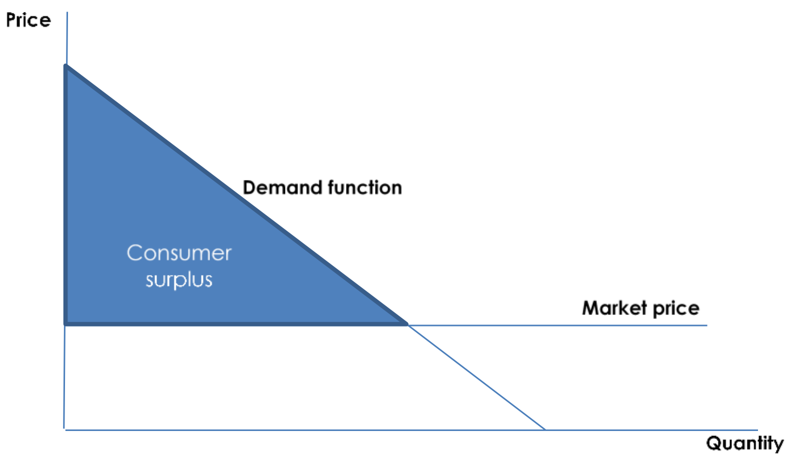
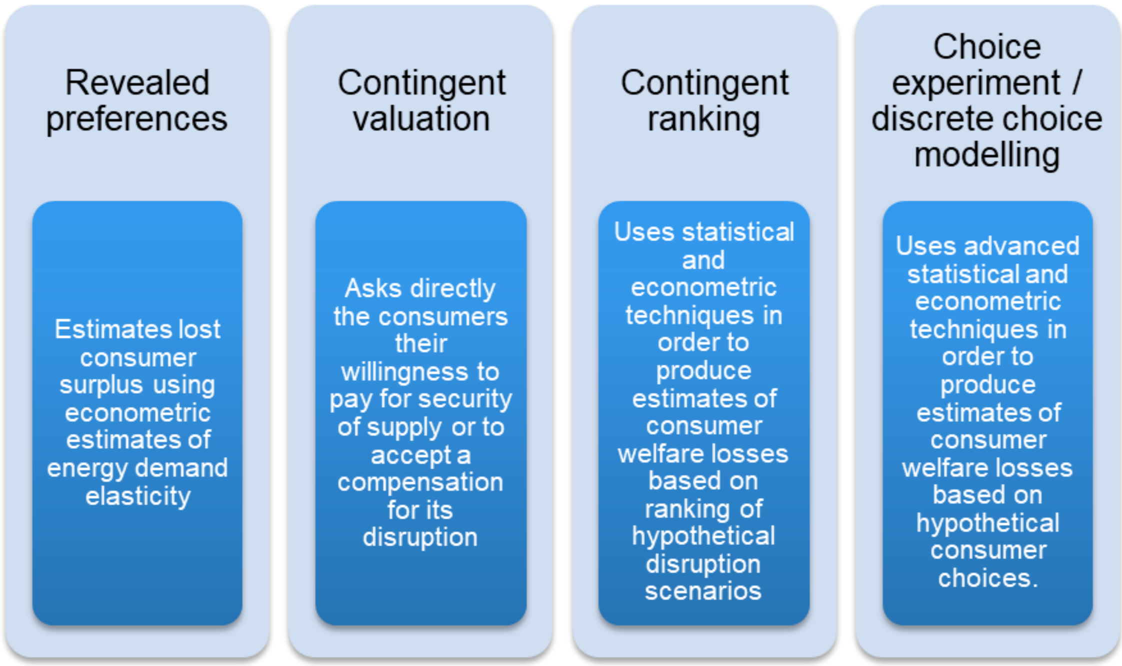


Figure 10: Demand-function approaches



We identified four approaches under this category (Figure 10). The key difference between them lies in the type of data that they use. In particular, the revealed preference approach is based on market data of prices and quantities, in order to construct the demand function for the studied energy sources and thus measure the consumer surplus. The remaining three approaches rely on survey techniques, extracting data on the consumers' willingness to pay to avoid a supply disruption or willingness to accept a compensation in case such a disruption occurs.

2.2.2.1 Revealed preferences

The revealed preferences approach constructs the demand curve for natural gas or electricity, using time series data on market prices and quantities and other variables that could affect the demand for these energy commodities. We identified four studies that followed this approach.

Two of these studies calculated the demand function with econometric methods and time series data (Serra & Fierro, 1997; Zachariadis & Poullikkas, 2012). In contrast, Leahy, Devitt, Lyons, & Tol (2012) used demand elasticities from other studies in order to construct the demand curve and estimate the corresponding consumer welfare loss and associated cost of supply disruption. Finally, the report of DNV KEMA, REKK, & EIHP (2013) relied on an energy model that had already incorporated demand function parameters to arrive at CoDG estimates.

The key appeal of this approach, compared to the other demand-function approaches, is that it relies on observed market behaviour, rather than stated preferences, which may be subjective and subjected to various cognitive biases. In addition, it might be less resource-intensive, as it does not require the conduct of surveys, however it might require data that is not publicly available or readily accessible. In addition, this approach allows for a certain degree of granularity, yet this is limited by the requirement that there should be sufficient data available to enable the introduction of other dimensions in the estimated demand function.

In addition, the market data on energy demand might not reflect well the value of the security of its supply, which is an attribute that is rarely absent. In other words, it might be argued that the security of supply is a separate good from the energy commodity itself. The proper market for it would be an insurance contract or a financial product (such as an option or a forward contract) to cover the risk of energy supply disruption, rather than the market of electricity or gas itself.

2.2.2.2 Contingent valuation

To overcome the criticism that security of supply is an attribute that is not necessarily priced in the energy market, while at the same time addressing the fact that there are not that many insurance or financial products that could provide market data to quantify that attribute, a number of studies ask directly the consumers their reserved price for this attribute. The simplest method is to ask how much the consumers are willing to pay to secure their energy supply (Willingness-to-pay or WTP) or how much they are willing to accept as a compensation in case that their supply is indeed disrupted (Willingness-to-accept or WTA).

We identified six studies that employ contingent valuation in order to obtain estimates of the WTP or WTA of consumers in the security of energy supply context (Table 55 in the Appendix 1). While this technique is primarily aimed at quantifying the attributes of preferences of final consumers, in three of the six reviewed studies, it was also used to obtain estimates for businesses.

Compared to the revealed preferences approach, the contingent valuation studies have the drawback that they require the execution of consumer surveys, which may be resource intensive. Another important drawback is that the estimates from contingent valuation studies might be unreliable due to cognitive biases. An indicative result is that often the estimates differ substantially, depending on whether the question is framed in terms of WTP or WTA (London Economics, 2011), largely due to the cognitive anomaly known as the "endowment effect" – the respondents feeling that security of supply is their endowment, thus they are unwilling to pay for it, while they demand significant compensation for its disruption.

2.2.2.3 Contingent ranking

There are several more sophisticated techniques developed in the literature to overcome the cognitive biases inherent in the contingent valuation approach. Under the contingent ranking approach, the respondents are presented with a set of options, which they are asked to rank according to their preferences (Willis & Garrod, 1997). A variant of this is to ask the consumer to mark, rather than rank, the various options (Hesseling & Sari, 2006), which has the added benefit that it also captures the intensity of preference between the different options.

This approach has a significant degree of flexibility with respect to possible differentiation of the estimates along other dimensions, such as duration of interruption, time of day, seasonality, etc. These dimensions are included as attributes along which the various options are differentiated, alongside the financial attribute.

A major drawback of this approach is the substantially higher sample size that it requires in order to arrive at a meaningful set of estimates, given that any given respondent has the capacity to rank or mark a limited number of options. For example, Hesseling & Sari (2006) employ estimates from a survey of more than 12,000 households and 2,500 small businesses, whereas Carlsson, Martinsson, & Akay (2011) implemented contingent valuation survey on 3000 individuals. In addition, the choice of options and the processing of the answers involves the use of sophisticated statistical techniques and tools, which limits the practicality of this approach.

2.2.2.4 Choice experiment / discrete choice modelling

Choice experiments or discrete choice modelling are approaches similar to the contingent ranking aiming to overcome the drawbacks of contingent valuation studies and arrive at more robust WTP or WTA estimates. Compared with the contingent ranking approach, the discrete choice modelling technique differs in that it asks the respondents to make a choice between two options.

Some studies incorporate the financial attribute as one of the dimensions along which the options in each pair differ. In other studies, the choice is between a supply disruption scenario, which does not have a financial attribute, and a monetary sum (usually in the WTA form of a compensation).

We identified six studies in the literature that follow this approach (Table 56). As in the contingent ranking or marking case, this approach can support several dimensions, with satisfactory level of granularity. It also suffers from the drawback of requiring large samples and employing sophisticated statistical techniques that limits its practicality for a broader use.

More broadly, the demand-function approaches suffer from the lack of intuitive appeal that the consumer welfare concept has among non-economists, which reduces its public acceptability. In addition, its reliance on reports of preferences gives it an air of subjectivity, which also hampers its broader acceptability.

Figure 11: Production-function approaches

GDP-at-risk
- Quantifies the reduction of GDP from energy supply disruption

GVA-at-risk
- Quantifies the direct GVA loss per unit of energy consumption.

Adjusted GVA-at-risk
- Identifies the extent to which production might be lost due to energy supply disruption in each sector, based on considerations such as fuel-switching possibilities, spare production capacity and storage capabilities

GVA-at-risk + Input-output
- Identifies upstream and downstream sectors that would most likely be affected by the interruption of production in the energy-consuming sectors

Producer surplus
- Quantifies the difference between the forgone revenue and the cost of energy supply

Real options
- Takes into account the possibility that the operators might choose not to produce when gross profit is negative.

Tax-at-risk
- Quantifies the direct tax revenue loss per unit of energy consumption.

Leisure-at-risk
- Quantifies the monetary value of leisure lost due to interruption of the supply of energy

2.2.3 Production-function approaches

The third and final set of approaches quantify the value of production at risk of loss from energy supply disruptions. While the terms ‘production’ and ‘risk’ are often used in relation to these approaches, we should clarify that neither physical units of production (e.g. tons of steel) nor the probability of disruption feature in the estimation process. The key idea here is that the lack of energy translates into a disruption of the production process and thus a loss of production value.

We identified eight approaches that fall under this category. The approaches defer with respect to the consumer type that they deal with. As discussed in the next session, production-function approaches are best suited for production processes where natural gas is used as a feedstock.

2.2.3.1 GDP-at-risk

The GDP-at-risk approach does not differentiate across different consumer types, as it quantifies the cost of energy supply disruption in terms of the loss of GDP at country level. We found two instances where this approach was used – one for electricity and one for natural gas (Table 57).

A key characteristic of this approach is its simplicity. It derives an estimate of CoDG or VoLL by dividing the GDP of a country with the annual volume of natural gas or electricity consumption respectively. The underlying assumption is that GDP is a linear function of energy consumption, thus a disruption of energy supply has a proportional impact on how much GDP is generated in the economy.

The simplicity of the approach allows for a straightforward calculation with very limited need for data and resources. At the same time, the simplicity implies that there is very limited room for taking into account the differentiation that the impact of energy disruption might have on its consumers, depending on factors such as season, time of day, consumer type, etc.

As stated in the Introduction, the ENTSOG approach yielding the value of 600 euros/MWh currently used in the CBA assessments and the TYNDP 2017 is based on a simple GDP-at-risk calculation. The value is computed from the ratio of the EU28 GDP to the overall gas consumption.

2.2.3.2 GVA-at-risk

The GVA-at-risk approach goes one step further than the simple GDP-at-risk. It considers the fact that the impact of an energy disruption differs across the various sectors in the economy, depending on the intensity of their energy use. In this approach, the cost of disruption is calculated by sector by dividing the Gross Value Added (GVA) produced by each sector to the gas consumption by sector.

We identified nine studies in the literature that employ this method (Table 58 in the Appendix 1). Some of these studies have introduced dimensions other than the sector of economic activity by taking into account additional parameters (such as time of day and day of week, based on hourly energy load profiles).

Compared with the GDP-at-risk approach, this method allows for a deeper granularity, while maintaining low input data requirements. Input data in most part is publicly available. The main criticism against the simple GVA-at-risk approach is that it does not take into account differences in the criticality of energy supply across the economic sectors. The highest estimates of CoDG is calculated in sectors that use the least amount of energy per unit of output, such as Construction, even though often the production processes in these sectors do not depend so strongly on the uninterrupted supply of energy.

2.2.3.3 Adjusted GVA-at-risk

Although the simple GVA-at-risk approach provides a solid, transparent and simple methodology for estimating the cost of electricity of gas disruption in the various sectors of the economy, it fails to respond to the fundamental question of "How critical the supply of electricity or natural gas actually is to a specific sector?" as discussed in Section 2.2.3.2. Consider Sector A with a certain GVA and a low gas consumption and

Sector B with the same GVA but a higher gas consumption. The simple methodology of the GVA-at-risk yields that the cost of disruption is higher in Sector A than Sector B. This however may not be necessarily true. To overcome this deficiency of the simple GVA-at-risk, a number of studies introduce additional empirical coefficients with values from zero to unity into the CoDG formula. These coefficients are quantified by taking into account fuel-switching possibilities, spare production capacity and storage capabilities of the production processes in each sector. We identified three such studies in the literature (Table 59 in the Appendix 1).

This approach corrects a substantial weakness of the simple GVA-at-risk method. This comes at the cost of having to establish how critical an energy source is for the production processes of each sector, which may require resources to conduct primary research.

2.2.3.4 GVA-at-risk + Input-output

Another GVA-at-risk based approach takes into account also the interdependencies that exist across the sectors in an economy. Given that each sector uses inputs from other sectors in its production process, while it also provides outputs to other sectors, the interruption of production in one sector has knock-on effects in other sectors.

We found two examples of this approach (Table 60 in the Appendix 1). ILEX (2006) uses input-output data to identify sectors along the supply chain of gas consuming manufacturing sectors that could be affected by a gas supply disruption. Once these sectors are identified, their GVA could be partly at risk from a gas supply disruption, even though they themselves may not even consume natural gas.

Praktiknjo (2016) employs input-output techniques to identify downstream sectors that might be affected from the disruption of electricity supply. The underlying idea is that if an energy-intensive sector, such as metal manufacturing, ceases its production, this would also disrupt the production of a sector that uses its products, such as just-in-time automobile manufacturing.

This method allows for an additional aspect of natural gas disruptions to be taken into account: the chain-reaction effect from a disruption in one sector affecting anther sector. Its implementation is comparatively straightforward as it relies on the use of input-output tables, which are readily available for EU Member States. The main drawback of its application is the fact that it is difficult to make a reliable estimate of intermediate storing levels or stocking inventories. If these are not taken into account, or accounted for but underestimated, substantial overestimation of the CoDG for the upstream and downstream sectors of a natural gas consuming process may occur.

2.2.3.5 Producer surplus

The GVA-at-risk approach and its variants presented above are applicable to all the sectors of economic activity, without any substantial differentiation for specific sectors. A number of methods are developed to supplement this approach, taking into account specific consideration of other parts of the economy.

The producer surplus approach, employed by Leahy et al. (2012) quantifies the CoDG of natural gas suppliers as the difference between the forgone revenue and the cost of energy supply. This approach requires data on retail and wholesale prices of gas, together with data on the volumes of sold gas. If the data has a sufficiently low frequency (e.g. per hour in a year), it can provide differentiated estimates per duration of disruption, day of the week, time of the day, season, etc. It is a straightforward method that is easily applied and has a high degree of accessibility, yet its scope is very limited (natural gas suppliers) and it relies on data that might not be readily available.

2.2.3.6 Real options

The real options approach is another example that addresses the particularities of a particular segment of the energy sector. In particular, it examines the lost revenue for gas-fired power generation plants from the disruption of gas supply, taking into consideration the variability of electricity prices and the fact that the plants would not operate under conditions of a negative spark spread (London Economics, 2011). In other words, during baseload hours, when the demand for electricity is low, the gas-fired plants might choose not to operate irrespective of whether gas is available or not. Not taking this into account, results in an overestimation of the CoDG for power producers.

This approach uses data on daily prices of electricity and natural gas, together with technical characteristics of each power generation plant (such as thermal efficiency, starting cost, stopping cost per plant), which are not readily available. It also employs real option pricing techniques from the field of Finance to quantify CoDG, which reduces its wider practicality.

2.2.3.7 Tax-at-risk

When there is a loss of production value, apart from the producers, another agent that loses revenue is public administration. We identified two studies that address this issue (Table 61 in the Appendix 1). This approach is quite similar to the GDP-at-risk, with the difference that it uses tax revenues in the formula's numerator, instead of GDP.

Apart from the excessive simplicity of the approach, another important drawback is the possibility that it might lead to double counting and overestimation of an aggregate CoDG. The GVA that the economic sectors lose in case of an energy supply disruption is not a measure of their loss in terms of net earnings, as GVA also includes public revenue in terms of taxes and social security contributions. Thus, adding tax losses to estimates of GVA losses would count the tax losses twice. Therefore, this method can be seen as redundant in cases when the scope of the estimation is not focused on the effect on public revenues per se.

2.2.3.8 Leisure-at-risk

Finally, production-function approaches have also been applied, somewhat counterintuitively, to domestic electricity consumers. This is justified by the economic idea that the households can be modelled as units consuming energy and other goods and services as inputs in order to produce labour and leisure as outputs. When the supply of energy is interrupted, the household can no longer "produce" goods such as watching TV, reading books after sunset and other leisurely activities that are valuable for the households and thus for the economy at large.

To quantify this value, the leisure-at-risk approach assumes that the households allocate their time between labour and leisure in an optimal way, which implies that an hour of leisure that they enjoy has the same value for them as an hour of labour that they provide. Under this assumption, the leisure-at-risk studies quantify the cost of lost leisure due to energy supply interruption from statistics on the labour cost per hour, together with data on time allocation of households and energy consumption.

We identified eight studies in the reviewed literature that employ this approach in order to quantify the VoLL of electricity (Table 62 in the Appendix 1). While this approach is based on publicly available data, it depends strongly on theoretical assumptions and considerations that reduce its public accessibility. More importantly, in the context of this work, this approach is not that suitable for the quantification of the cost of natural gas supply disruptions, given that natural gas in the household is not used to provide energy for leisure activities.

2.2.4 CoDG estimates found in the literature

The application of the above approaches has resulted in a wide range of estimates of VoLL and CoDG.

In the case of electricity, VoLL estimates in certain cases exceed 20,000 EUR/MWh, Figure 12. Most of these values are derived by applying GVA-at-risk and input-output approaches to sectors with high value added and low electricity consumption, such as construction and financial services.

The CoDG estimates on natural gas have a more limited range, Figure 13. Most CoDG estimates (about 80%) fall below the 600 EUR/MWh value adopted by ENTSOG, yet a few estimates reach up to 1000 EUR/MWh. It is worth to note that although we identified a total of 35 estimates of CoDG, these were drawn from only 2 studies[7]. Thirty-one estimates were calculated with an adjusted GVA method which successfully removes outliers in sectors such as construction of high GVA value and low natural gas consumption. The remaining 4 estimates were derived with a combination of a GVA + Input-output method, Appendix 1. There the lack of high estimates may be attributed to the high level of aggregation (no subsectors).

Overall, in both VoLL and CoDG estimates, the variance in the estimates points to the importance of taking into account differences across countries and sectors of economic activity. Such differences tend to explain most of the observed variability.

Some of the variance also comes from other granularity elements, such as duration and level of curtailment, but also from the year when they were estimated and from the application of different estimation approaches to the same problem.

[7] London Economics (2011), ILEX (2006) see Appendices 1 and 2.

Figure 12: Histograms of VoLL and CoDG estimates from the reviewed studies

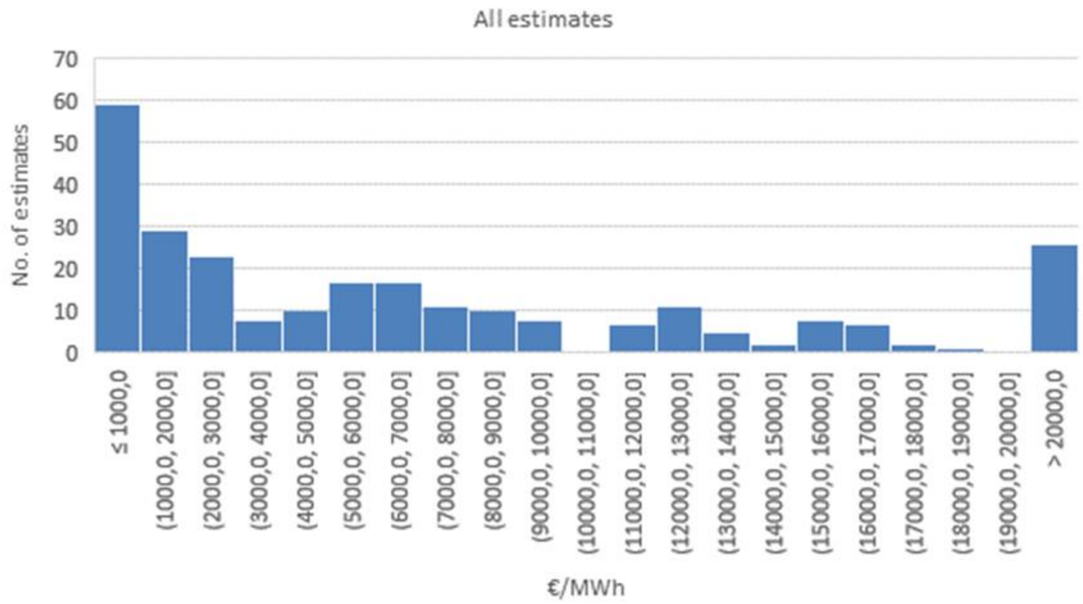
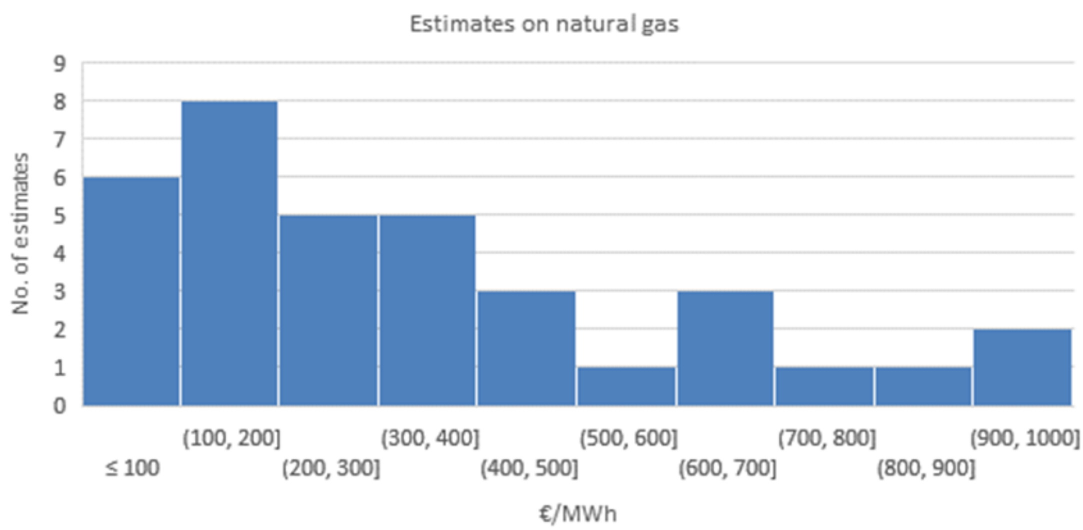


Figure 13: Histograms of CoDG estimates from the reviewed studies



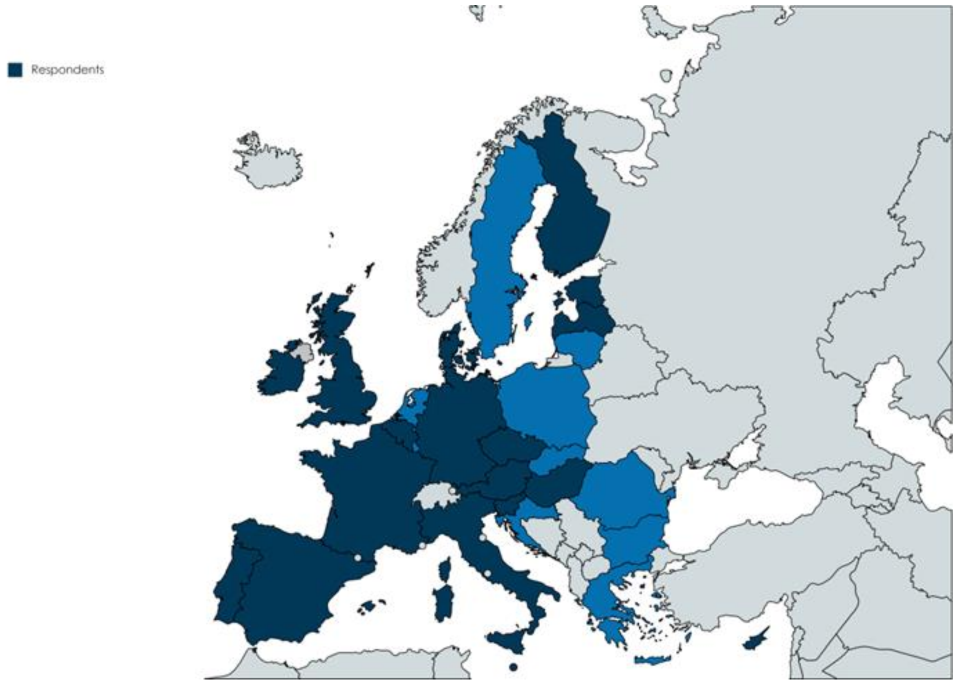
2.3 Review of existing practices to address natural gas disruptions in the EU Member States.

This section reports on the results of a survey addressed to the NRAs with an aim to look into more detail into:

- Gas supply disruptions experienced by MS in the past and their implications (including cost estimates where available) and
- Existing measures (including demand side management and compensation mechanisms) already in place.

The purpose of the survey was to provide a baseline of currently available and applicable approaches in the EU on dealing with the disruption of gas supply.

Figure 14: Geographical coverage of NRA responses



Eighteen (18) NRAs responded to the survey, including the regulators of Cyprus (CERA) and Malta (REWS). Neither of these two countries have yet access to natural gas. Their responses are not considered further in this Chapter.

The main findings from the survey are summarised below.[8]

NRAs as Competent authorities for security of Gas Supply	**3 NRAs** responded that they are competent authorities for Security of Gas Supply according to Regulation 2017/1938. The remaining NRAs (81%) informed that competent authorities are other governmental bodies (e.g. a Minister). It is thus acknowledged that NRAs may

[8] The survey questionnaire, the main responses per country and additional information provided by the NRAs in the survey are included in the

Appendix 27 NRA Survey.

not have always been the best placed authorities to provide the detailed information requested.

CoDG methodology and CoDG values	**1 NRA** (Ofgem-GB) responded positively to the question "*Is there a methodology for calculating the cost of gas disruption (CoDG) in your country?*". A uniform CoDG value of approx. 549 [€/MWh] is applicable for all non-daily metered customers (e.g. residential consumers)
Voluntary gas demand reduction schedules (DRS) and compensation levels	**Almost half of the respondents (7/16)** acknowledged the existence of a voluntary gas demand reduction schedule (DRS) in their countries. Three out of 7 NRAs informed that gas consumers participating in a DRS receive compensation. It is understood that the DRS, when applied, is market based. Values of DSR compensations were not provided.
Fuel switching obligations for gas-fired power producers and compensation levels	**Almost half of the respondents (7/16)** acknowledged the existence of a fuel switching obligation for gas-fired power producers. One NRA responded positively on the existence of a compensation scheme for maintaining alternative fuel in storage. Compensation levels were not provided.
Supplier and strategic storage obligations and compensation levels	**Almost half of the respondents (7/16)** informed that suppliers of protected customers have storage obligations and that obligations for strategic storage exist in their countries. In 2 countries, the suppliers are compensated for the cost of maintaining SoS gas in storage. One NRA (CRE-FR) informed that consumers that participate in a DRS mechanism do not pay the dedicated storage tariff fee included in the Gas Transmission Tariff (297,1 €/MWh/d/y). Another NRA (LT) indicated that storage obligations are funded through the transmission tariffs. Compensation levels were not provided.
Security of supply levy to fund SoS actions.	**Three NRAs** responded positively to the question "Is there a security of supply levy imposed on gas customers to fund security of supply actions (e.g. emergency actions in the case of disruption) in your country. No information on the actual value of such a levy was provided.

The eSurvey addressed to the NRAs confirmed initial understanding that methodologies related to the estimation of the Cost of Disruption of Gas supply are in general not available amongst the Member States. With the exception of the UK, all other respondents to the questionnaire acknowledged that such methodologies (and related values) do not exist at national level.

Voluntary demand response measures have been recognised as a key mechanism to address disruptions before administrative measures such as the solidarity mechanism of Article 13 of Regulation (EU) 2017/1938 are invoked. Nevertheless, less than half the NRA that participated in the study (7 out of 16) commented that such mechanisms are in place with only 3 acknowledging the existence of a compensation. It is understood that such mechanisms where they exist are in their majority market based.

Less than half of the NRAs that responded to the Questionnaire (7 out of 16) confirmed the existence of alternative fuel obligations for power plants in their counties. Compensation however is provided only in one case (IE).

It is noted that only 3 out of 16 NRAs are competent authorities for security of supply in their countries. Thus further, more detailed information if needed should be sourced from the respective competent authorities.

2.4 Assessment of the methods for the calculation of the CoDG

2.4.1 Definition of assessment criteria

The previous sections provided a review of the various practices and scientific approaches to quantify the cost of disruption. Here we aim to evaluate the various approaches with a view to select those that are most suitable to form the base of our methodology.

The criteria developed here aim to take into account the particular scope of the present study. For example, it would be useful for the new methodology to take into account a number of parameters that differentiate the CoDG. In this context, one criterion that we used in our assessment is the capability of the approaches to accommodate a form of granularity.

Most of the studies reviewed previously dealt with electricity disruptions. On many occasions, regardless of the study topic (electricity rather than gas), the methodology is also applicable to the case of natural gas (for example, all approaches that are based on surveys, fuel switch, GVA at risk). There are cases, however, where the applicability of a particular method to natural gas may be limited for a number of reasons. We also took this aspect into account when developing the assessment criteria.

Finally, it is important to note that the new methodology is meant for practical application by energy regulators and other public institutions, in a set-up requiring the widest possible understanding and acceptability of the adopted approaches by all stakeholders. Thus, a special consideration should be given to data availability, estimation practicality, conceptual acceptability and also simplicity and transparency.

In light of the considerations outlined above, we assess here the various approaches reviewed previously along the lines of the following criteria:

- **Granularity:** the new methodology will have to be able to differentiate the CoDG along several dimensions, such as:
    - Geography (member states)

    - Sectors and consumer types (households, small commercial outlets, SMEs, industrial clients, heavy industries, power generation plants)
    - Duration of disruption (hours, days, weeks)
    - Timing of disruption (e.g. day, night)
    - Seasonality (e.g. winter, summer)
    - Curtailment level
    - Prior notice
- **Applicability to natural gas disruptions:** some approaches (e.g. leisure-at-risk) are designed with particular electricity uses in mind and are not suitable in natural gas settings
- **Data availability, accessibility, homogeneity and robustness:** ideally all required data should stem from a single reliable data base, e.g. Eurostat and if any additional data are required, these should also be derived from reliable and transparent, preferably publicly available, sources. It is noted that in parallel to this work, ACER runs a second study focusing on the estimation of the cost of electricity supply disruptions (hereinafter "VoLL Electricity Study" or VoLL ES) and that the methodologies from both studies should be compatible – to the extent possible - so that they can be used in the revised CBA methodology. We understand compatibility to also refer to alignment of input data (same assumptions, data drawn from the same databases e.g. Eurostat of the same year). Thus, by this criterion we indirectly also assess the potential of alignment between the two models concerning common input datasets.
- **Estimation practicality and replicability:** academic sophistication is not the aim of this study – the approaches that do not require sophisticated software and estimation techniques are ceteris paribus preferable in the context of this work.
- **Public acceptability:** some of the approaches are simple in their execution, yet their underlying justification relies on economic theory concepts that might be hard to justify to all stakeholders, thus conceptual appeal should also receive a credit in the approach assessment and selection. The methodology should be easily and equally understandable by regulators, policy makers, stakeholders and the general public.

We also note that cost estimates (VoLL and CoDG values) should be expressed in the same units (e.g. euros/ MWh) so that they can be easily added if necessary. In most of the studies we have reviewed above, the cost estimates were either directly provided in monetary form per unit of energy or it was easy to obtain such estimates from the information included in the publication. We thus chose not to add an additional criterion in our assessment to reflect the units of the CoDG as this would have no practical meaning in terms of assessing the relative merits of the various approaches.

2.4.2 Performance of the existing practices in view of the assessment criteria

In this section, we assess the existing practices of estimating the cost of disruption in view of the assessment criteria outlined above. We assess separately the approaches per category, as each one addresses an aspect of CoDG and thus the approaches are not all directly comparable to each other. For example, the cost-function approaches look into the quantification of measures to mitigate or adapt to the disruption whereas the demand function approaches aim to quantify consumer welfare losses. In an essence, complementarity amongst approaches from the different categories is also identifiable.

Thus, the purpose of this assessment exercise is not to establish an overall ranking of approaches, based on their absolute merits and disadvantages, or select a single, best, universally applicable, approach.

Instead, we assess the approaches, highlighting their relative strengths and weaknesses, with a view to identify a set of approaches that are most suitable for the estimation of the various aspects of CoDG within the context of this study.

As this is not a ranking exercise, the assessment criteria are not weighted in terms of their importance.

To summarise our assessment in a visual form we have developed Table 4, Table 5 and Table 6. In the Tables, a form of qualitative scoring (from a triple-minus to a triple-plus) has been adopted to highlight the applicability (or non-applicability) of each method to the relative criterion. These is no overall score for each approach.

2.4.3 Discussion on the suitability of cost-function approaches

This section discusses the suitability of the cost-function approach regarding the criteria defined above. Table 4 is a visual summary of the discussion.

Granularity	*In terms of potential granularity, the hypothetical cost approach is the most promising (*Table 53*), as it relies on surveys to collect the required data. This allows for flexibility in the survey design to cover sufficiently the granularity requirements of the CoDG estimation.* *The fuel-switch approach, which attempts to estimate CoDG based on available cost data of alternatives to gas use, also allows for some degree of granularity, depending on the extent of variability of the underlying data. For example, given that electricity prices differ across Member-States and time of day (in constituencies that have night-tariff option), the CoDG estimates based for example on electricity as a substitute to gas could correspondingly differentiate from one MS to another, according to a diurnal pattern and per consumer category as typically electricity tariffs differ for example between industries and households. That said, the granularity of this approach is set by data availability.* *The Case Studies approach has a very limited degree of granularity. CoDG is calculated for incidents of supply disruption. The estimates are specific to the circumstances of each case, although in principle if sufficient number of Case Studies are available, their results can be combined to arrive at estimates of some granularity.* *The EIB approach has also limited granularity. Calculations allow only for country dependence.*
Applicability to natural gas disruptions	*The fuel-switch approach is well suited to quantify the cost of disruptions. Alternatives to natural gas per use (e.g. electricity for space heating, electricity for cooking and water heating, light fuel oil for electricity generation) are easily identifiable and their*

	capital and operational cost can be used for the estimation of CoDG. *The remaining cost-function approaches are also applicable to natural gas disruptions and have already been used or can easily be adapted to account for natural gas.*
Data availability, accessibility, homogeneity and robustness	*To a large extent, the fuel-switch approach relies on publicly available data, such as the cost of alternative energy sources (e.g. electricity), which can be found in Eurostat. Published data on typical equipment costs are generally available although scattered in multiple sources (e.g. manufacturer websites) and can be country dependent.* *Case studies often rely on data from secondary sources, which may not be readily available. In addition, we did not manage to identify Case Studies on interrupted gas supply, and thus consider the overall data availability for this approach as scarce.* *The hypothetical cost approach is also challenging, as it relies on surveys as its main data source.* *Data availability in the EIB approach is also limited. Some data needed as input (e.g. the risk aversion of consumers) are not directly obtainable and are often substituted with assumptions.*
Estimation practicality and replicability	*The fuel-switch approach does not involve sophisticated estimation techniques. Estimates are practical and can be easily replicated.* *In the hypothetical cost approach, replicability can be limited by the need to update the estimates periodically through surveys. That said, over a medium-term horizon, when the pace of technological change is reasonable, the estimates can be updated through indexing with publicly available cost data (e.g. using publicly available data on the components of the Consumer Price Index). Over a longer-term horizon (e.g. 5 years or more), however, it is possible that new technological solutions (e.g. heat pumps, thin-film PV, etc.) have introduced new options as to alternatives of natural gas during a disruption, thus making an implemented questionnaire obsolete.* *In Case Studies, practicality and replicability is limited. Results are not easily generalised to different contexts and time periods.* *The EIB approach relies on methods of relatively high level of sophistication (e.g. the Black-Scholes option value formula) and its usability in non-academic settings is limited.*
Public acceptability	*Case studies are well accepted as they report on actual incurred costs in an ex-post context.*

Calculations with the fuel-switch approach are usually performed ex-ante and assumptions about typical equipment costs are introduced. It is acknowledged that reaching a consensus on capital costs can be a challenging exercise.

The hypothetical cost estimates receive an additional one-point penalty, as they are based on estimates from surveys, rather than hard data.

The EIB approach receives the lowest score along this criterion, as it relies on economic models and assumptions, which are not easy to communicate to the wider public and secure public acceptability.

Table 4: Summary of the assessment of cost-function approaches

Practice/ approach	Granularity	Applicability to natural gas disruptions	Data availability, accessibility, homogeneity and robustness	Estimation practicality and replicability	Public acceptability
Case studies	− −	+ + +	−	−	+ + +
Fuel switch	+	+ + +	+	+ +	+ +
Hypothetical estimates of costs	+ + +	+ + +	− −	+	+
EIB	− − −	+ + +	− − −	− − −	− −

In conclusion, among the cost-function approaches, the fuel-switch approach receives a balanced positive score across the five criteria. However, its applicability to the CoDG case can be challenged by the lack of consensus in the capital cost estimates and related data.

The Case Studies approach is intuitively appealing, particularly in the context of ex-post estimation of the value of solidarity gas, but there are not that many available Case Studies to cover the needs of the CoDG estimation.

The use of the hypothetical cost approach may be warranted, to ensure the estimation of CoDG for all cost elements, consumer categories and other required dimensions alone or in combination with other survey methods as outlined below together with the fuel switching approach.

The above assessment points to a limited usefulness of the EIB approach in the context of this study.

2.4.4 Discussion on the suitability of demand-function approaches

This section discusses the suitability of the demand-function approach regarding the criteria defined above. Table 5 is a visual summary of the discussion.

Granularity	*The contingent ranking and the choice experiment approaches allow for the highest degree of granularity. Granularity is an integral part of the choice attributes that are provided to potential respondents to rank or choose from. Still, the choice of granularity is not unlimited. Having too many choice attributes may overcomplicate the exercise for the consumers, preventing the derivation of meaningful answers.* *The contingent valuation method, where the consumers are asked directly for their willingness to pay or accept, also allows for some granularity in the design of the questionnaire. However, the contingent valuation questions usually do not involve a number of choice attributes, although in principle it is possible to ask a number of contingent valuation questions, differing along the CoDG dimensions (e.g. willingness-to-pay in the winter, in the summer, etc.).* *The granularity of the revealed preferences approach depends on the granularity of the underlying data on prices and quantities of gas demand. It is reasonable to expect that such data can be found per country, although it is less certain that such data can be made readily available with sufficient granularity for certain dimensions (e.g. pricing per sector of economic activity, quantities per hour of day or day of the week, etc.).*
Applicability to natural gas disruptions	*All approaches have been applied in natural gas settings.*
Data availability, accessibility, homogeneity and robustness	*All three survey-based demand-function approaches receive a negative score, given their dependence on field research.* *In principle, the contingent valuation approach is less resource-intensive, compared to the contingent ranking and choice experiment methods, as it requires a lower sample size to arrive to meaningful results. Yet as a method, contingent valuation is more prone to suffer from cognitive biases of the respondents and thus it is penalized for having a relatively lower degree of robustness, which is by far the most serious drawback of this approach.* *The revealed preferences approach receives a positive score for data availability, as it relies on market data, rather than field research. Nevertheless, it is acknowledged that market data is not always readily available, especially at the granularity level required for the CoDG estimation.*

Estimation practicality and replicability	*All demand-function methods receive negative scores along this criterion, except for the contingent valuation approach. Indeed, the latter relies on fairly simple statistical techniques (e.g. calculation of mean, median, standard deviation, etc.), which are readily available in popular spreadsheet programmes, such as Microsoft Excel. Nevertheless, its replicability is limited by the fact that underlying preferences may not be easily generalized to other Member States or over time, thus requiring a wide geographical coverage of the survey and their update in time.* *The revealed preferences approach requires the use of econometric techniques to arrive at demand elasticity estimates and replicability in a wider context may be limited.* *The contingent ranking and choice experiment methods require even more advanced statistical techniques (such as fractional factorial design) in order to limit the choice of possible options to an informative and efficient set. They also require econometric estimation from the ranking or choice data, to arrive at CoDG estimates.*
Public acceptability	*It is argued that all demand-function approaches can suffer from limited public acceptability, as they measure consumer welfare losses, a rather abstract concept outside the economic profession. Overall, the derivation of consumer welfare loss from market data involves assumptions on the functional form of the demand function, which may further reduce the extent to which this method is intuitively appealing.* *It may also not be easy to explain to the wider public how the CoDG estimates are derived from the ranking or choice of numerous gas supply disruption options. The contingent valuation method can be probably the most acceptable of the four assessed approaches, as it directly asks for CoDG estimates. Yet its score remains negative due to the inherently subjective nature of the derived answers, particularly when applied to domestic consumers.*

Table 5: Summary of the assessment of demand-function approaches

Practice/ approach	Granularity	Applicability to natural gas disruptions	Data availability, accessibility, homogeneity and robustness	Estimation practicality and replicability	Public acceptability
Revealed preferences	⊖	⊕⊕⊕	⊕	⊖⊖	⊖⊖⊖
Contingent valuation	⊕	⊕⊕⊕	⊖⊖⊖	⊕	⊖
Contingent ranking	⊕⊕	⊕⊕⊕	⊖⊖⊖	⊖⊖⊖	⊖⊖
Choice experiment	⊕⊕	⊕⊕⊕	⊖⊖⊖	⊖⊖⊖	⊖⊖

Overall, most demand-function approaches are not considered suitable for the context and requirements of this work, due to their academic sophistication and dependence on large-sample consumer surveys. Furthermore, these methods are primarily designed to monetize the preference of non-marketed goods of individuals or households. Yet, in the context of natural gas supply disruption, their use is less warranted, compared to other approaches, given that as long as the disruption of gas does not result in a disruption of electricity as well, there are readily available fuel-switching alternatives in the residential sector. More importantly, the results from the survey-based demand-function approaches, and particularly from contingent valuation studies, often suffer from cognitive biases. Therefore, the use of more objective approaches, such as the fuel switching or hypothetical cost estimates, as outlined in the previous subsections, are considered as better suited in the context of this study.

2.4.5 Discussion on the suitability of production-function approaches

This section discusses the suitability of the production-function approaches regarding the criteria defined above. Table 6 is a visual summary of the discussion.

Granularity — *The production-function approaches, which aim to monetise CoDG in terms of lost revenues from disrupted production, have in general relatively low degree of granularity. For example, GDP-at-risk and Tax-at-risk, examine corresponding losses only at country level, without further granularity.*

The GVA-at-risk and input-output approaches have a marginally better granularity. They provide CoDG estimates, differentiated across sectors of economic activity. The adjustment parameter of the adjusted GVA-at-risk approach allows for further granularity, so that CoDG values can in principle differ not only amongst sectors, *but also along other dimensions (e.g. season for gas consumers with seasonal pattern of activity).*

The richer structure of the underlying data in the producer surplus, real option and leisure-at-risk approaches allows for a somewhat stronger degree of granularity of the CoDG estimate, in comparison to the simple GVA-at-risk or input-output methods. For example, the reliance of the real option approach on high-frequency (e.g. hourly) data of electricity and gas prices allows for different CoDG estimates in different seasons, days of the week, hours of the day, etc.

However, these approaches are penalized along this criterion with a negative score, as they are designed for particular user categories in mind. In particular, the real option approach is only relevant to gas-fired power plants, as it takes into account the fact that their activity is intermittent, depending on the difference between wholesale electricity and gas prices, which varies on an hourly basis. Similarly, the leisure-at-risk approach estimates the cost of disruption, based on the idea that the value of an hour of leisure equals the wage rate, which is not applicable to other consumer categories. Similarly, the producer surplus approach derives the cost of disruption, based on the difference between retail and wholesale gas prices, which is only applicable to retail suppliers of natural gas.

Applicability to natural gas disruptions

All approaches, except for leisure-at-risk have been applied in natural gas. The real options and producer surplus approaches, in fact, were designed specifically for gas-fired power plants and natural gas distribution companies respectively. The input-output approach, however, is considered as less relevant, as the likelihood of production disruption in sectors supplying materials to gas consumers or using products from the gas consumers is less likely, given the lower criticality of natural gas in production, compared to electricity and taking into account the option of maintaining inventories of raw materials and finished products. Having said that, the supply disruption of natural gas to sectors that use it as feedstock may in principle have knock-on effects to other sectors along the supply chain. The applicability of the input-output approach in these specific cases is restrained by the fact that the input-output tables are available at the level of NACE[9] heading or 2-digit sector codes. Thus, the input-output approach combines in a sector production processes that do not necessarily participate in the affected supply chain, alongside affected production activities.

[9] NACE is the classification of economic activities in the European Union (EU); the term NACE is derived from the French Nomenclature statistique des activités économiques dans la Communauté européenne.

The leisure-at-risk approach assumes that the households cease their leisure activities (e.g. reading a book or watching television) as a result of energy supply disruption. This can be the case in electricity, but it cannot be extended to natural gas, given its specific uses in households (space heating, water heating and cooking).

Data availability, accessibility, homogeneity and robustness

The level of data availability in all production function approaches is generally good. In general, these approaches are not data-intensive and rely primarily on data readily available in free-access databanks, such as Eurostat.

The only exception is the real options approach, which relies on high-frequency energy pricing data and plant thermal efficiency parameters. Such data is not readily available, at least not in all Member-States. Thermal efficiency parameters may also be considered as confidential commercial information.

Among the other approaches, the producer surplus approach receives lower score, as it relies on wholesale gas prices, which vary throughout the opening hours of the relevant wholesale markets, yet the corresponding data in statistical databases has significantly lower frequency (e.g. monthly or quarterly averages). It is questionable if data of such frequency are available to all regulators and/or the responsible authorities for security of supply per Member State. Data availability challenges are also identified with the Adjusted GVA-at-risk approach, due to its adjustment parameter, which often takes values from expert guesses.

Estimation practicality and replicability

Many production function approaches are straightforward to implement and can be replicated. With the exception of the leisure-at-risk, which involves relatively more estimation parameters, all value-at-risk approaches have a simple estimation formula. Even the leisure-at-risk method, despite its relative sophistication in comparison to the other production-function methods, does not require sophisticated estimation tools. The producer surplus approach is also fairly straightforward to implement, provided that necessary data are available.

The real options approach on the other hand requires the implementation of the Black-Scholes formula for option valuation, which is not as straightforward, compared to the at-risk approaches.

The input-output approach is even more challenging as it requires the implementation of Leontief-type economic models. These models require in principle the inversion of a matrix of technological coefficients, which is not straightforward to implement without the use of advanced mathematical software tools (such as MATLAB or R).

Public acceptability	*Most production-function approaches are considered to be of limited public acceptability. This is based on the fact that a disruption of natural gas is not expected to lead to pervasive disruption of the production process, primarily due to fuel-switching possibilities and the flexibility provided by the option to replenish (in advance) or draw (during the disruption) from stocks of raw materials and finished goods. Particularly in the case of the simple GVA-at-risk approach, quantifying the cost of gas disruption through the total cost of lost production in cases when the production process is not interrupted is counterintuitive.* *Given that the Adjusted GVA-at-risk takes such possibilities into account through the adjustment parameter, it receives a positive score for this criterion. The score is positive especially in the context of the application of the approach in economic activities, where natural gas is used as a feedstock or critical input (e.g. manufacture of fertilizers). In these cases, the production processes that use natural gas are indeed interrupted during natural gas supply disruption, which would lead to a loss of revenue. Thus, the application of production-loss approaches to these activities is not counterintuitive and can be easier accepted by the wider public.* *Similarly, the narrow application of the producer surplus and real options approach, to natural gas distributors and gas-fired electricity plants, improves their intuitive appeal, as they essentially measure the lost profit of activities relying critically on the availability of natural gas.*

Table 6: Summary of the assessment of production-function approaches

Practice/ approach	Granularity	Applicability to natural gas disruptions	Data availability, accessibility, homogeneity and robustness	Estimation practicality and replicability	Public acceptability
GDP-at-risk	−−−	++	+++	+++	−−
GVA-at-risk	−−	++	+++	+++	−−
Adjusted GVA-at-risk	+	++	−	+++	++
Input-output	−−	+	+++	−−−	−−
Producer surplus	−	+++	+	+	+
Real options	−	+++	−−−	−−	+
Tax-at-risk	−−−	++	+++	+++	−−
Leisure-at-risk	−	−−−	+++	++	−−−

Overall, the production function approaches suffer from low granularity. On the other hand, they are easy to implement, replicate and require a minimum of data input, which is publicly available from well accepted sources. Methods in this category, particularly GVA-at-risk and adjusted GVA can serve well in estimates of CoDG in the industrial sector where gas is used as feedstock.

2.4.6 Assessment summary

The assessment exercise carried out here revealed that a number of approaches can be utilized (independently or in combination with each other) towards the estimation of CoDG.

The fuel switch approach can well provide a base for calculating the CoDG in the residential and business sectors, as well as in industrial and power generation firing natural gas as a fuel.

These estimates can be supplemented with findings from Case Studies (where applicable and available), so as to provide a form of ex-post assessment of the methodology and the calculated CoDG values.

For the remaining elements of the CoDG that are not related to the use of alternative fuels (e.g. machinery adjustment or damage costs), especially in sectors with high intensity of natural gas use, and also to ensure CoDG estimates with sufficient granularity, the hypothetical cost approach can provide a useful supplementary input.

The Adjusted GVA-at-risk seems to be the best suited approach to monetize CoDG in sectors that rely critically on the use of natural gas for their production, either as feedstock or as energy input.

We note that this review and assessment was done with a view of establishing a CoDG methodology. This process also forms a base for the estimation of the solidarity price - with the CoDG being one of its components.

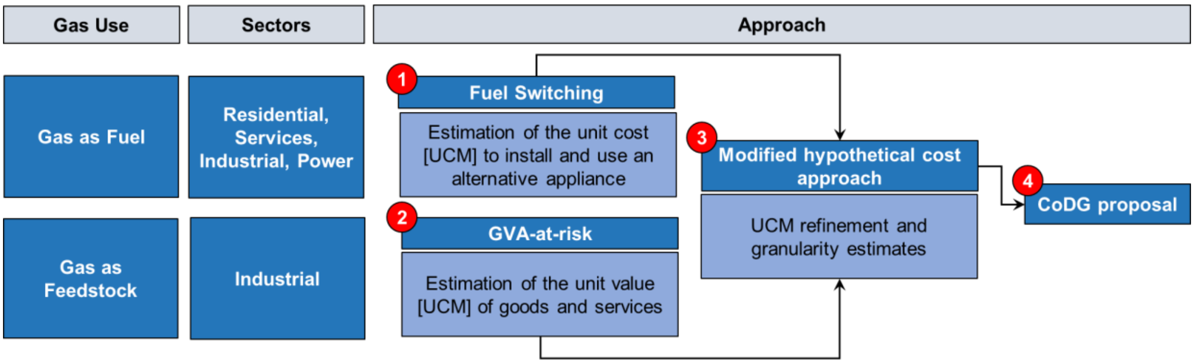
3 Methodological approach for the monetisation of the CoDG

This section highlights our proposed methodology for monetizing the CoDG, based on the analysis of the previous chapter.

Our approach, Figure 15, can be summarized in the following four steps:

1. Estimate a Unit Cost Measure (UCM) as defined in the next section for all sectors where natural gas is used as a fuel. A modified fuel switching approach is used as a base for this estimation.
2. Estimate a UCM, using an adjusted GVA-at-risk in sectors where natural gas is used as feedstock (i.e. as a raw material in an industrial production process).
3. Use a modified hypothetical cost approach to understand whether the UCM can be used to represent the CoDG and or if it needs to be further modified/refined. This approach involves asking consumers about their estimates of the CoDG under hypothetical scenarios that consider several granularity options.
4. Use the results from steps 1, 2 and 3 above to propose CoDG values.

Figure 15 Methodology for the estimation of the CoDG.



3.1 Methodology for the estimation of a unit cost (UCM) for natural gas-as-fuel

The proposed methodology is bottom-up approach, Figure 16. For each Member State, sector, sub-sector and type of end use, a fuel UCM is estimated at appliance type level. Then UCM values are evaluated at more aggregate levels (end-use type, subsector, sector and Member State), using appropriate weighting factors, Figure 17.

All estimates correspond to the cost per unit of energy (UCM -€/MWh) when natural gas firing equipment is substituted by alternative appliances and fuels.

Figure 16 Fuel UCM estimation levels

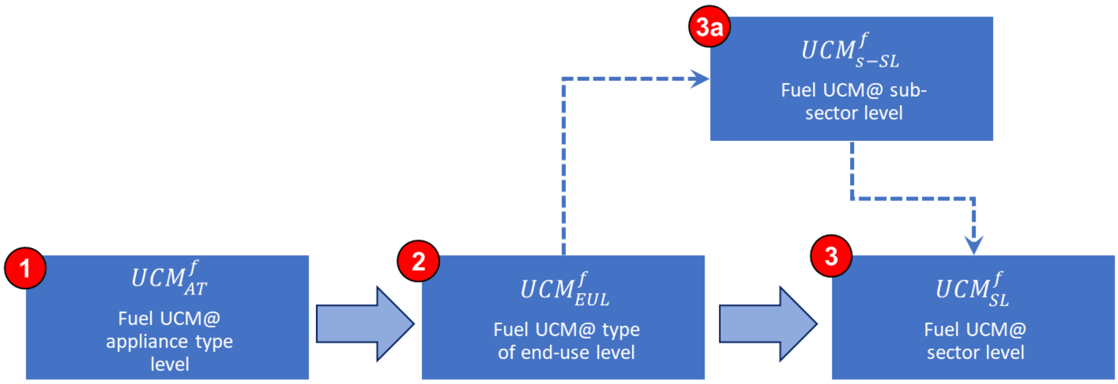


Figure 17 Overview of the UCM calculation process

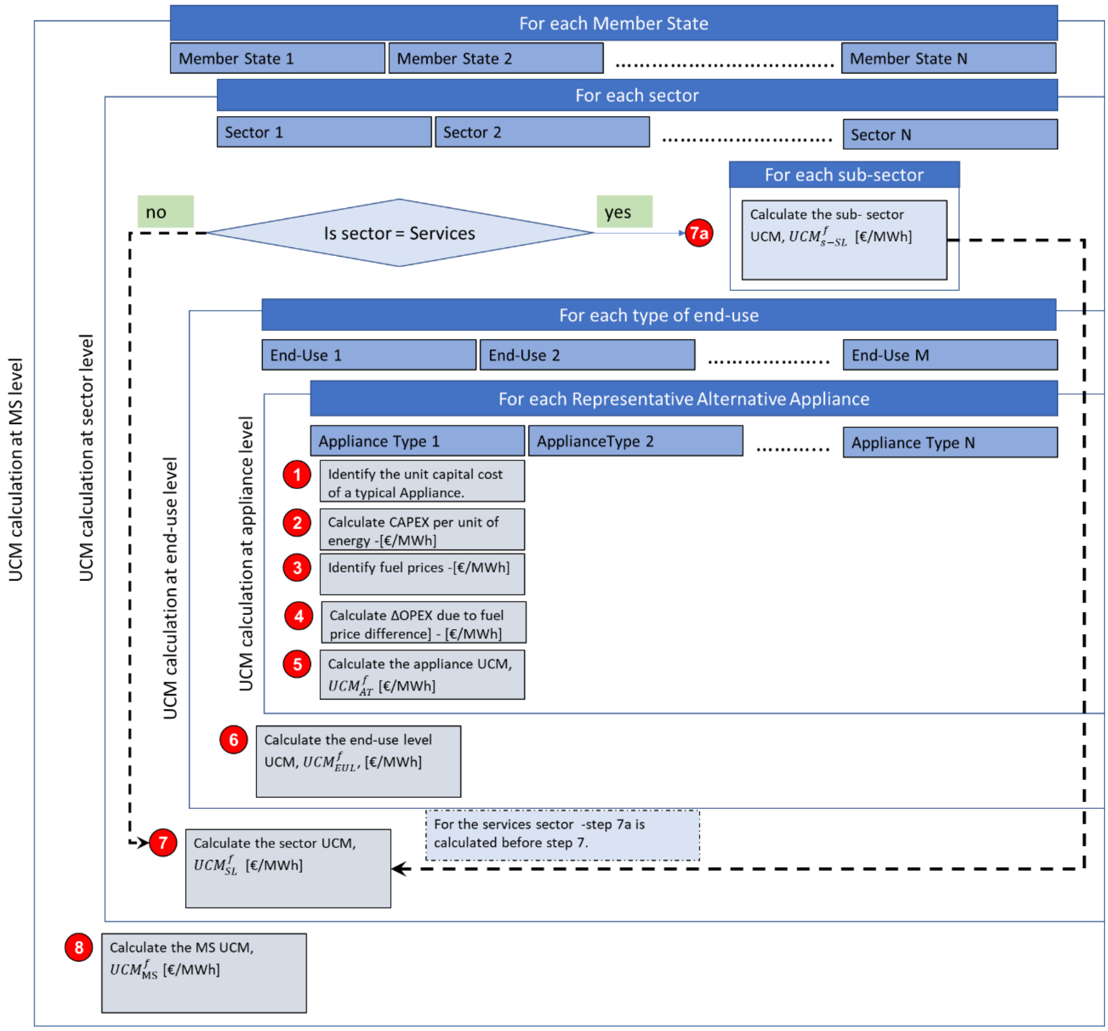
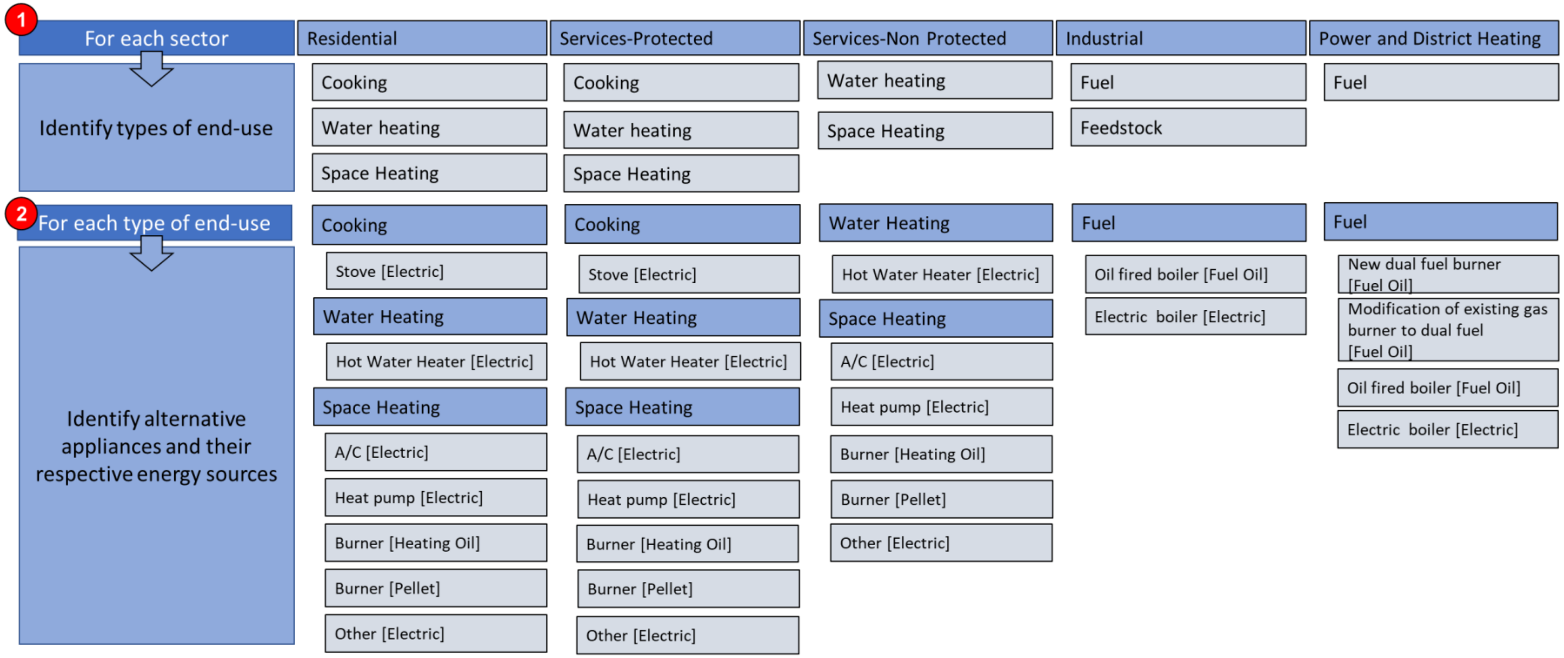


Figure 18 Sector overview by type of end-use and appliances



3.1.1 UCM at the level of appliance type

For each sector, we first identify the type of end-uses of gas per sector (item 1 of Figure 18). For example, in the residential and protected services sector, we identified as main uses cooking, water heating and space hearing, while in the industrial sector gas is used either as fuel or as feedstock in the production process.

We then identify potential alternative appliances for each end-use (item 2 of Figure 18). Indicatively, for cooking we identify as representative alternative an electric stove (see also Box 1), while for space heating more alternatives are considered (including electric air conditioner and heat pump or burner using pellets or heating oil). We note that the methodology is generic so that is comparatively straightforward to include as many representative appliances as required.

UCM values [10], $UCM^{f}_{AT j}$, at appliance level j are then calculated for each Member State, MS_i, end-use level, sub-sector and sector as.

$$UCM^{f}_{ATj} = \frac{CAPEX_{ATj}}{\sum_{y=1}^{TL}\sum_{d=1}^{365} H_{d,y}} + \Delta OPEX \quad \left[\frac{€}{MWh}\right] \tag{1}$$

where

$CAPEX_{AT j}$	is the capital cost of a Representative Alternative Appliance [€/MW] listed in Appendix 4
$H_{d,,y}$	are the hours in the day *d* and year *y* that the appliance is in operation.
TL	is the appliance lifetime
$\Delta OPEX$	is the operating cost for the production of 1 MWh of energy by the utilization of an alternative fuel.

[10] A strict mathematical representation of the UCM value at this level would be to write $UCM^{f}_{AT,MSi}$ as $UCM^{f}_{AT}(i, s, ss, eul, j)$ where *i* is the Member State, *s* is the Sector, *ss* is the subsector where applicable (i.e. services sector), *eul* the type of end use and *j* the representative alternative appliance. To avoid the complexity, we use a simpler, albeit mathematically less precise expression.

Box 1 UCM_{AT}^{f}, at appliance level – Specific implementation considerations

CAPEX of the Representative Alternative Appliance

For the purposes of the UCM calculations, a *Representative Alternative Appliance (RAA)* is an appliance that provides the same type of end-use as the original gas appliance (e.g. an air-conditioning unit can substitute a gas fired boiler for heating). The *Representative Alternative Appliances* are shown in item 2 of Figure 18. Capital costs of RAAs were obtained from an extended desktop research as follows:

- ***Residential, services sectors***
  - For each Member State we identified e-shops selling home appliances. Appendix 3 lists our sources per Member State.
  - For each RAA type, we recorded prices (pre-tax, non-VAT, in €] and the respective capacity [e.g. heating, cooling capacity, in MW] for up to 5 products.
  - The average unit cost [€/MW] was then calculated, dividing the appliance price with its respective capacity.
- ***Industrial sector:*** We used the boiler costs included in the final report "Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)" of the European Commission[11].
- ***Power Sector (including CHP):*** For the power sector, common values for all EU are proposed as our research did not show a differentiation among MS.

Appliance Utilisation

Differences in the operation of a certain equipment/appliance between weekdays and weekends (or public holidays) are fully accounted for. Seasonality is also reflected, where applicable. The approach also allows for reduced operation due to equipment aging, planned or unplanned maintenance.

To implement Equation (1), we made assumptions regarding

(a) The operating hours, H_D, of each RAA within a day

(b) The number of days in a week, N_D that the appliance is in operation

(c) The number of weeks, N_w , in the year that the RAA is in operation.

For simplicity, the denominator of equation (1) was re-casted from $\sum_{y=1}^{TL}\sum_{d=1}^{365} H_{d,y}$ to $\cong TL \times H_D \times N_D \times N_w$.

The same values were used for all Member States although it is recognised that differences exist particularly in space heating requirements.

[11] https://ec.europa.eu/energy/sites/ener/files/documents/Report%20WP2.pdf

The modified hypothetical cost approach can be used to refine these estimates further.

Operating costs difference

$\Delta OPEX$ is equal to the cost difference from burning an alternative fuel rather than natural gas and an additional operating costs item $\boldsymbol{OPP_{add}}$.

$$\boldsymbol{\Delta OPEX = (Alternative\ fuel\ price - Price\ of\ natural\ gas) + OPP_{add}}\ [\frac{€}{MWh}]$$

Our analysis in Chapter 4 shows that the price difference between the alternative fuel and natural gas is an important determinant of the overall UCM value.

We recognise that the term *fuel price difference* may be perceived as referring to several alternatives, including the wholesale market price (e.g. day-ahead price, intraday or long-term contracts) but also the retail price of gas and the alternative fuel. The latter is a longer-term price, which includes in addition to the supply cost (most commonly from a portfolio of short and longer-term supply contracts), transmission and distribution costs and the retailer's profit margin.

In Chapter 5 we address the cost of gas supply in the event of a gas disruption leading to the implementation of the solidarity mechanism under Article 13 of the Regulation 2017/1938. There, we maintain that such a cost of gas could be, amongst other options, related to the values perceived in a wholesale market (spot prices). Here however, we argue that retail prices are more relevant indicators to be included in a sectoral UCM.

The table below provides further information on the fuel prices included in the UCM calculation. Appendix 6 lists the actual values and the value of $\Delta OPEX$.

Fuel Prices	Definition and Assumptions	Sources
Gas/Household consumers	Medium standard household consumption band with an annual consumption of natural gas (only piped gas is considered) between 5 555 kWh and 55 555 kWh (20 Gigajoule (GJ) and 200 GJ).	EUROSTAT (2017)[12] Residential and Services sectors.
Gas/Non-household consumers	Medium standard non-household consumption band with an annual consumption of natural gas between 2 778 and 27 778 GWh (10 000 and 100 000 GJ).	EUROSTAT (2017)[13] Industrial and Power sectors

[12] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_202&lang=en
[13] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_203&lang=en

Electricity/Household consumers	Medium standard household consumption band with annual electricity consumption between 2500 and 5000 kWh.	EUROSTAT (2017)[14] Residential and Services sectors
Electricity/Non-household consumers	Medium standard non-household consumption band with an annual consumption of electricity between 500 and 2000 MWh.	EUROSTAT (2017) [15]Industrial and Power sectors
Heating Oil prices	Weekly retail prices for fuel oil including taxes and levies excluding VAT.[16]	EUROSTAT (2017)
Fuel Oil prices	Weekly retail prices for heating oil including taxes and levies excluding VAT.[17]	EUROSTAT (2017)
Pellet prices	Retail prices for pellet excluding VAT.	DESKTOP RESEARCH

Additional operating costs $\boldsymbol{OPP_{add}}$ maybe due to any cost item in relation to maintaining an alternative fuel. For example, for industrial equipment (large scale boilers) or power plants firing alternative fuel, the additional operating costs may be related to the storage of alternative fuel and the planned maintenance of the alternative fuel storage facilities and combustion equipment (including maintenance runs on alternative fuel.

In the implementation of the UCM method r, as reported herein, we only considered the fuel price difference as other costs could not be retrieved from public sources or desktop research. Then in the context of the modified hypothetical cost approach we enquired about this additional operating cost for the industrial and power services with equipment burning alternative fuel.

[14] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en
[15] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_205&lang=en
[16] https://ec.europa.eu/energy/en/data-analysis/weekly-oil-bulletin, prices in force on 30/4/2018
[17] https://ec.europa.eu/energy/en/data-analysis/weekly-oil-bulletin, prices in force on 30/4/2018

3.1.2 UCM at the level of end-use type

As a second step, aggregate UCM values at each type m of end-use level, $UCM^{f}_{EUL,MSi}$[18],are estimated as follows:

$$\boldsymbol{UCM^{f}_{EULm} = \sum_{j=1}^{N_{AT}} WF^{f}_{ATj} \times UCM^{f}_{ATj} \quad \left[\frac{€}{MWh}\right]} \qquad \textbf{(2)}$$

where

m	Is the end use (e.g. water heating, cooking, space heating)
WF^{f}_{ATj}	is a weighting factor which quantifies the probability of the *RAA* (AT_j) to be selected by users as an alternative appliance.

Box 2 UCM^{f}_{EULm} at type of end use level – Specific implementation considerations

For simplicity we assume

$$WF^{f}_{ATj} = \frac{1}{N_{AT}}$$

where

N_{AT}	is the number of Representative Alternative Appliances for the particular end-use (i.e. 1 in cooking, 1 in water heating, 5 in space heating).

This approach includes the inherent assumption that all Representative Alternative Appliances have equal probabilities to be selected by the gas user. Such an assumption is not strictly valid as some technologies have larger capital costs and reduced consumer acceptability than others (e.g. a heat pump versus an oil burner). An alternative approach would be to use specific assumptions for the share of each technology for each type of end-use. Such shares could be sourced for example from projections included in the EU Impact assessments in the context of the 2016 Winter Package in relation to Energy Efficiency and can form part of a future parametric study.

3.1.3 Sub-sector level

This is an additional step of the implementation approach, implemented solely for the services sector.

[18] A strict mathematical representation of the UCM value at this level would have been to write $UCM^{f}_{eul,MSi}$ as $UCM^{f}_{eul}(i, s, ss, eul)$

We split the services sector in a protected part and a non-protected part. The former (Services-Protected part) includes the following sub-sectors, as set in Regulation 2017/1938 (Article 2):

- Healthcare
- Education
- Emergency
- Security
- Essential social care
- Public administration

In the latter (Services-non-Protected part), we distinguished the following subsectors:

- Commercial (e.g. restaurants, hotels)
- Retail stores
- Private offices

Appendix 4 shows that the RAA capital cost is the same irrespective of sector and subsector. On the other hand, operating times differ (Appendix 5). As a result, UCM values, $UCM^{f}_{AT,MSi}$, at appliance level are subsector dependent.

The UCM values $\boldsymbol{UCM^{f}_{s-SL}}$ for each subsector j of the services sector are estimated as follows

$$UCM^{f}_{s-SLj} = \sum_{k=1}^{N_{EUL}} WF^{f}_{sub-EULk} \times UCM^{f}_{EULk} \quad \left[\frac{€}{MWh}\right] (3)$$

where

$\boldsymbol{WF^{f}_{sub-EULk}}$ is a weighting factor, which quantifies the contribution of each type of end use of energy to the overall gas consumption of the sub-sector. The values used are listed in

Appendix 7.

$\boldsymbol{N_{EUL}}$ is the number of end-uses of gas in the subsector (see

Appendix 7.)

Box 3 UCM^{f}_{s-SLj} at type of end use level – Specific implementation considerations

EUROSTAT reports on the consumption by fuel and type of end use[19] (cooking, water heating, space heating) for the residential sector. The ratios of gas consumption for one type of end use to the overall gas consumption, which can be used as weighting factors, are also reported. Similar data are not available for other sectors and subsectors.

Here, we used the EUROSTAT residential weighting factors for subsectors where all three end types are identified, e.g. healthcare and education. For subsectors where only 2 of the three end types are identified (e.g. water heating and space heating) we defined the overall gas consumption as the sum of the two types of end use and based estimates on equal weightings.

3.1.4 UCM at the sector level

UCM values UCM^{f}_{SL} for the residential, industrial and power sectors were estimated as:

$$UCM^{f}_{SLj} = \sum_{k=1}^{N_{EUL}} WF^{f}_{s-EULk} \times UCM^{f}_{EULk} \quad \left[\frac{€}{MWh}\right] \quad (4)$$

where

WF^{f}_{s-EULk} is a weighting factor which quantifies contribution of each type of end-use of energy to the overall gas consumption of the sector. For the residential sector the values used are listed in Appendix 8.

UCM values UCM^{f}_{SL} for the services sector is estimated as:

$$UCM^{f}_{SLj} = \sum_{k=1}^{N_{EUL}} WF^{f}_{s-EULk} \times UCM^{f}_{s-SLj} \quad \left[\frac{€}{MWh}\right] \quad (5)$$

[19] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households#Energy_consumption_in_households_by_type_of_end-use. Data are for 2016, as 2017 data are not yet available.

Box 4 UCM_{SLj}^{f} at type of end use level – Specific implementation considerations

The Table below lists the $\boldsymbol{WF_{sub-EULk}^{f}}$ data sources

Sector	Source
Residential	EUROSTAT, see Appendix 8
Services	$\boldsymbol{WF_{s-EULk}^{f} = \frac{1}{N_{s-Sl}}}$ Were N_{s-Sl} is the sum of the subsectors in the services protected (6) and the services non-protected sectors (3).
Industrial	$WF_{sub-EULk}^{f} = 1$
Power and District Heating	$WF_{sub-EULk}^{f} = 1$

3.1.5 Member State level

UCM values $\boldsymbol{UCM_{SL}^{f}}$ for the residential, services, industrial and power sectors were estimated as as

$$\boldsymbol{UCM_{MSj}^{f} = \sum_{k=1}^{N_{SL}} WF_{SLk}^{f} \times UCM_{SLk}^{f}} \quad \left[\frac{€}{MWh}\right] \qquad (6)$$

where

$\boldsymbol{WF_{SLk}^{f}}$ is a weighting factor which quantifies contribution of each type of sector to the overall natural gas consumption as fuel. Values are listed in Appendix 9, as sourced from EUROSTAT (2016)[20].

3.2 Methodology for the estimation of a unit cost (UCM) for natural gas-as-feedstock

UCM values for natural gas-as-feedstock are calculated at Member State level.

Natural gas in the production process is used in the chemical and petrochemical industry. Methane, a prime component of natural gas, is used in hydrogen production

[20] 2016 is the latest year for which values were available at the time of the study.

(for hydrocracking, hydrodesulfurization, and ammonia). Methanol is produced from natural gas and can in turn serve as feedstock for manufacturing more chemical substances such as formaldehyde, insulation materials, varnishes, paints, glues, fuel additives, acetic acid and MTBE (Methyl tert-butyl ether). Mineral fertilizers are also produced from natural gas through a series of chemical conversions.

The argument developed herein, i.e. that natural gas-as-feedstock is mainly encountered in the chemical and petrochemical industry is well supported by data included in the EUROSTAT Energy Balances reports[21], produced separately for each MS.

EUROSTAT reports two numbers in relation to the non-energy consumption of natural gas in the industrial sector: the quantities used for the sector overall and the part due to the Chemical/Petrochemical Industry. With the exception of the Czech Republic where the natural gas used in the Chemical/Petrochemical industry exceeds the overall value over a series of years (rather than being less or equal), in all remaining MS with a gas-dependent industrial sector (Belgium, Bulgaria, Germany, Greece, Spain, France, Croatia, Italy, Lithuania, Hungary, the Netherlands, Austria, Poland, Romania Slovenia, Slovakia, Finland, Sweden and the United Kingdom) the part of non-energy consumption due to petrochemicals equals to a good approximation the overall non-energy consumption of natural gas. Minor deviations are only identified in Hungary and Poland, where the total non-energy consumption and the non-energy consumptions due to petrochemicals differ in the period 2015 to 2017 by less than 1%.

Thus, it is of practical significance to evaluate a UCM for gas-as-feedstock solely for the chemical and petrochemical sector of the countries mentioned above. UCM will not be calculated for Denmark, Estonia, Ireland, Latvia, Luxembourg and Poland since natural gas is not used as a feedstock in these Member States[22]. A feedstock UCM is also not calculated for Sweden as the country does not disclose the GVA of the chemical/Petrochemical sectors.

3.2.1 UCM values for gas-as-feedstock at Member State level

UCM values [23], are calculated for natural gas-as-feedstock as follows

$$UCM_{MSj}^{CP} = \frac{m_{gas}^{CP}}{m_{all\ fuels}^{CP}} \times \frac{GVA_{MSj}^{CP}}{m_{gas\ as\ feedstock}^{CP}} \qquad [\frac{€}{MWh}] \quad (7)$$

Where

[21] https://ec.europa.eu/eurostat/web/energy/data/energy-balances

[22] Natural gas Non-Energy use in Chemical /Petrochemical Industry (2015 values) Energy-Balances-June2017editionFinal: https://ec.europa.eu/eurostat/web/energy/data/energy-balances

[23] A strict mathematical representation of the UCM value at this level would be to write $UCM_{AT,MSi}^{f}$ as $UCM_{AT}^{f}(i, s, ss, eul, j)$ where *i* is the Member State, *s* is the Sector, *ss* is the subsector where applicable (i.e. services sector), *eul* the type of end use and *j* the representative alternative appliance. To avoid the complexity, we use a simpler, albeit mathematically less precise expression.

UCM_{MSj}^{CP}	is the feedstock UCM (due to the use of natural gas as input to an industrial process) in Member State j.
m_{gas}^{CP}	is the overall natural gas consumption in the Chemical and Petrochemical Sectors
$m_{all\ fuels}^{CP}$	is the final consumption in the Chemical and Petrochemical Sectors
GVA_{MSj}^{CP}	is the gross value added of the Chemical and Petrochemical industry of Member State j.
$m_{gas\ as\ feedstock}^{CP}$	is the consumption of natural gas-as-feedstock in the Chemical and Petrochemical Sectors

Box 5 Feedstock UCM_{MSj}^{CP}, – Specific implementation considerations

As shown in equation (7), the Chemical/Petrochemical UCM is calculated through a modified GVA approach as follows:

- The industry-specific GVA (Chemical-Petrochemical) is firstly identified from EUROSTAT published data.
- The part of the Chemical-Petrochemical GVA that is related to the use of natural gas is then isolated. Assuming that each MWh of fuel contributes equally to Chemical-Petrochemical GVA, the part of the GVA due to natural gas (either as fuel or as feedstock) is the ratio of the sector specific natural gas consumption to the sector specific final consumption.
- The feedstock UCM_{MSj}^{CP} is then computed from the ratio of the natural gas part of the GVA to the natural gas consumption for feedstock purposes

The table below provides further information on the input data.

Input data	Units	Definition and Assumptions	Requirement for an annual update	Sources
Gross Value Added (GVA)	Euro	The Gross value added (GVA) is defined as output (at basic prices)	No every 5 years. Annual data	EUROSTAT (2015) [25][26] (National

[25] 2015 is the most recent year that have more available data

[26] GVA values http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

		minus intermediate consumption (at purchaser prices); it is the balancing item of the national accounts' production account.[24]	sets are not complete	accounts aggregates by industry (up to NACE A*64) [nama_10_a64] Code C20, Manufacture of chemicals and chemical products
Final Consumption in Chemical/ Petrochemical Industrial Sector	MWh	Equals the sum of the final Energy consumption (all fuels) in chemical/petrochemical industry and the final non-energy use (all fuels) in the same sector. It refers to fuel quantities consumed by the industrial undertaking in support of its primary activities.[27]	No every 5 years	EUROSTAT (2015).[28]
Natural Gas Consumption in Chemical/ Petrochemical Industrial Sector	MWh	Equals the sum of natural gas consumption as fuel and the natural gas use as a feedstock in the chemical/ petrochemical industry (non-energy use data).	No every 5 years	EUROSTAT (2015)[29]

24 Definition from Eurostat http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Gross_value_added
27 Definition from Eurostat's report http://ec.europa.eu/eurostat/documents/38154/4956233/RAMON-CODED-ENERGY-20150212.pdf/4814055b-de02-404a-b8e0-909fb82cbd54
28 Energy consumption in Chemical and Petrochemical Industry and Non-Energy use in Chemical /Petrochemical Industry
Energy-Balances-June2017editionFinal: https://ec.europa.eu/eurostat/web/energy/data/energy-balances
29 Natural gas consumption in Chemical and Petrochemical Industry and Natural gas Non-Energy use in Chemical /Petrochemical Industry
Energy-Balances-June2017editionFinal: https://ec.europa.eu/eurostat/web/energy/data/energy-balances

Natural Gas Consumption as a Feedstock in Chemical/ Petrochemical Industrial Sector	MWh	Equals the value reported as non-energy gas consumption in the specific sector.	No every 5 years	EUROSTAT (2015) [30]

3.3 Methodology for the implementation of a modified hypothetical cost approach

The modified hypothetical cost approach was implemented through three sectoral based questionnaires were prepared targeting the residential, services and industry and power sectors. Questions focused on the following:

- Natural gas use (e.g. heating, cooling, water heating, power and/or steam production, feedstock etc)
- Fuel and feedstock switching potentials and related costs
- Natural gas consumption per month, day of week, time of time
- Consequential damages from disruption as a function of duration, early warnings and curtailment levels.

30 Natural gas Non-Energy use in Chemical /Petrochemical Industry Energy-Balances-June2017editionFinal: https://ec.europa.eu/eurostat/web/energy/data/energy-balances

Table 7: Participants to the e Surveys

Sector	Start Page Views	Number of Respondents that accessed the Questionnaire	Number of respondents that completed the Questionnaire
Residential	292	32	26
Services	133	5	3
Power and Industrial	930	98	48

In all Questionnaires participants were asked to express views on the proposed methodology. They were also asked if the proposed UCM values (which were included in the questionnaire and differentiated by country and sector) could be accepted as CoDG. In the case of a negative response, participants were asked to express their views on how much the proposed UCM value should be increased or decreased to meet their perceptions of a fair value.

Questionnaires were made available on line for period of approximately 5 weeks.

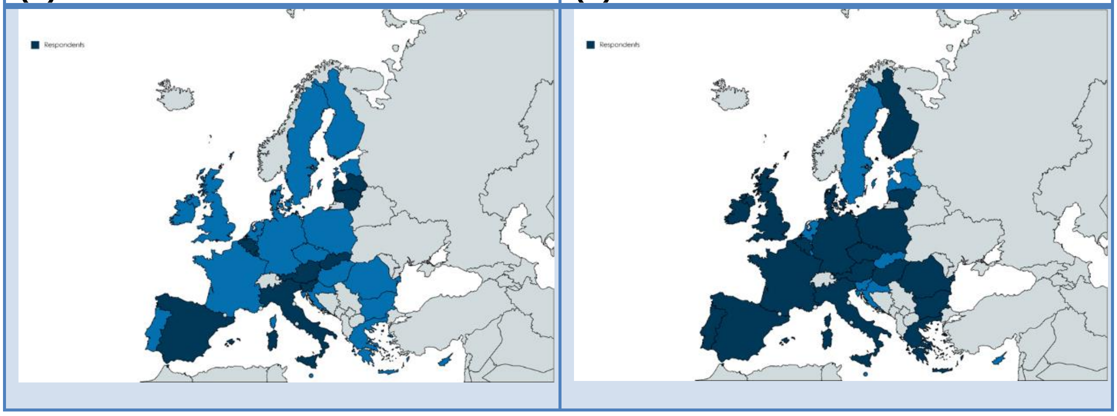
Eight interviews with industrial and power stakeholders and associations willing to provide additional comments were also carried out.

Readers are referred to Appendix 20 for details on how we conducted the MHC process and to Appendix 27, Appendix 28, Appendix 29 and Appendix 30 for the Questionnaires.

Unfortunately, participation was limited, Table 7. Responses from 9 MS were received for the questionnaire targeting the Residential Sector. Almost no responses were received for the Services Sector. Respondents from 18 MS completed the industrial/power sector questionnaire, Figure 19.

Figure 19: Map of (a) residential and (b) industrial and Power sector respondents

(a) (b)



3.4 Methodology for the calculation of a unit cost value at Member State level

A cross sectoral CoDG value per Member State is finally calculated.

First for each Member State, a total industry UCM (gas-as-fuel and gas-as-feedstock) is evaluated from:

$$UCM_{Industry} = WF^{f}_{Industry} \times UCM^{f}_{Industry} + WF^{CP}_{Industry} \times UCM^{CP}_{industry} \quad (8)$$

Where

$WF^{f}_{Industry}$	is a weighting factor which quantifies the contribution of the fuel based UCM to the overall sector value? It is defined as the ratio of the natural gas consumption as a fuel to the natural gas final consumption. Values are listed in Appendix 10, as sourced from EUROSTAT (2016).
$UCM^{f}_{Industry}$	is the fuel UCM (due to the use of natural gas-as-fuel to an industrial process) in Member State j.
$WF^{CP}_{Industry} = 1 - WF^{f}_{Industry}$	is a weighting factor which quantifies contribution of the feedstock based UCM to the overall sector value?
$UCM^{CP}_{industry}$	is the feedstock UCM (due to the use of natural gas as input to an industrial process) in Member State j.

Then for each Member State, a total UCM (gas-as-fuel and gas-as-feedstock) is evaluated from:

$$UCM_{MSj} = WF^{GasTot}_{Residential} \times UCM^{f}_{Residential} + WF^{GasTot}_{services} \times UCM^{f}_{services} + WF^{GasTot}_{power} \times UCM^{f}_{power} + WF^{GasTot}_{Industry} \times UCM_{Industry} \left[\frac{€}{MWh}\right] \quad (9)$$

where

$WF^{GasTot}_{Residential}$ $WF^{GasTot}_{services}$ WF^{GasTot}_{power} $WF^{GasTot}_{Industry}$	are sector specific weighting factors defined here as the ratio of the sector natural gas consumption to the natural gas final consumption (including non-energy uses)

The UCM value calculated from equation (9) above, taking into account further input provided through the modified hypothetical cost approach may be used as a proxy to formulate a basis for the CoDG.

3.5 Assessment and challenges of the approach

A high-level assessment of our approach is summarised in Table 7.

Table 8: Assessment of the proposed approach for the estimation of the CoDG

Gas Use	Applied Approaches	Steps of the Methodology	Granularity	Applicability to natural gas disruptions	Data availability, accessibility, homogeneity and robustness	Estimation practicality and replicability	Public acceptability
Fuel	Modified fuel switch & Modified hypothetical cost	1,3,4	⊕⊕	⊕⊕⊕	⊕	⊕⊕	⊕⊕
Feedstock	Adjusted GVA-at-risk & Modified hypothetical cost	2,3,4	⊕⊕	⊕⊕⊕	⊕	⊕⊕	⊕⊕

The next paragraphs describe further our assessment and the challenges related to the approach.

Granularity	The UCM approach provides numerical values by country, sector and type of end-use. The modified fuel switch approach takes into account the utilisation of

	alternative equipment at hours in days, days in weeks and weeks in years the modified hypothetical cost approach allows for further assessment of parameters that may influence the CoDG such as disruption duration and curtailment magnitude.
Applicability to natural gas disruptions	The approach targets specifically natural gas.
Data availability, accessibility, homogeneity and robustness	The UCM estimation for the case of natural gas as a fuel requires on an extensive amount of data both from publicly available and also ad-hoc sources (e.g. "mystery shopping" in e-shops in order to determine the capital cost of alternative appliances by Member State). There is a risk that the values collected from e-shopping exercises involve some sample biasing (limited sources, large international firms selling appliances at prices lower than average). The modified hypothetical cost approach (hereinafter MHC-approach) introduces a further subjective element as it depends on the input provided by the respondent. Nevertheless, the MHC is still less subjective, compared to direct willingness-to-pay and willingness-to-accept questions, as the respondents in MHC are asked to provide a quantitative assessment to specific CoDG values included in the questionnaires. Questionnaires distributed as part of this study were made available only in English and were web based. Although language is not expected to be a substantial barrier for the European industrial and power sectors, considerable sample bias is acknowledged for the residential and services sectors.
Estimation practicality and replicability	The estimation does not require sophisticated software and estimation techniques and thus it is easily reproducible. The UCM methodology depends to a large extent on CAPEX data of alternative equipment and fuel costs. These values may change over time so that input data may need to be revisited on a regular basis.
Public acceptability	Respondents found the proposed approach generally acceptable.

4 Findings

4.1 Estimation of the UCM for natural gas-as-fuel

This Section presents UCM values for gas-as-fuel calculated at appliance, end-use, sub-sector, sector and Member State level according to the proposed approach

4.1.1 Fuel UCM Values at appliance level

Figure 20 shows that stove-UCM values for the residential and services sectors range from 58 (BG) to 261 €/MWh (BE). Min and max values result from a combination of low/max capital costs and also low/max differences between the price of the alternative fuel and natural gas. Differences across sectors are due to the different assumptions in relation to the appliance operating hours[31].

Average values shown in the figure (and in all figures in this section) correspond to simple unweighted averages for EU-26, i.e. values calculated as the sum of all appliance-specific UCM values across EU-26 divided by 26[32].

Table 9 shows the breakdown of the minimum and maximum Stove-UCM values to its two main components (CAPEX and ΔOPEX parts). As shown in the Table 9, the price difference between the alternative fuel and natural gas is the main driver to the UCM price formation at appliance level.

Figure 21 shows that hot-water heater UCM values for the residential and the services subsectors range from 53 (BG) to 230 €/MWh (BE). Once again differences are due to the different operating hours assumed for each category[33]. The price difference between the alternative fuel and natural gas remains the main driver to the UCM price formation, Table 10.

[31] E.g. for the case of residential cooking 7 operating hours per week have been assumed. For healthcare the respective vale is 28 operating hours per week, Appendix 5)

[32] Average values shown here mainly for presentation purposes so as to avoid the tedius long listing of individual values by Member State. These are included in Appendix 13 and

Appendix 14. Further Appendix 11 and Appendix 12 present separately the parts of the UCM due to the capital and operating costs.

[33] E.g. for the case of residential hot-water heating 7 operating hours per week have been assumed. For healthcare the respective vale is 168 operating hours per week, Appendix 5

Figure 20: Residential and Services Sector - Appliance Level UCM^{f}_{AT} (EU-26 average) - Stove

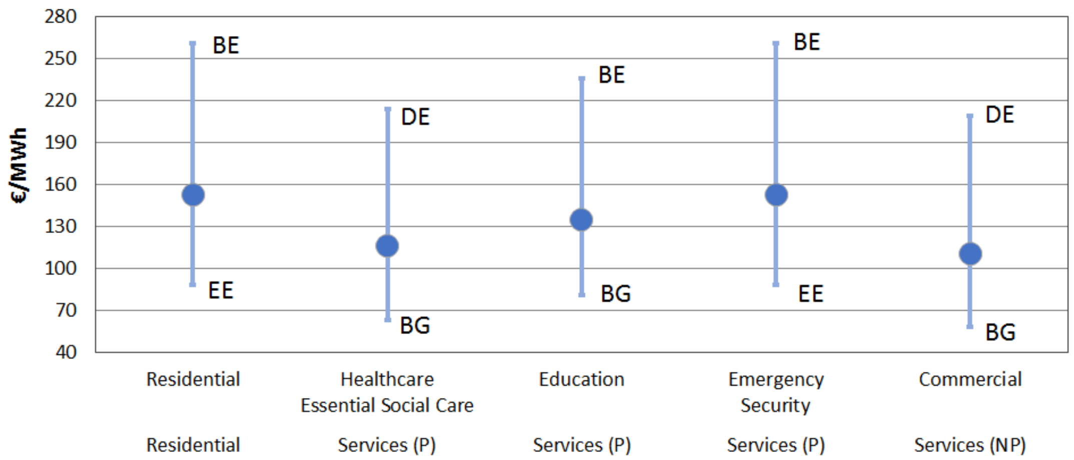


Table 9 Assessment of the relative contribution of the CAPEX and ΔOPEX parts in the value formation of the stove- UCM^{f}_{AT}. For brevity only the minimym and maximum values by sector and subsector are reported..

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
Residential	**Residential**	EE	18	82	BE	27	73
Services (P)	**Healthcare Essential Social Care**	BG	17	83	DE	4	96
Services (P)	**Education**	BG	35	65	BE	19	81
Services (P)	**Emergency Security**	EE	18	82	BE	27	73
Services (NP)	**Commercial**	BG	10	90	DE	2	98

Figure 21: Residential and Services Sector - Appliance Level UCM_{AT}^{f} (EU-26 average) - Hot water heater. In the Figure H-E-S-ESC stands for Healthcare, Emergency, Services and Essential Social Services

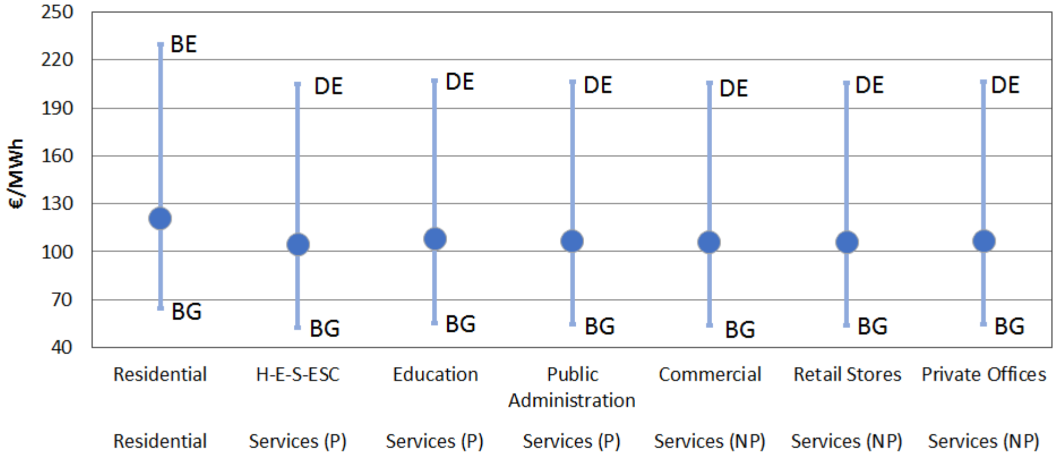


Table 10: Assessment of the relative contribution of the CAPEX and ΔOPEX parts in the value formation of the hot water heater - UCM_{AT}^{f}. For brevity only the minimum and maximum values by sector and subsector are reported.

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
Residential	**Residential**	BG	19	81	BE	17	83
Services (P)	**Healthcare Emergency Security Essential Social Care**	BG	1	99	DE	0	100
Services (P)	**Education**	BG	5	95	DE	1	99
Services (P)	**Public Administration**	BG	4	96	DE	1	99
Services (NP)	**Commercial**	BG	3	97	DE	1	99
Services (NP)	**Retail Stores**	BG	3	97	DE	1	99

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
Services (NP)	**Private Offices**	BG	4	96	DE	1	99

Figure 22 shows the respective UCM **values for appliances used in space heating**. Here values range from

- 54 (BG) to 215 (DE) €/MWh for A/C units
- 17 (IE) to 102 (HU) €/MWh for heating oil burners
- 58 (BG) to 217 (BE) €/MWh for Heat Pumps
- 0 to 23 (HU) €/MWh for Pellet Burners and
- 53 (BG) to 208 (DE) €/MWh for other electrical appliances

Once again differences across sectors are due to the different operating hours assumed. The price difference between the alternative fuel and natural gas remains the main driver to the UCM price formation and explains the very low UCM value for Pellet Burners UCMs.

Figure 22: Residential and Services Sector - Appliance Level UCM^{f}_{AT} (EU-26 average) - Appliances for space heating/cooling

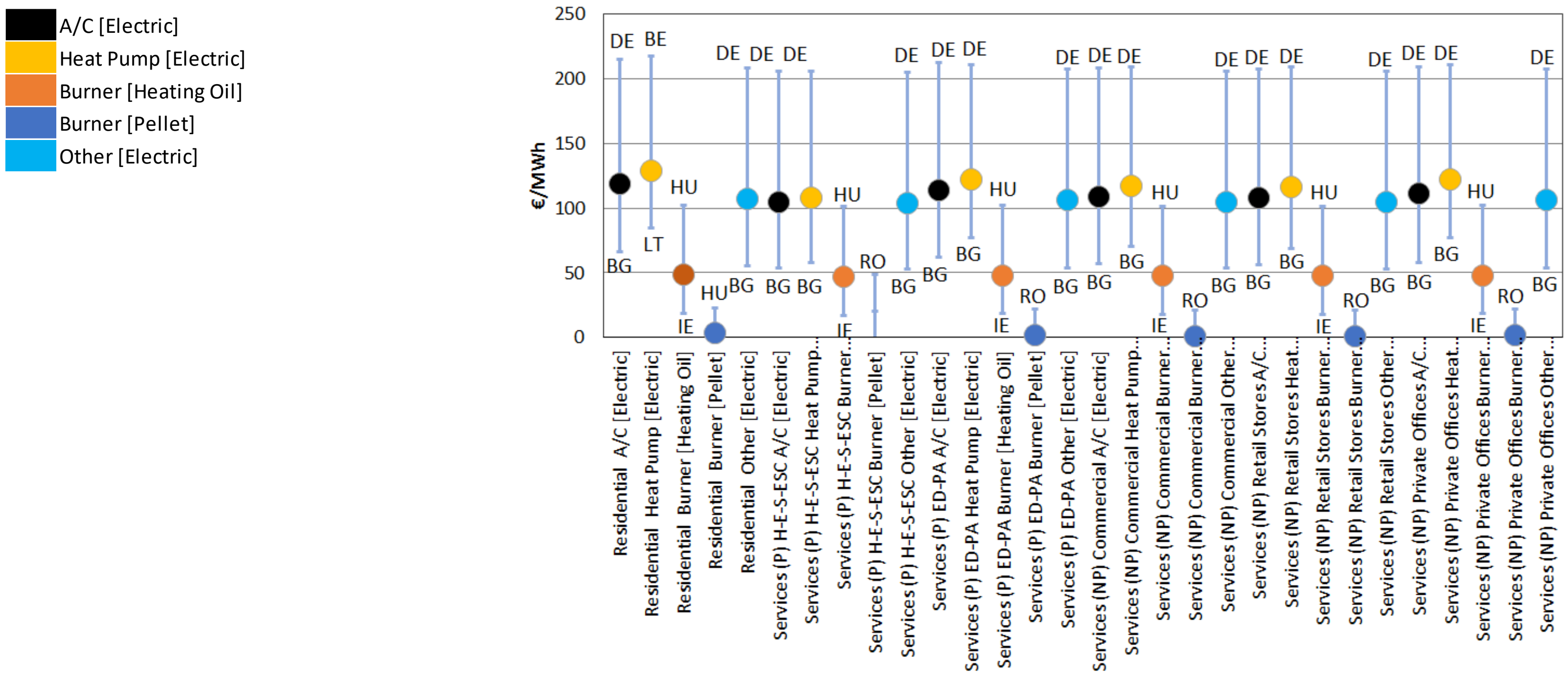


Table 11: Assessment of the relative contribution of the CAPEX and ΔOPEX parts in the value formation of the A/C - UCM_{AT}^{f}. For brevity only the minimum and maximum values by sector and subsector are reported.

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
Residential	Residential	BG	21	79	DE	5	95
Services (P)	Healthcare Emergency Security Essential Social Care	BG	3	97	DE	1	99
Services (P)	Education Public Administration	BG	15	85	DE	3	97
Services (NP)	Commercial	BG	8	92	DE	2	98
Services (NP)	Retail Stores	BG	6	94	DE	1	99
Services (NP)	Private Offices	BG	11	89	DE	2	98

Table 12: Assessment of the relative contribution of the CAPEX and ΔOPEX parts in the value formation of the heat pump - UCM_{AT}^{f}. For brevity only the minimum and maximum values by sector and subsector are reported.

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
Residential	Residential	LT	27	73	BE	12	88
Services (P)	Healthcare Emergency Security	BG	10	90	DE	1	99

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
	Essential Social Care						
Services (P)	Education Public Administration	BG	33	67	DE	3	97
Services (NP)	Commercial	BG	26	74	DE	2	98
Services (NP)	Retail Stores	BG	24	76	DE	2	98
Services (NP)	Private Offices	BG	33	67	DE	3	97

Table 13: Assessment of the relative contribution of the CAPEX and ΔOPEX parts in the value formation of the heating oil burner - UCM^{f}_{AT}. For brevity only the minimum and maximum values by sector and subsector are reported.

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
Residential	Residential	IE	12	88	HU	1	99
Services (P)	Healthcare Emergency Security Essential Social Care	IE	2	98	HU	0	100
Services (P)	Education Public Administration	IE	9	91	HU	1	99
Services (NP)	Commercial	IE	6	94	HU	0	100
Services (NP)	Retail Stores	IE	6	94	HU	0	100

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
Services (NP)	Private Offices	IE	9	91	HU	1	99

Table 14: Assessment of the relative contribution of the CAPEX and ΔOPEX parts in the value formation of the Pellet burner - UCM^{f}_{AT}. Here only maximum values are shown. As pellets are priced lower than natural gas the minimum UCM value calculated was zero.

Sector	Subsector	Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part
Residential	Residential	HU	26	74
Services (P)	Healthcare Emergency Security Essential Social Care	RO	3	97
Services (P)	Education Public Administration	RO	10	90
Services (NP)	Commercial	RO	7	93
Services (NP)	Retail Stores	RO	7	93
Services (NP)	Private Offices	RO	10	90

Table 15: Assessment of the relative contribution of the CAPEX and ΔOPEX parts in the value formation of the other electric appliances - UCM_{AT}^{f}. For brevity only the minimum and maximum values by sector and subsector are reported.

Sector	Subsector	Min UCM value [%]			Max UCM value [%]		
		Country	CAPEX part	$\Delta OPEX$ Part	Country	CAPEX part	$\Delta OPEX$ Part
Residential	**Residential**	BG	5	95	DE	2	98
Services (P)	**Healthcare Emergency Security Essential Social Care**	BG	1	99	DE	0	100
Services (P)	**Education Public Administration**	BG	4	96	DE	1	99
Services (NP)	**Commercial**	BG	3	97	DE	1	99
Services (NP)	**Retail Stores**	BG	3	97	DE	1	99
Services (NP)	**Private Offices**	BG	4	96	DE	1	99

Figure 23 shows that equipment level UCM values range from less than 10 €/MWh (EE) for an oil-fired boiler to the order of 120 €/MWh (DE) for an electric boiler. Differences in the UCM values due to different operating modes (continuous or intermittent, i.e. operating only part of the year) are minor as the difference between the price of the alternative fuel and natural gas remains the dominant contributor to the UCM value.

We used one common EU wide value for the price of a new dual fuel gas turbine and one for the modification of existing gas burner to dual fuel gas turbine. UCM values for the power sector range from 47 €/MWh (EE) to 87 €/MWh (DK).

Figure 23: Power and Industrial Sector - Appliance Level UCM^{f}_{AT} (EU-26 average) - Appliances for power/industrial sectors

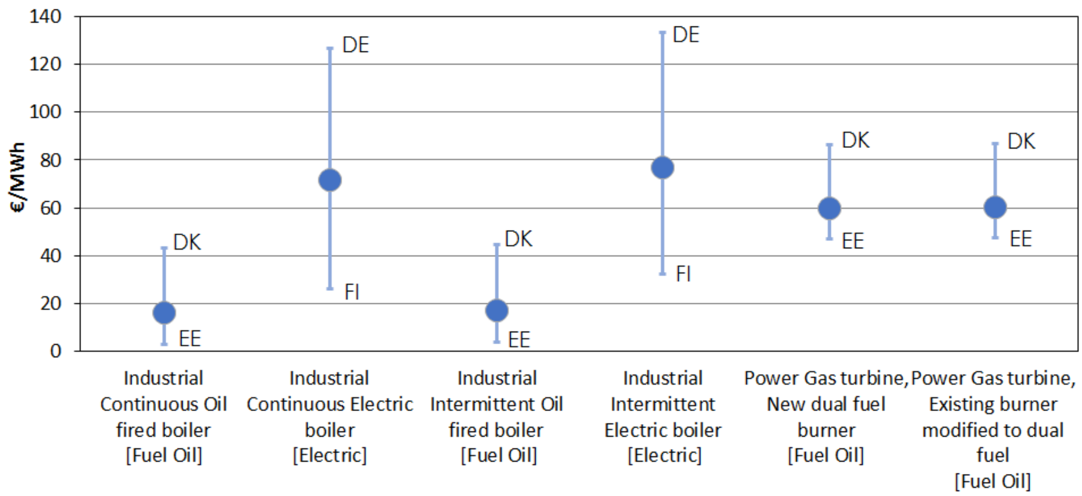


Table 16 Breakdown of the minimum and maximum - UCM^{f}_{AT} values for the industrial and power sectors to its CAPEX and ΔOPEX components.

Sector	Type of utilisation and RAA type	Min UCM value [%]			Max UCM value [%]		
		MS	CAPEX part	$\Delta OPEX$ Part	MS	CAPEX part	$\Delta OPEX$ Part
Industrial	**Continuous Oil fired boiler**	EE	28	72	DK	4	96
Industrial	**Continuous Electric boiler**	FI	23	77	DE	5	95
Industrial	**Intermittent Oil fired boiler**	EE	43	57	DK	8	92
Industrial	**Intermittent Electric boiler**	FI	37	63	DE	10	90
Power	**N.A New dual fuel burner**	EE	0	100	DK	0	100
Power	**N.A. Modification of existing gas burner to dual fuel**	EE	1	99	DK	1	99

4.1.2 Fuel UCM Values at end-use-level

Figure 24, Figure 25, and Figure 26 present the UCM values at end-use level. Once more, for the sake of brevity only EU-26 average values and minimum and maximum values for each end-use, subsector and sector are reported. Readers are referred to Appendix 14. Values range from

- 58 (BG – Services (NP) - Commercial) to 261 (BE – Residential, Services (P) – Emergency and Security) €/MWh for cooking
- 53 (BG – Services (P) – Healthcare, Emergency, Security, Essential Social Care) to 230 (BE – Residential) €/MWh for water heating
- 30 (SE – Services (NP) – Retail Stores) to 132 (BE - Residential) €/MWh for space heating

Differences are due to the different CAPEX and operating costs as identified in the previous sections.

Figure 24: Residential and Services Sector - End Use Level UCM^{f}_{EUL} (EU-26 average) - Cooking

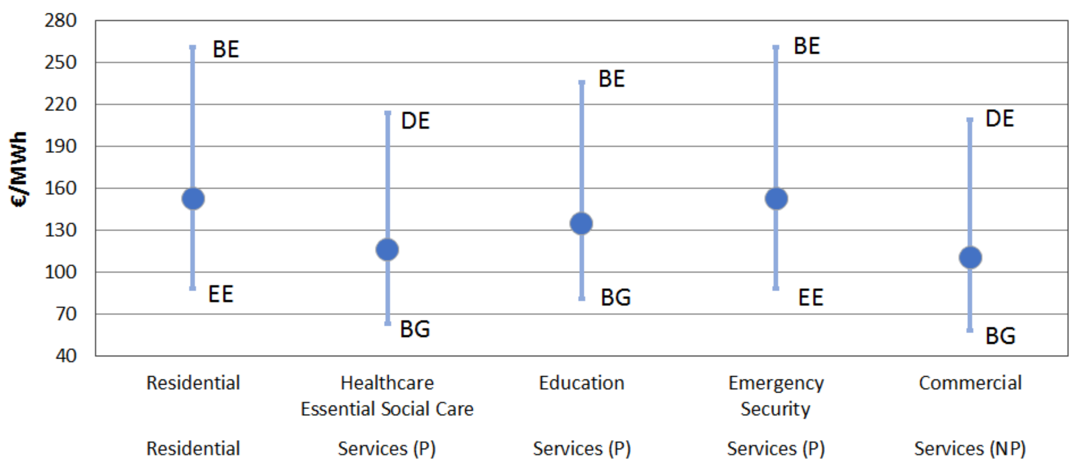


Figure 25: Residential and Services Sector - End Use Level UCM^{f}_{EUL} (EU-26 average) - Water heating

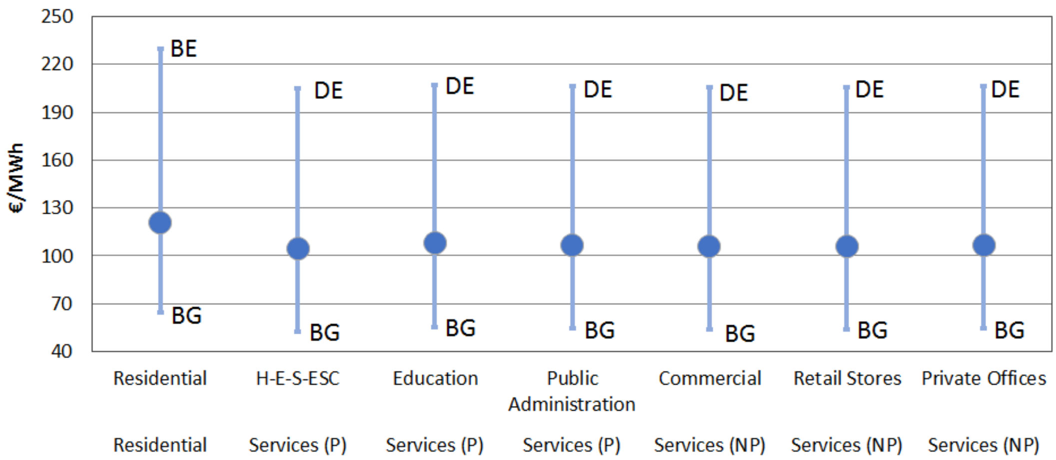
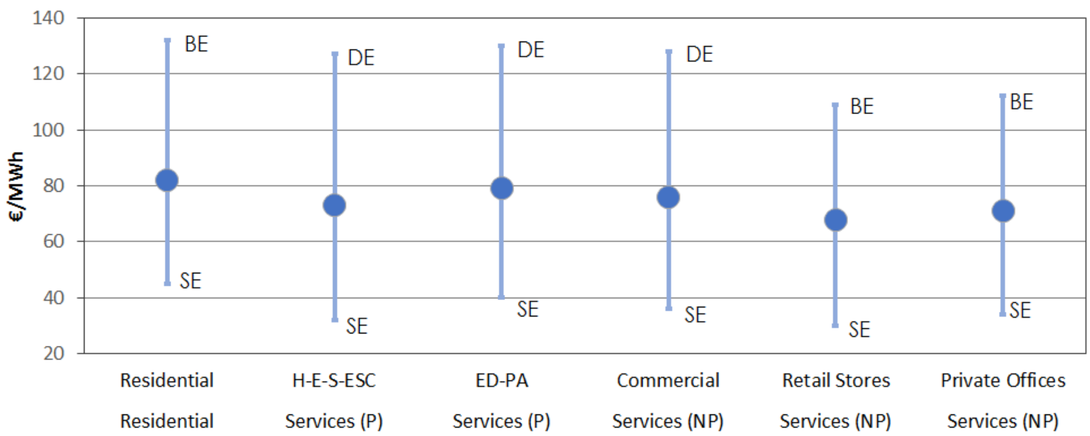


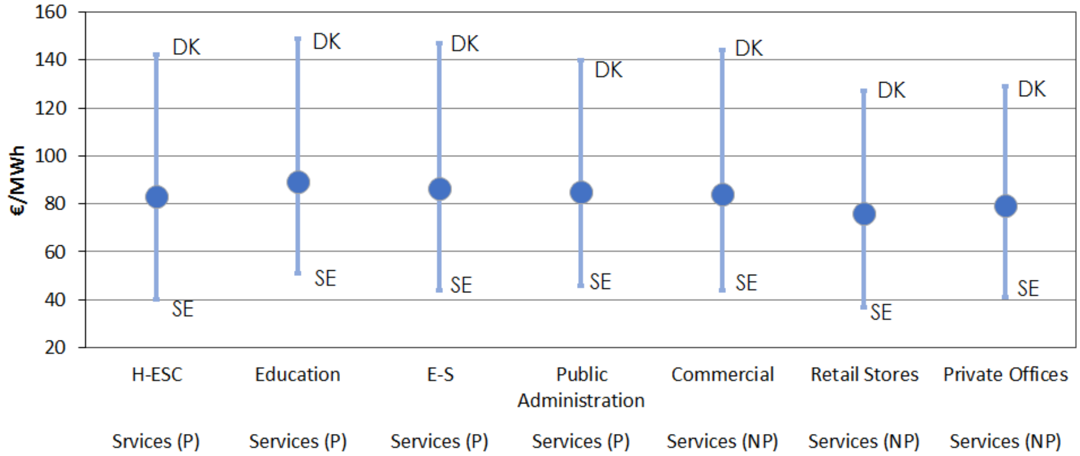
Figure 26: Residential and Services Sector - End Use Level UCM^{f}_{EUL} (EU-26 average) - Space heating



4.1.3 Fuel UCM Values at sub-sector level

As discussed in Section 3.1.3, for services, we also proceeded in the calculation of UCM values at subsector level. Figure 27 shows the respective values are in the range of 37 (SE) to 149 €/MWh (DK). Denmark has been recognized as the MS with the highest value, due to the high prices of electricity and heating oil, in comparison with the price of natural gas. Sweden showed up the lowest value, due to the low differences between the prices of electricity and natural gas and between the prices of heating oil and natural gas. Readers are referred to Appendix 15 for the respective sub-sector values by Member State.

Figure 27: Services Sector - Subsector Level UCM^{f}_{s-SL} (EU-26 average)



4.1.4 Fuel UCM Values at sector level

Average EU-26 values at sector level are in the range of 40 to 100 €/MWh, Figure 28. Minimum values are identified in Czech Republic (Industrial Sector) mainly due to the low price of electricity, in comparison with price of natural gas. Maximum values of the order of 160 €/MWh were calculated in Denmark (Residential Sector). Table 17 provides a summary. Readers are referred to Appendix 17 for further detailed values by Member State.

Figure 28: Sector Level UCM^{f}_{SL}- (EU-26 average)

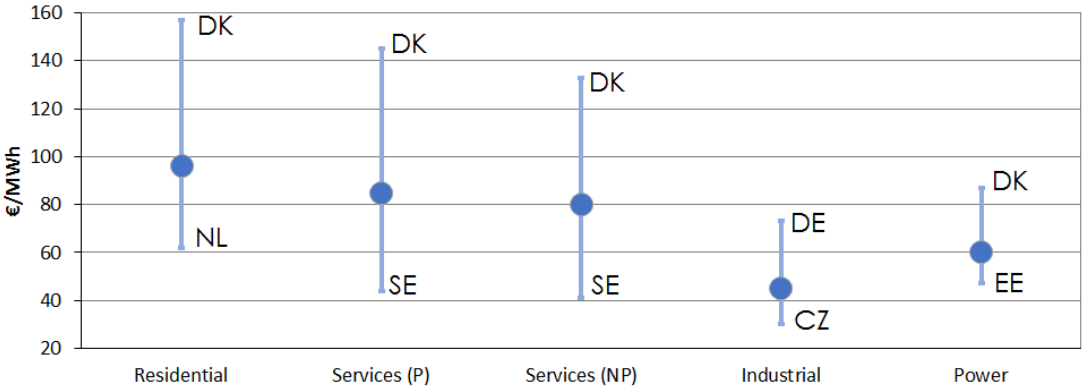


Table 17: Member State level summary UCM_{MS}^{f}

Sector	Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
			Value [€/MWh]	Difference from Mean [%]	MS	Value [€/MWh]	Difference from Mean [%]	MS
Residential	96	85	62	-36	NL	157	64	DK
Services (P)	85	76	44	-48	SE	145	70	DK
Services (NP)	80	71	41	-49	SE	133	67	DK
Industrial	45	45	30	-35	CZ	73	61	DE
Power	60	58	47	-22	EE	87	44	DK
Total	**67**	**62**	**47**	**-31**	**BG**	**103**	**52**	**DE**

4.1.5 Uncertainties and Sensitivity

The fuel UCM approach is comparatively straightforward. However, it depends on a substantial number of input data and assumptions.

Table 19 lists all fuel UCM input variables and presents a high-level assessment of the uncertainty related to each variable and its relative contribution to the UCM values calculated at appliance, end-use type, sub-sector, sector and Member State levels.

Four sensitivity scenarios where explored and reported herein, Table 18. The next sections report on the findings. For the purposes of the sensitivity assessments we refer to the values of Sections 4.1.1, 4.1.2, 4.1.3 and 4.1.4 as the Base Case.

Table 18 Scenarios used in the sensitivity analysis

Scenario	Description
1	Increase in the appliance/equipment CAPEX by 30%,
2	ΔOPEX calculated using the retail fuel prices of 2014 S2.
3	Change in the number of weeks of operation (scenario based on the results of the MHC approach)
4	Increase of the appliance and equipment lifetime by a factor of 2 (Scenario based on the results of the MHC approach for industrial uses)

Table 19 Variables and uncertainties in the UCM estimates

No.	Variable		Annual Update requirement (Yes/No)	Source	Uncertainty	
	Name	Value			Description	Evaluation
1	**RAA**	Stove, A/C, Heat Pump etc	No. Need to update only if a new technology becomes available	Own knowledge	Uncertainty is related to the risk of a certain RAA type not being represented	We used the Modified Hypothetical Cost approach to assess whether other RAAs should be considered. Results from the survey, revealed 3 more relevant RAA in the residential sectors: LPG stove, microwave and solar water heater.
2	**End-Use type**	Cooking, Water Heating, Space Heating etc	No	Own knowledge	Uncertainty is related to the risk of a certain type of end use not represented	EUROSTAT includes data for cooking, water heating and space heating for the residential sector. No data are available for space cooling and were not able attain reliable estimates from other sources. Nevertheless, as gas-fired cooling units are used solely in the services sector (e.g. healthcare and by large commercial consumers), we argue that this uncertainty concerns solely the services sector.

No.	Variable		Annual Update requirement (Yes/No)	Source	Uncertainty	
	Name	Value			Description	Evaluation
3	$CAPEX_{ATj}$	Appendix 4	Yes	Desktop research (Appendix 3)	Uncertainty is related to the value of the capital cost retrieved and its potential increases/decreases in time.	The contribution of the CAPEX part of the UCM to its overall value is minor as shown in Appendix 11, Appendix 12 and Appendix 13 and also in Table 9 to Table 16.
4	$\Delta OPEX$	Appendix 6	Yes	See sources listed in Appendix 6	Uncertainty is related to the value of the alternative fuels and natural gas considered in the calculation and the relative increases/decreases in time.	The contribution of the ΔOPEX part of the UCM to its overall value is substantial as shown in Appendix 11, Appendix 12 and Appendix 13 and also in Table 9 to Table 16. With the exception of pellets, EUROSTAT data for the retail sector were used in all estimates
5	**Operating hours, H_D, of each RAA within a day**	Appendix 5	No	Own knowledge and EUROSTAT for max HDD	Operating hours comprise the denominator of the CAPEX part of the UCM at appliance level. Uncertainty is related to the various assumptions involved concerning the operating hours	The contribution of operating hours is only minor to the final value of the UCM due to the major contribution of ΔOPEX. For example, Figure 23 shows that the UCM values at appliance level in the industrial sector for continuous and intermittent operation (are to a good approximation similar despite

No.	Variable		Annual Update requirement (Yes/No)	Source	Uncertainty	
	Name	Value			Description	Evaluation
						the fact that in the intermittent operation the alternative equipment operates only half the time of the continuous mode.
6	**Number days in the week, N_D**	Appendix 5	No	Own knowledge and EUROSTAT for max HDD	As above	As above
7	**Number of weeks, N_w , in the year**	Appendix 5	No	Own knowledge and EUROSTAT for max HDD	As above	As above
8	**Appliance lifetime**	Appendix 5	No	Own knowledge and assumptions	As above	As above
9	**Weighting factor, WF^{f}_{ATj} which quantifies the contribution of the *RAA* UCM into the**	See Equation (2)	No	Assumption	This weighting factor reflects the probability of a certain RAA to be selected by a customer. It is therefore related to the relative contribution of a certain appliance	The contribution of this weighting factor is expected to be minor to due to the small contribution of the CAPEX part of the UCM to its actual value.

No.	Variable		Annual Update requirement (Yes/No)	Source	Uncertainty	
	Name	**Value**			**Description**	**Evaluation**
	overall value (RAA selection probability)				in the value of the UCM. Here equal probabilities for all RAAs were assumed. In practice values maybe different as some technologies have larger capital costs and reduced consumer acceptability than others	
10	**Weighting factor, $WF^{f}_{sub-EULk}$ which quantifies the contribution of each type of end-use of energy to the overall gas consumption of the sub-sector.**	Appendix **7** and Appendix 8	Only if necessary	Assumption (for sub-sectors with cooking, hot-water heating and space heating the Eurostat data for the residential sector were used).	This weighting factor quantifies the contribution of the end-use UCM to the UCM at subsector level for the Services Sector. Uncertainty is related to the weighting factor values.	The contribution of this weighting factor is expected to be minor to due to the small contribution of the CAPEX part of the UCM to its actual value.
11	**Weighting factor, $WF^{f}_{s-EULk'}$ which quantifies contribution of**	Appendix 7	Yes, for residential No for Power and Industrial	Residential data are available from EUROSTAT.	Uncertainty relates only to the Services Sector where it is assumed that contribution of each subsector	The contribution of this weighting factor is expected to be minor to due to the small contribution of the

No.	Variable		Annual Update requirement (Yes/No)	Source	Uncertainty	
	Name	Value			Description	Evaluation
	each type of end-use of energy or subsector (for services only) to the overall gas consumption of the sector.		Sectors as the value is Unity.		to the overall sector gas consumption is equal.	CAPEX part of the UCM to its actual value.
12	**Weighting factor, WF^{f}_{SLk} which quantifies contribution of each type of sector to the overall gas consumption.**	Appendix 9	Yes (data available from Eurostat)	Eurostat	n.a.	nap

4.1.5.1 Scenario 1 – Sensitivity of the UCM values on a change in the CAPEX of appliances and industrial and power generation equipment

This scenario looks into the effect of the CAPEX on the UCM values.

For the purposes of the scenario, all CAPEX components were increased by 30%.

As shown in Table 20, sector UCMs increase only moderately due to the comparatively lower contribution of the CAPEX part of the UCM in its overall value (in comparison to the ΔOPEX). The most significant increase of circa 14% is identified in the Residential Sector.

On average an increase in the CAPEX of household appliances by 30% leads to a subsequent increase of 5% in the sector UCM values. Increases in the remaining sectors are on average lower, in the range of 1.5 to 3%

Table 20: Scenario 1: Percentage change in the sector UCM in comparison to the Base Case

	Residential	Services (P)	Services (NP)	Industrial (fuel UCM only)	Power
EU-26 max value	13,72% (SE)	5,98% (LT)	6,83% (SE)	5,94% (SE)	0,22% (LV)
EU-26 min value	1,66% (DE)	0,62% (DE)	0,71% (DE)	1,47% (PT)	0,12%(DK)
EU-26 average value	4,94%	1,97%	2,05%	3,04%	0,18%
EU-26 median value	4,39%	1,67%	1,91%	2,73%	0,18%

4.1.5.2 Scenario 2 – Sensitivity of the UCM values on a change in fuel prices

This scenario looks into the effect of the ΔOPEX on the sector UCM values.

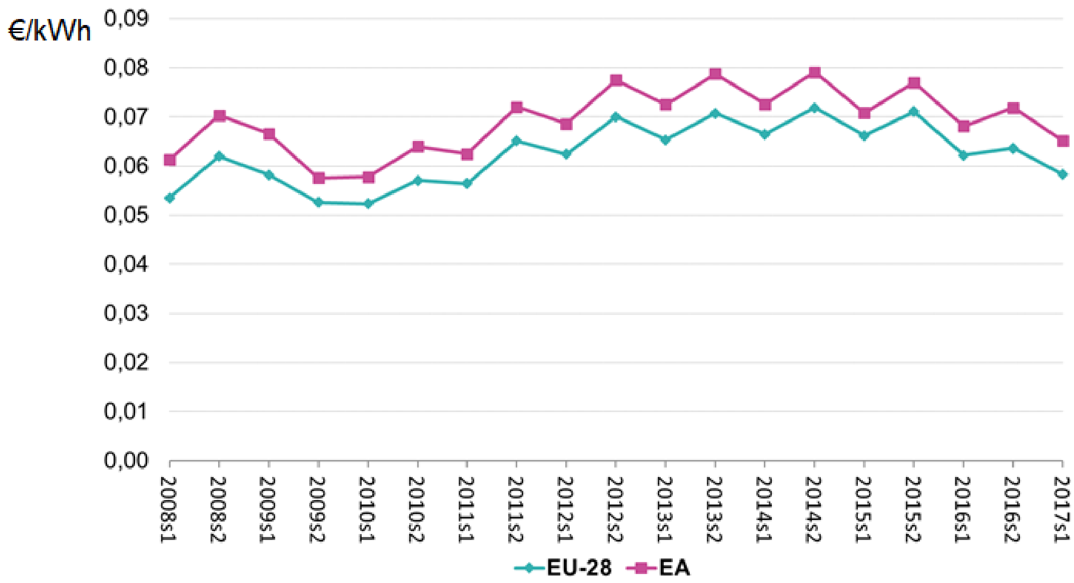
We note that results for the Base Case (Sections 4.1.1, 4.1.2, 4.1.3 and 4.1.4) correspond to EUROSTAT retail prices of 2017, 1st semester. The time period used in the Base Case corresponds to a period of relatively low values of natural gas in comparison to previous years, Figure 29. On the contrary, EUROSTAT reported that household natural gas prices of the 2nd semester of 2014 were the highest of the last decade.

For the sake of this Scenario we chose to assess the difference in UCM values calculated using fuel prices of 2014 S2 with the respective values for the Base Case. Unfortunately, no data for pellet prices were available so that the effect of a change in pellet prices on the UCMs was not assessed.

Figure 29 and Table 21 show the change in fuel prices between the values considered in this Scenario (Scenario 2), and the Base Case. One direct observation that can made is that the behaviour of fuel prices at retail level per Member State is complex. Substantial increases in gas prices (2014s2 vs 2017s1) of the order of 10 to over 40% were followed by even more substantial decreases in heating oil prices (20-66%) in all Member States. The behaviour of fuel oil prices is shown to be even more complex with increased values of up to 35% in 11 MS (BE, EE, ES, HR, HU, IE, LT, LV, PL, RO, UK)and a decrease of up to -60% in 15 MS (AT, BG, CZ, DE, DK, FI, FR, GR, IT, LU, NL, PT, SE, SI, SK). Household and non-household electricity prices also demonstrate a complex behaviour with some MS experiencing increases of up to 20% and others equivalent decreases of similar rates. Table 23 provides as summary.

As shown in Table 22 and Table 23, an increase or decrease in ΔOPEX results in a proportional increase/decrease in the UCM values.

Figure 29: Development of natural gas prices for household consumers, EU-28 and Euro Area, 2008-2017 (€/kWh)[34]



[34] Source: Eurostat

Table 21: Scenario 2: Percentage change in the fuel and electricity prices between 2014 S1 and 2017 S2[35]

MS	Natural Gas price (%)		Electricity price (%)		Heating Oil price (%)	Fuel oil price (%)
	Households	Non-Households	Households	Non-Households		
AT	8,19%	19,35%	1,91%	13,44%	-36,09%	-23,00%
BE	25,12%	20,08%	-19,70%	-3,64%	-20,65%	-6,24%
BG	46,55%	56,42%	-6,28%	-0,79%	-44,91%	8,76%
CZ	2,42%	27,73%	-4,04%	19,04%	-26,86%	-17,03%
DE	11,48%	26,50%	-2,42%	0,07%	-28,79%	-15,20%
DK	8,50%	13,85%	-0,45%	19,12%	-48,36%	-47,39%
EE	13,54%	33,70%	-8,53%	-13,40%	-24,64%	32,00%
ES	43,92%	25,08%	3,06%	9,99%	-28,79%	1,19%
FI	19,30%	0,86%	-2,75%	8,25%	-47,14%	-48,30%
FR	19,74%	16,26%	0,69%	-5,44%	-37,29%	-33,39%
GR	42,34%	65,02%	-9,14%	20,97%	-45,81%	-18,73%
HR	32,40%	63,01%	-11,45%	-13,23%	-27,53%	32,99%
HU	-0,36%	49,04%	-19,82%	1,47%	-51,86%	17,00%
IE	17,95%	25,30%	10,04%	9,70%	-24,11%	14,76%
IT	31,51%	27,31%	9,37%	17,47%	-51,29%	-16,26%
LT	36,75%	52,03%	18,22%	39,90%	-29,51%	32,00%
LU	24,03%	21,98%	1,55%	26,54%	-19,94%	-10,90%
LV	29,49%	31,85%	-14,35%	0,34%	-13,73%	32,00%
NL	7,45%	-7,95%	15,26%	8,03%	-66,02%	-35,39%
PL	20,06%	33,33%	-3,46%	-5,02%	-29,57%	19,14%
PT	34,34%	59,14%	-2,15%	3,67%	-48,97%	-9,84%
RO	1,18%	20,78%	-16,03%	-19,78%	-54,88%	34,69%
SE	-6,08%	6,78%	-3,49%	2,78%	-60,35%	-58,37%
SI	14,57%	41,75%	1,44%	8,04%	-44,90%	-23,54%
SK	23,08%	33,33%	6,10%	2,26%	-44,90%	-30,61%
UK	37,58%	39,92%	14,04%	5,52%	-27,41%	24,11%

[35] Source: Eurostat

Table 22: Scenario 2: Percentage change in the values of ΔOPEX at sector level

	Residential	Services (P)	Services (NP)	Industrial (fuel UCM only)	Power
EU-26 max value	0,75% (IE)	0,64% (IE)	-1,00% (UK)	6,06% (LT)	13,01% (RO)
EU-26 min value	-48,75% (BG)	-48,91% (BG)	-52,22% (BG)	-82,82% (SE)	-59,29% (SE)
EU-26 average value	-19,98%	-20,13%	-23,07%	-15,79%	-21,18%
EU-26 median value	-20,72%	-20,78%	-22,57%	-11,93%	-21,89%

Table 23: Main findings of sensitivity scenario 2

	Residential	Services (P)	Services (NP)	Industrial (fuel UCM only)	Power
EU-26 max value	0,65% (IE)	0,60% (IE)	-0,96% (UK)	24,20% (LT)	12,93% (RO)
EU-26 min value	-38,25% (GR)	-44,68% (BG)	-46,69% (BG)	-66,43% (SE)	-59,03% (SE)
EU-26 average value	-16,82%	-18,93%	-21,36%	-19,04%	-21,06%

	Residential	Services (P)	Services (NP)	Industrial (fuel UCM only)	Power
EU-26 median value	-14,70%	-19,25%	-20,73%	-20,18%	-21,75%

4.1.5.3 Scenario 3 – Sensitivity of the UCM values on a change in the number of weeks that an appliance is in operation.

This scenario takes into account input received from the eSurvey, Section 4.3. The modifications introduced in the values of the input parameters to the UCM model are shown in Table 24.

Table 24: Scenario 3: Changes introduced in comparison to the Base Case

Sector	Operating weeks in year		
	Base case value	Scenario 3 value	Diff from Base Case [%]
Industrial	52	48 (no operation in August)	-8%
Residential – Space Heating	34	24 for Southern MS: (PT, ES, IT, GR)	-30%
Residential – Space Heating	34	44 for northern MS (GB, IE, DK, SE, FI, EE, LT, LV)	+30%

Findings are as follows, Table 25:

- Fuel UCM values in the Industrial Sector increase on average by less than 1%. A maximum increase of 1.65% is identified in the industrial UCM value of Sweden due to the larger contribution of the CAPEX part of the SE UCM in comparison to other MS.
- For the Southern countries, UCM values in the Residential Sector increased by a maximum of 3.5%
- For the Northern countries, UCM values in the Residential Sector decrease by up to 4%.

As the UCM is inherently related to utilisation, here we note that with increased utilisation reduced values are observed. In practice an opposite behaviour is anticipated for the CoDG with increased utilisation implying an increased dependence on natural gas.

Overall, we see that a change in the utilisation of alternative appliances results in a corresponding change in the sector UCM that is approximately an order of magnitude less than the change introduced.

Table 25: Scenario 3: Percentage change in the sector UCM in comparison to the Base Case

Southern MS			Northern MS		
MS	Residential	Industrial (fuel UCM only)	MS	Residential	Industrial (fuel UCM only)
PT	3,62%	0,41%	DK	-0,86%	1,16%
ES	2,34%	0,75%	EE	-1,99%	0,66%
IT	2,47%	0,46%	FI	-2,20%	1,48%
GR	3,25%	0,60%	IE	-2,28%	0,75%
			LV	-2,14%	0,67%
			LT	-1,22%	0,85%
			SE	-4,21%	1,65%
			UK	-0,92%	0,80%

4.1.5.4 Scenario 4 – Sensitivity of the UCM values on an increase in the appliance and equipment lifetime

Scenario 4 takes into account input received from the eSurvey, Section 4.3. Modifications introduced in comparison to the Base Case are shown in Table 26.

Table 26: Scenario 4: Changes introduced in comparison to the Base Case

Sector	Appliance	Appliance and equipment lifetime		
		Base case value	Scenario 3 value	Difference from Base Case [%]
Residential Services (P) Services (NP)	Stove	10	20	+100%
Residential Services (P)	Electric water heater	10	20	+100%

Sector	Appliance	Appliance and equipment lifetime		
		Base case value	Scenario 3 value	Difference from Base Case [%]
Services (NP)				
Residential Services (P) Services (NP)	A/C	10	20	+100%
Residential Services (P) Services (NP)	Other electric appliances (space heating)	7	20	+186%
Residential Services (P) Services (NP)	Heat pump	15	20	+33%
Industrial	Oil fired boiler	10	20	+100%
Industrial	Electric boiler	10	20	+100%

An increase in the equipment lifetime by as much as 100-150% results in a decrease in the average UCM values by about 5%, Table 27. The maximum decrease in absolute terms was identified in the Residential sector of Sweden (up to -19,5%). Due to increased contribution of the CAPEX part of the UCM (in comparison to the ΔOPEX) and the relatively high contribution of the residential consumption to the overall gas consumption.

Table 27: Main findings of sensitivity scenario 4

	Residential	Services (P)	Services (NP)	Industrial (fuel UCM only)
EU-26 max value	-2,11% (DE)	-0,79% (DE)	-0,62% (DE)	-2,45% (PT)
EU-26 min value	-19,50% (SE)	-9,49% (LT)	-7,58% (SE)	-9,90% (SE)
EU-26 average value	-6,78%	-2,67%	-2,07%	-5,07%
EU-26 median value	-5,54%	-2,03%	-1,82%	-4,55%

4.2 Estimation of the UCM for natural gas-as-feedstock

Figure 30 presents feedstock UCM sectors by Member State. As discussed in Section 3.2, these values are essentially relevant solely for the chemical/petrochemical sub-sectors.

Substantial differences amongst MS are identified: The feedstock UCM is

- **below 100 euros/MWh for 7 MS** (HR, LT, SK, HU, BG, PL, NL),
- **ranges from 100-200 €/MWh for 4 MS** (GR, BE, RO, CZ, FI),
- **from 200-300 €/MWh for 1 MS** (AT) and
- **from 300-400 €/MWh for 2 MS** (IT, DE).
- **For France, United Kingdom and Spain the respective UCM values are at 657, 694 and 807€/MWh respectively**.
- **Slovenia is an outlier of this approach peaking at 2067 €/MWh**.

Figure 30: Industrial Sector (Gas as a feedstock) – Member State level UCM_{MS}^{CP}

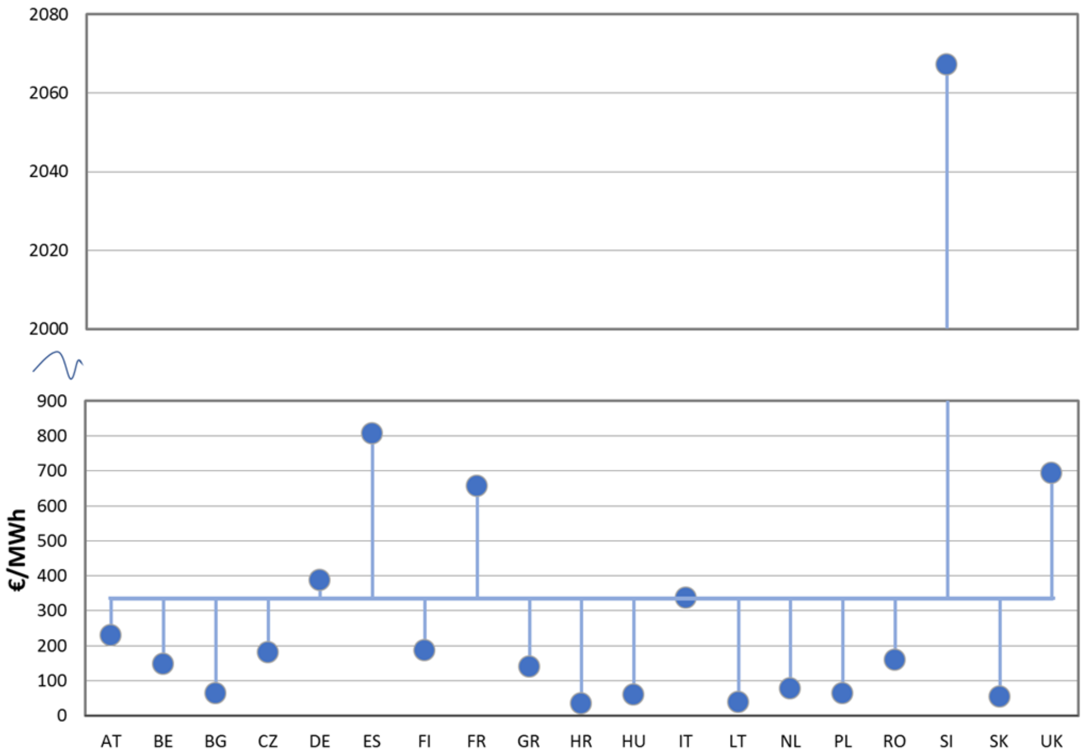


Table 28: Industrial Sector (Gas as a feedstock) – Summary of Member State level UCM_{MS}^{f}

Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
		Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
336	159	34	-90	HR	2067	516	SI

Table 29: Input data to the feedstock UCM calculation[36]

MS	GVA_{MSj}^{CP} [million €]	Proportion of GVA_{MSj}^{CP} to the total GVA of Industry sector [%]	$m_{gas\ as\ feedstock}^{CP}$ [MWh]	$\frac{m_{gas\ as\ feedstock}^{CP}}{m_{gas}^{CP}}$ [%]	UCM [€/MWh]	Difference from EU Mean [%]
AT	849	3	3,728,333	43	228	-32
BE	1,690	11	11,484,444	46	147	-56
BG	198	4	3,166,111	46	63	-81
CZ	200	3	1,115,556	26	180	-46
DE	10,697	6	27,588,056	33	388	16
ES	4,097	5	5,075,278	21	807	141
FI	44	4	236,667	52	186	-45
FR	4,195	5	6,386,667	16	657	96
GR	566	4	4,044,722	89	140	-58
HR	162	2	4,763,333	79	34	-90
HU	304	4	5,138,889	66	59	-82
IT	2,242	3	6,658,333	38	337	0
LT	415	5	10,953,333	88	38	-89
NL	1,857	8	24,114,722	55	77	-77
PL	1,552	3	24,623,333	86	63	-81
RO	616	2	3,880,833	36	159	-53
SI	121	4	58,611	10	2067	516
SK	234	2	4,488,889	79	52	-84
UK	3,289	4	4,740,278	26	694	107

36 Please refer to Section 3.2 for a definition of the symbols

From Table 29, it is straightforward that the high value for Slovenia is due to the low non-energy use of natural gas and the comparatively high GVA.

In an effort to assess further the reasons leading to the high value of the Slovenian UCM and also to quantify the sensitivity of the calculations, we examined historical data for the period 2013-2015, Table 30. We looked into the feedstock EU-26 average UCM value and respective values for Croatia and Slovenia. Croatia was chosen for this exercise as its Chemical/Petrochemical Sector GVA is similar to the Slovenian. However, the resulting UCM value is a factor of 1000 lower.

As shown in the Table 30, feedstock UCM levels seem to change only moderately with time. For the particular case of Slovenia, it is recommended that the specifics of its Chemical Petrochemical sector are looked into more detail in a future study.

Table 30: Selected estimates of feedstock UCM for the period 2013-2015

MS	UCM Value [€/MWh] 2013	UCM Value [€/MWh] 2014	Percentage change between 2013 and 2014 [%]	UCM Value [€/MWh] 2015	Percentage change between 2013 and 2015 [%]
HR	31	36	13	34	8
SI	2420	2485	3	2067	-15
EU 26 – Average	326	322	-1	336	3

4.3 Main Findings from the modified hypothetical cost estimate approach.

This section reports on the findings from the implementation of the modified hypothetical cost approach.

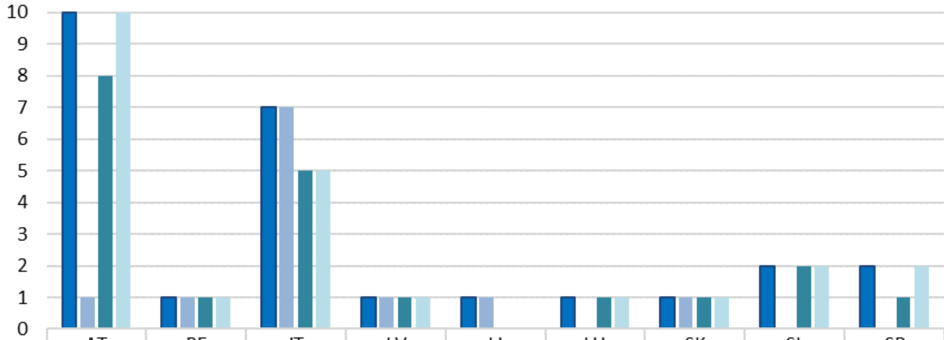
4.3.1 Residential Sector

4.3.1.1 Participation

Reponses to the Residential Sector Questionnaire were received from Austria (10), Belgium (1), Italy (7), Latvia (1), Lithuania (1), Luxembourg (1), Slovakia (1), Slovenia (2) and Spain (2).

All respondents from Austria use gas for space heating, 8 use gas for water heating and only 1 uses gas in cooking, Figure 31. On the other end, all Italian respondents use gas for cooking and 5 out of 7 respondents use gas for both space heating and water heating. Slovenian and, Spanish participants and the respondent from Luxembourg use gas for water and space heating. Overall, all end-user types are represented however the limited participation calls for caution in the interpretation of the findings presented in the forthcoming sections.

Figure 31: Residential Sector: Respondents by Member State and end-use of gas



	AT	BE	IT	LV	LI	LU	SK	SL	SP
All respondents	10	1	7	1	1	1	1	2	2
cooking	1	1	7	1	1	0	1	0	0
water heating	8	1	5	1	0	1	1	2	1
space heating	10	1	5	1	0	1	1	2	2

Table 31: Residential Sector - Alternative appliances in case of gas disruption

use of natural gas	alternative appliances in case of gas disruption	number of respondents	Appliance considered as an RAA in the UCM methodology (Y/N)
cooking	electric kitchen	10	Y
	LPG cooking appliance	3	N
	microwave	17	N
	other (e.g. food out)	1	N
	Nothing	2	nap
water heating	electric water heater	24	Y
	solar water heater	3	N
space heating	air conditioning	11	Y
	heat pumps	7	Y
	burner using alternative fuel	10	Y
	Nothing	1	nap

4.3.1.2 Findings

Fuel switching

Table 31 shows that in the event of a gas disruption most of the respondents would use

- An electric kitchen or a microwave for cooking
- An electric or a solar heater for water heating
- An air-conditioning unit, a burner burning heating oil or other alternative fuel or a heat pump for space heating.

We note that the LPG cooking appliance, the microwave and the solar water heater were not included in the UCM calculations and that these should potentially also be taken into account in a future study.

Only 2 out of 26 respondents informed that their decision to purchase an alternative appliance was a result of a gas disruption.

Table 32: Residential Sector - Monthly dependency on natural gas – all uses. Colours indicate the percentage of responses received for each cell. The colour scale is shown below.

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Months	Dependence on natural gas (%)					Total respondents
	0-20	20-40	40-60	60-80	80-100	
January	8%	8%	8%	23%	54%	26
February	8%	12%	12%	15%	54%	26
March	15%	8%	15%	42%	19%	26
April	23%	12%	31%	31%	4%	26
May	42%	35%	8%	12%	4%	26
June	58%	19%	12%	8%	4%	26
July	58%	19%	12%	8%	4%	26
August	62%	12%	15%	8%	4%	26
September	42%	15%	23%	15%	4%	26
October	23%	23%	12%	23%	19%	26
November	23%	4%	19%	15%	38%	26
December	8%	15%	12%	19%	46%	26

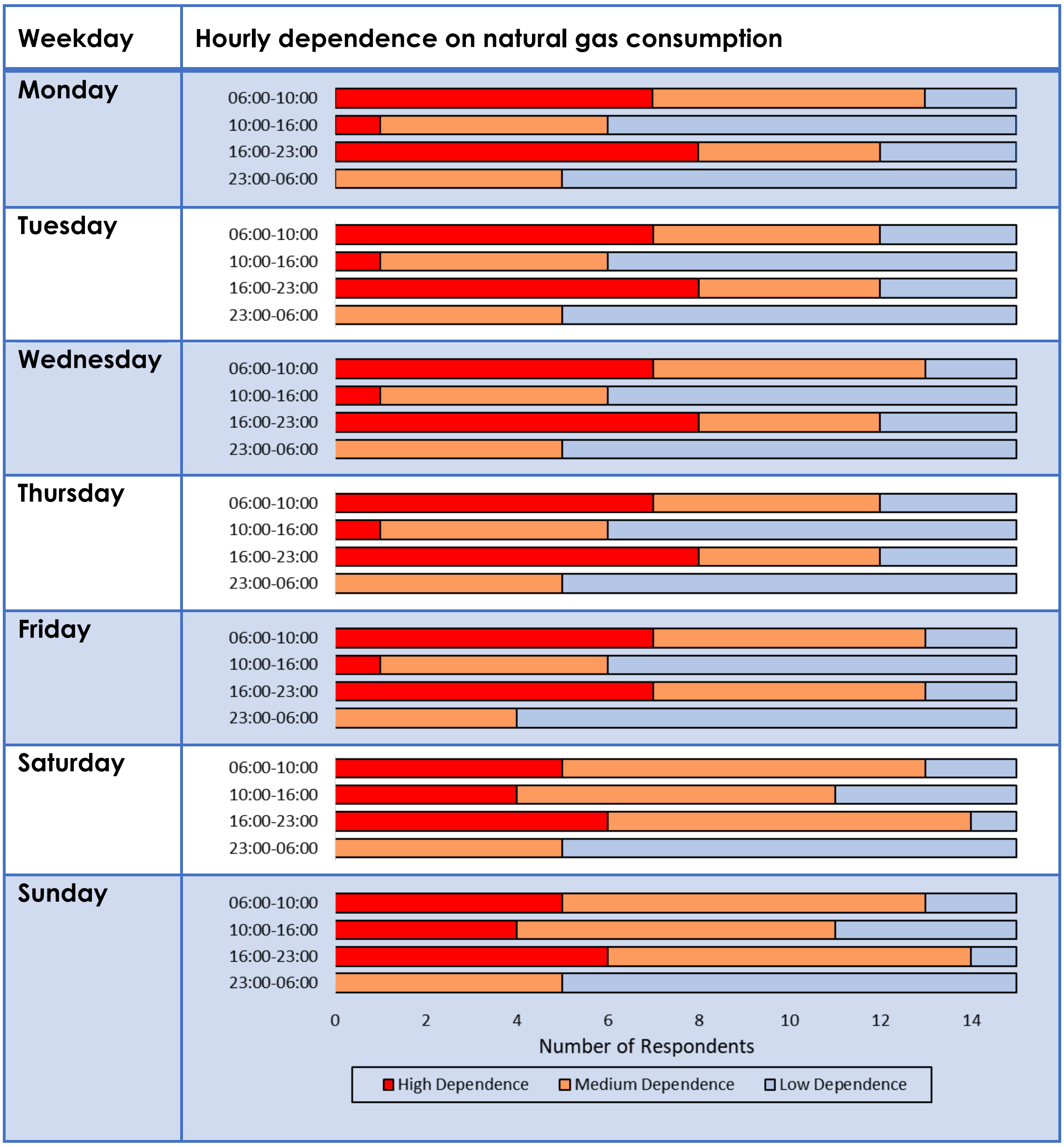
Sector dependence on natural gas consumption by month and time of day

Table 32 shows the monthly dependence of respondents on natural gas consumption. The Table has been drawn as an aggregate of all end-uses. Over 60-70% of the respondents indicated that their maximum consumption is in the months of January, February, March, October, November and December due to increased heating requirements and also due to requirements for water heating as confirmed by Table 100 and Table 101 in Appendix 21. Some increased dependence from October to March is also identified in cooking, Table 102 in Appendix 21. Further analysis over a larger sample is required to confirm these findings.

Table 33 shows that natural gas consumption in the residential sector is highest during from 06:00 to 16:00 am and 23:00 a.m. from Monday to Friday. During weekends, increased consumption is also identified during the morning/early afternoon hours from 10:00-16:00. Natural gas consumption dependence by time of day, day of week and type of end-use is shown in Table 103, Table 104 and Table 105 in Appendix 21.

We note that hourly consumption patterns have been taken into account when determining the operating times of alternative appliances in the UCM calculations, Appendix 5.

Table 33: Residential Sector - Hourly dependency on natural gas



Participants reaction on the proposed CoDG methodology and values

Table 34 presents the respondents reaction to the proposed UCM values and their own proposals for a potential CoDG. As shown in the Table 34, most participants proposed values approximately 2-3 times higher the proposed UCMs but well below the ENTSOG.

Once again, we stress that findings in this section should be treated with caution due to the limited sample size. A systematic study by Member State and at national languages is in our view required to further assess these findings.

Table 34: Residential Sector – Participants reaction on the UCM values and CoDG proposals

MS	Responses	Residential UCM (€/MWh)	Realistic values		Proposed CoDG values (€/MWh)					
			Yes	No	1	2	3	4	5	6
AU	10	**82**	8	2	*130-163*	*196-246*	-	-	-	-
BE	1	**147**	0	1	*293-390*	-	-	-	-	-
IT	7	**119**	1	6	*0*	*146-183*	*220-290*	*366-549*	*366-549*	*549-1098*
LV	1	**91**	0	1	*145-191*	-	-	-	-	-
LU	1	**107**	1	0	-	-	-	-	-	-
LT	1	**84**	1	0	-	-	-	-	-	-
SK	1	**118**	0	1	*98*	-	-	-	-	-
SI	2	**87**	0	2	*140-175*	*210-263*	-	-	-	-
ES	2	**111**	0	2	*243-324*	*324-486*	-	-	-	-

4.3.2 Power and Industrial Sectors

4.3.2.1 Participation

Reponses to the Power and Industrial Sector Questionnaire were received mainly from Italy (30 out of 48 responses, 63%). The next larger contribution was from the UK (6 responses, 13%). Participation of the remaining countries was limited, Figure 32 and Figure 33.

Figure 32: Power and Industrial Sectors: Respondents by Member State

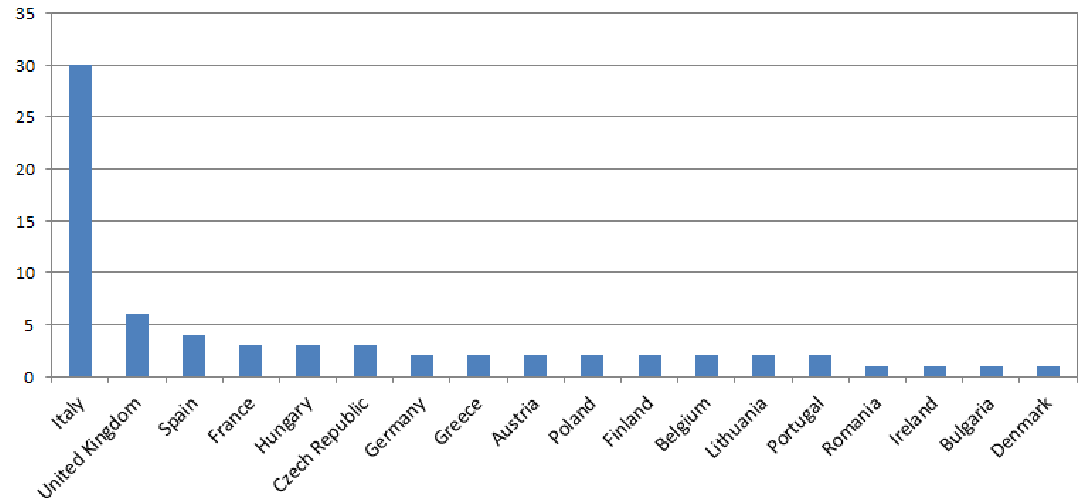


Figure 33: Industrial Sector only: Respondents by Member State

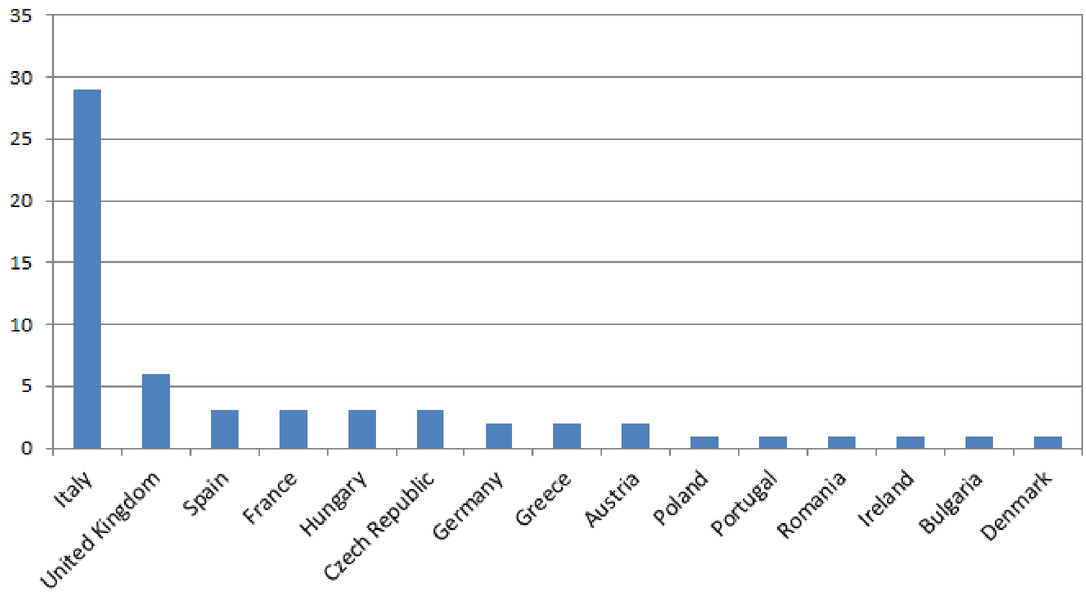
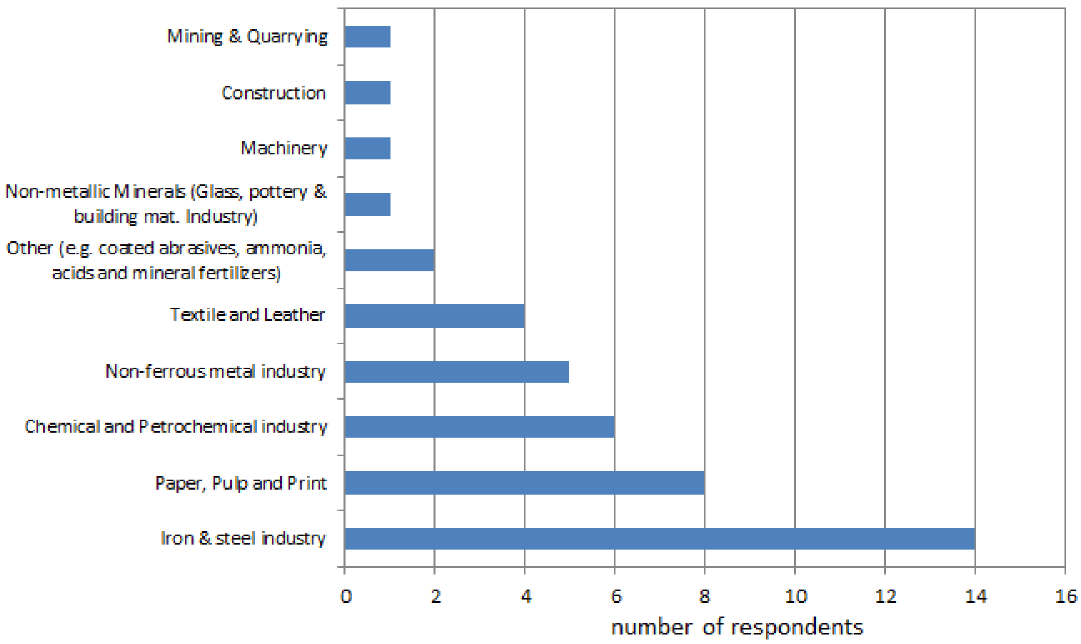


Table 35: Industrial Sector - Total respondents

industrial Sector		
Use of natural gas	as fuel	30
	as feedstock	12

Figure 34: Industrial Sector - Breakdown of industrial respondents by subsector



Industrial Sector

Figure 35 confirms the substantial contribution of Italy to this effort and the limited contribution of the remaining Member States. Thus, in addition to the fact that caution needs to be exercised while interpreting the results reported herein due to the limited sample size, we also caution about a potential geographical bias.

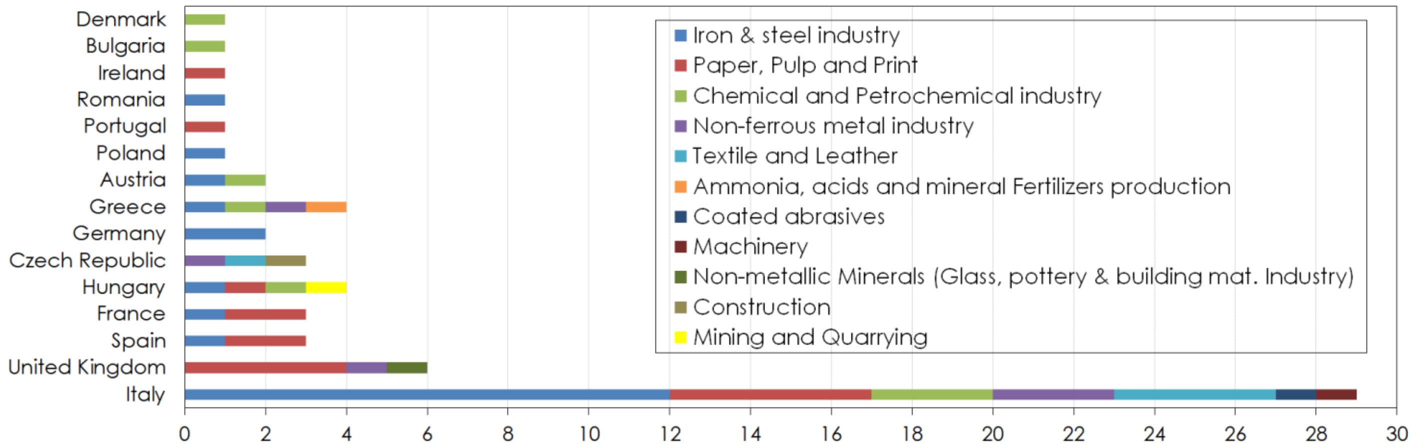
Out of 40 participants, 30 (75%) acknowledged that they use gas only as a fuel, 8 use gas only as feedstock and 4 responded use gas both as a fuel and as feedstock. Respondents acknowledge that they fire natural gas in several types of facilities such as boilers, CHP units, furnaces, ovens etc.

Responses were received mostly from the following industrial sub-sectors, Figure 34 and Figure 35:

- **Iron and Steel** (21 responses from 9 MS - IT, ES, FR, HU, DE, GR, AT, PL and RO)
- **Paper, Pulp and Print** (16 responses from 7 MS - IT, UK, ES, FR, HU, PT, IE)
- **Chemical and Petrochemical Industry** (8 responses from 6 MS - IT, HU, GR, AT, BG, DK)
- **Non-ferrous metals** (6 responses from 4 MS – IT, UK, CZ, GR)

Representation for the remaining industrial subsectors was limited.

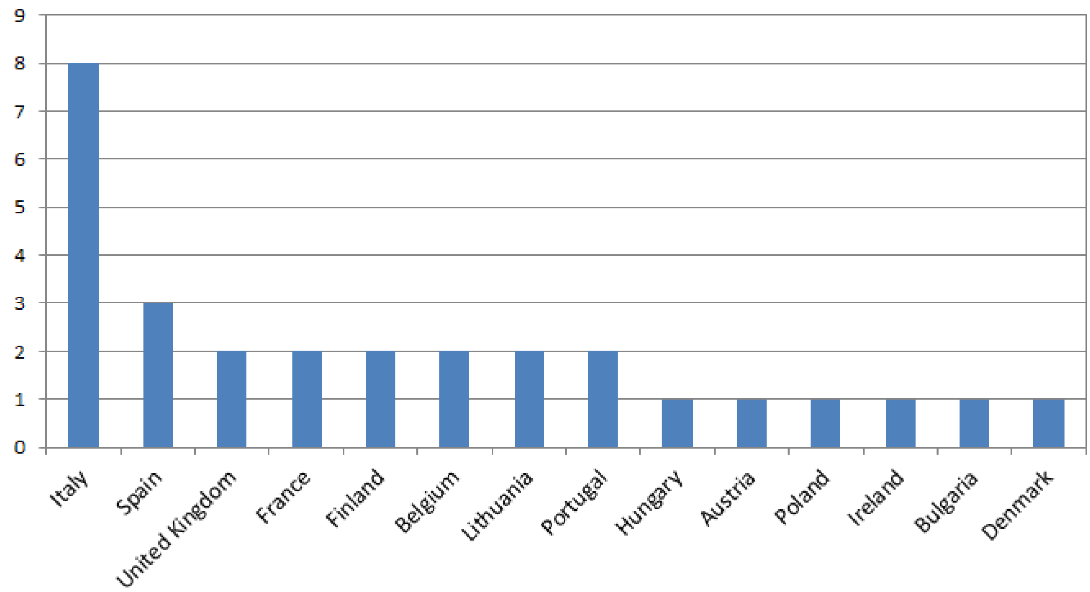
Figure 35: Industrial Sector – Respondents by country and sub-sector



Power Sector

Figure 36 presents the geographical distribution of power sector respondents. Once more the substantial contribution of Italy is noted although overall sampling size is low (8 responses from Italy, less than 5 by the participants from the remaining Member States).

Figure 36: Power Sector - Countries at which power production facilities are located



Eleven (11) out of 17 respondents acknowledged that they are active in the power markets of their respective countries, Table 36. Nine (9) respondents are also active in the industrial sector and use electricity for their own needs.

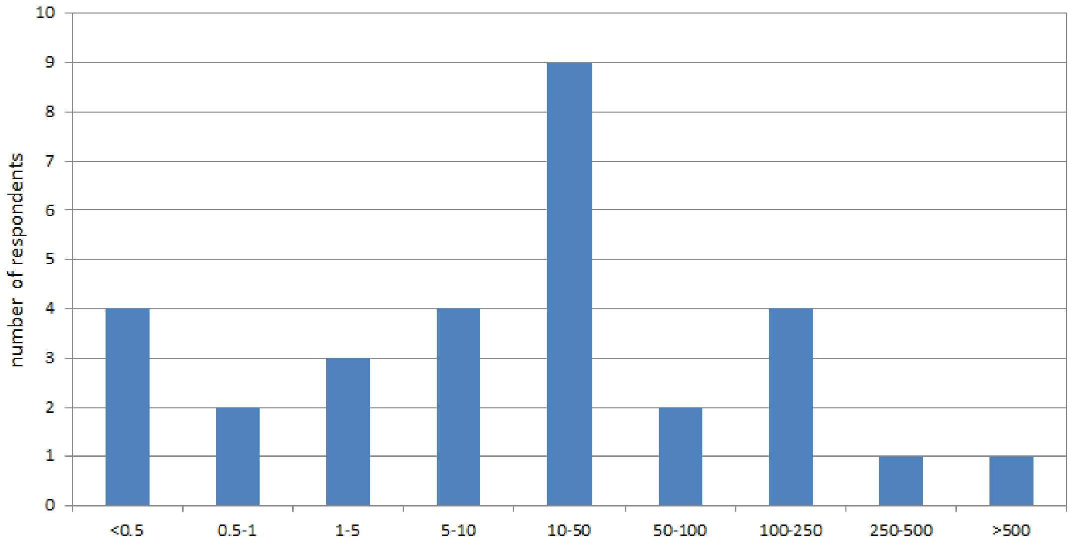
Table 36: Power Sector - Total respondents

Power Sector		
use of electricity	electricity production for own needs	9
	active in power market	11

4.3.2.2 Findings

Industrial Sector

Figure 37: Industrial Sector – Capacity (MW) of natural gas firing equipment



Natural gas-as-fuel

This section presents collected information in relation to the use of natural gas-as-fuel in the European industries. Once more readers are cautioned that due the relatively small sample size and the potential geographical bias, results should be treated with caution.

Natural gas firing equipment owned by the respondents is mostly below 100 MW, Figure 37. It may be postulated that this type of equipment refers most likely to comparatively small size combustion equipment (burner-boiler) for the production of heat and steam for industrial processes. Four out of 30 respondents indicated that they own facilities in the range of 100-250 MW (CHP Unit). One respondent indicated the presence of firing facilities of the order of 250-500 MW (Furnaces). Only one participant mentioned natural gas firing equipment over 500 MW (Furnaces). Despite the small number of samples, which inevitably leads to conclusion biasing, it is noted that results indicate that the industrial sector is dominated by comparatively a large number of small scale) firing appliances (<100 MW). This finding may have implications to the design of demand response mechanisms and the potential of certain industrial sectors to partly limit down production.

Figure 38: Industrial Sector – Per annum average utilization of natural gas firing equipment (percentages correspond to production at full load)

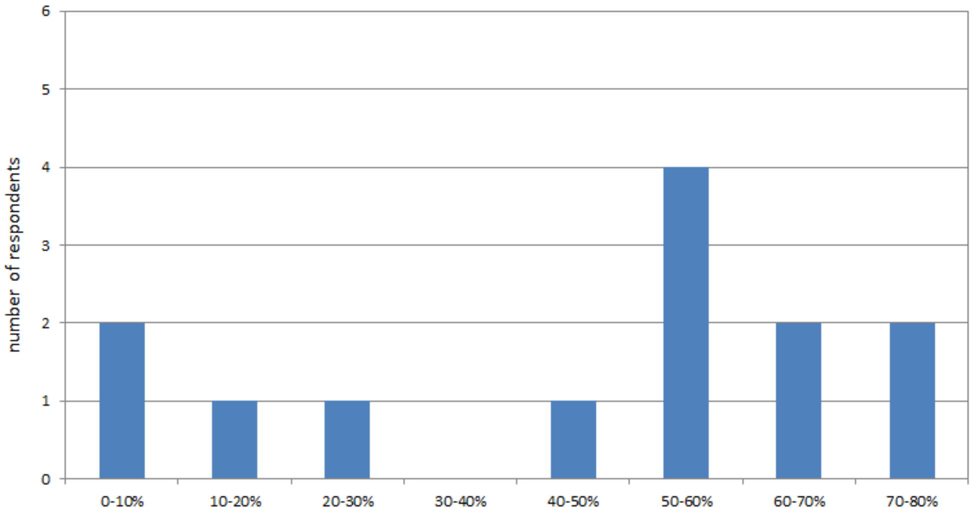


Figure 38 shows that most of the natural gas firing appliances of the respondents are used at loads from 50 to 80%. No respondent acknowledged utilisation at full load. It is unknown if partial loading of equipment is due to capacity oversizing or other reasons. In any case, if this operational mode is indeed true (and not a result of the sample biasing of this survey), it clearly indicates that the capacity of gas firing equipment alone may not be an appropriate indicator for regulators and security of supply competent authorities of Member State should they be needing to evaluate gas consumption requirements of the industrial sector. For the purposes of our work, this finding indicates that the operating time, as taken into account in the UCM calculations can indeed be an appropriate parameter in the context of quantifying the cost of gas disruptions in addition to the other parameters incorporated in the model.

Half of the eSurvey participants responded that natural gas is consumed as fuel at a percentage of 90-100% of their overall fuel requirements. This means that half of the survey participants use exclusively natural gas and no other fuel, Figure 39. Thirty (30%) of the respondents use natural gas-as-fuel at levels of 50-90% of their overall consumption. This finding implies that certain facilities have access to and use alternative fuels in addition to natural gas. Another 20% are using gas-as-fuel at limited levels below 40% of their overall fuel consumption.

Once more we call for caution in the interpretation of findings which here suggest that some industrial users are more dependent on natural gas than others. Nevertheless, we acknowledge the importance of this finding on CoDG levels.

Figure 39: Industrial Sector - Requirements in natural gas-as-fuel as a percentage of overall fuel consumption

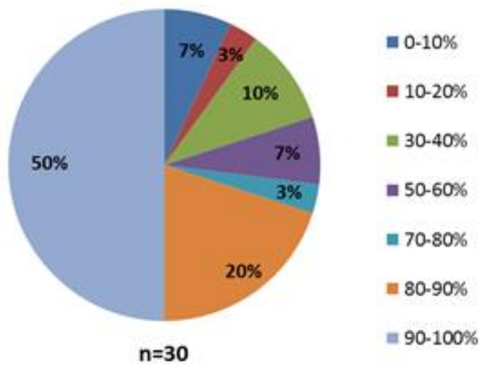
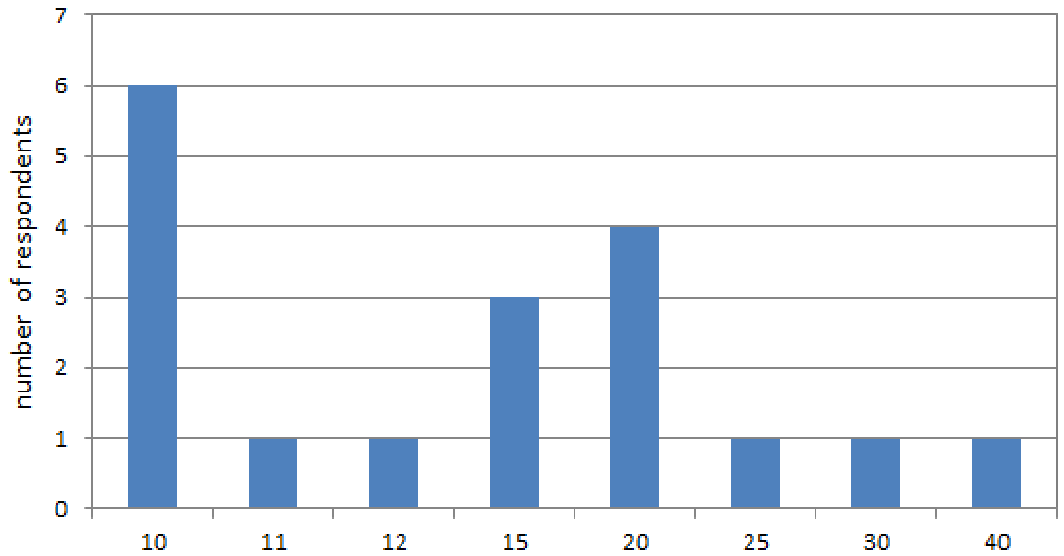


Figure 40: Industrial Sector – Lifetime of natural gas firing equipment



An input parameter to the UCM methodology is the lifetime of the alternative equipment, Section 3.1.1. Figure 40 shows that 6 out 18 respondents (30%) tend to replace equipment in 10 years. Five (5) out of 18 respondents (27%) replace equipment in 11-15 years, 4 respondents (22%) replace equipment in 20 years. Finally, 3 more respondents noted that they replace equipment in 25, 30 and 40 years. We note that in the UCM calculations presented in Section 4.1, a lifetime of 10 years was used. The effect of increased values as those provided by respondents in the MHC approach were also assessed. The reader is referred to the sensitivity analysis of Section 4.1.5 for further details.

Table 37: Industrial Sector – Responses to questions related to fuel switching

Questions	Number of responses		Total respondents
	Yes	no	
Do your facilities have fuel switching capabilities?	4	27	31
Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?	2	2	4

As the UCM methodology is to a grant extent based on a fuel switching assumption, we considered it useful to enquire if fuel switching is actually currently available in European industrial facilities. Table 37 indicates that the use of alternative fuel is not a common practice. Half of the respondents, however, mentioned that they reached a decision to install dual fuel facilities following a gas supply interruption. Table 141 and Table 142 in Appendix 22 provide further analysis by industrial subsector and country.

eSurvey participants with fuel switching capabilities informed that the level of fuel maintained in storage is commonly adequate to meet demand of 1-2 days of peak consumption. Alternative fuels kept in storage include LPG or CNG rather than light fuel oil which was considered as an alternative fuel in the context of the UCM approach implemented herein.

Participants were also asked about the cost of maintaining alternative fuel in storage. According to the responses received, the operating cost per annum for maintaining fuel switching facilities (not including the cost of the alternative fuel e.g. alternative fuel replacement fired during a planned maintenance procedure) is of the order of, or less than 5-10% of the overall OPEX of the facility. The additional operating cost for replacing alternative fuel fired during a planned maintenance is also of the order of 5-10%. Participants further informed that alternative fuel facilities (including storages) require weekly and annual checks and testing of the fuel-firing appliances by use of the alternative fuel. Such information may be taken into account in a future refinement of the UCM methodology to include additional costs related to the capital and operating costs of installing and maintaining alternative fuel storage facilities.

Natural gas-as-feedstock

Most respondents (92%) stressed that it is impossible to modify the production chain by substitution of natural gas for an alternative substance, Figure 41. However, when asked which alternative material they would be using if they were to substitute natural gas 24% indicated that natural gas maybe substituted by LPG, hydrogen or other substances, Figure 42.

Figure 41: Industrial Sector: Reponses on Feedstock substitution potential; (a) all responses;(b) breakdown by sector,

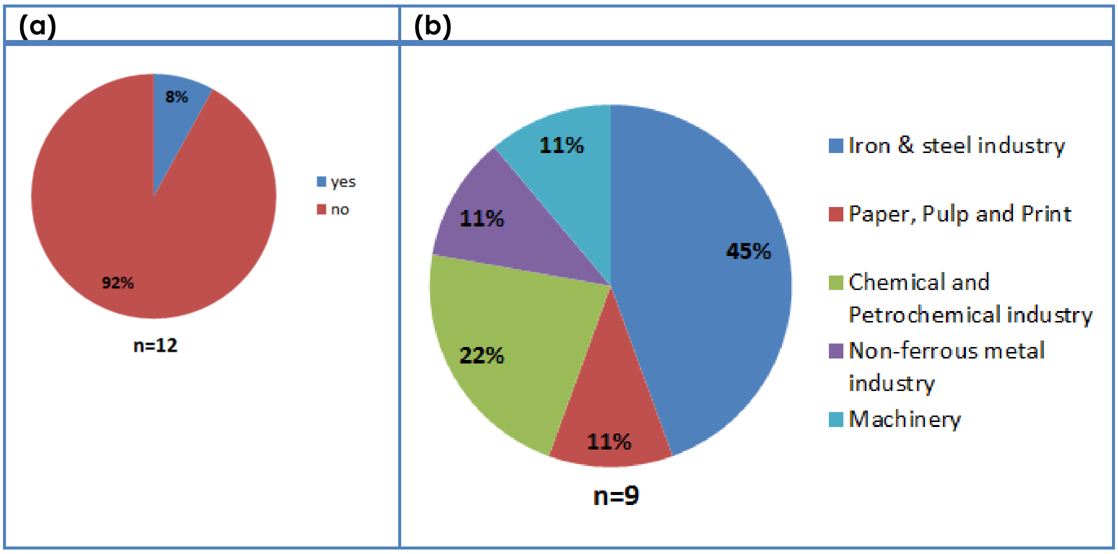
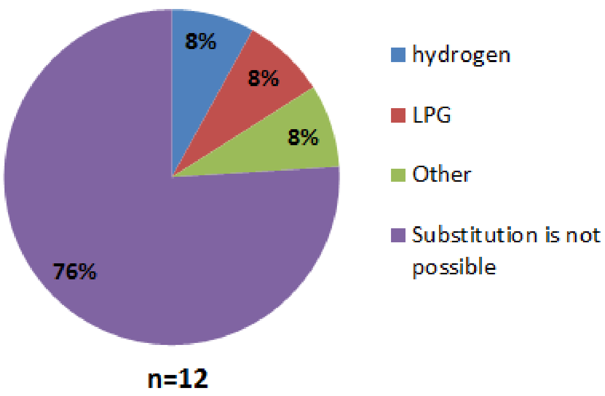


Figure 42: Industrial Sector: Substances commonly used to substitute natural gas in the production chain



Sector dependence on natural gas consumption by month and time of day

Respondents confirmed that with exception of the month of August, overall natural gas consumption is to a good approximation constant throughout the year, Table 38.

Appendix 22 presents similar information at industrial sub-sector level.

We note that in the UCM calculations of Section 4.1, we assumed utilisation of gas firing equipment in the industrial sector 52 weeks per year (i.e. 12 months). This assumption is revisited and assessed under Sensitivity Scenario 3 (Section 4.1.5.3) were it is shown that the effect of a reduction in the weeks of operation from 52 to 48 (to account for the reduced consumption in August) is only minor (of up to 1.5%).

Table 38: Industrial Sector - Monthly dependence on natural gas

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

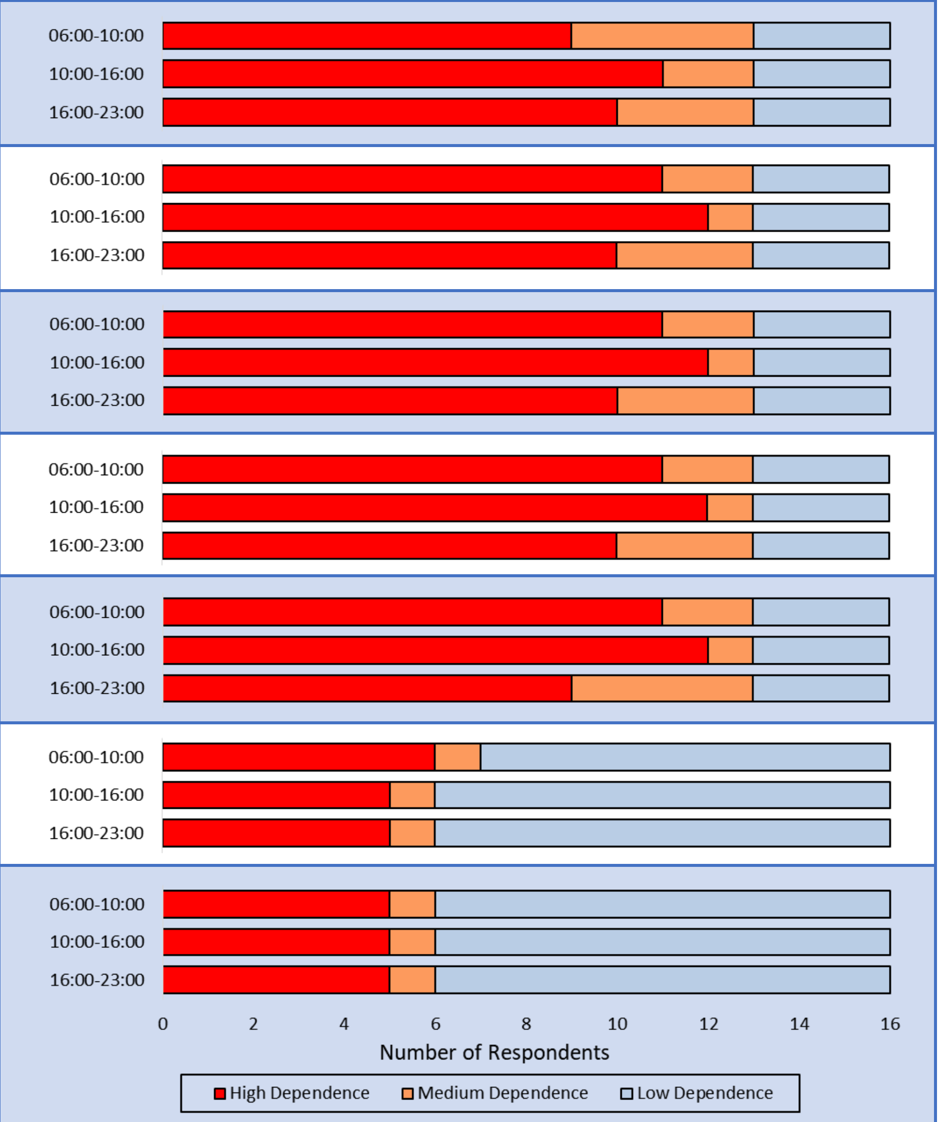
Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	10%	5%	0%	5%	79%	39
February	8%	8%	0%	3%	82%	39
March	13%	3%	0%	3%	82%	39
April	13%	5%	0%	5%	77%	39
May	13%	5%	0%	5%	77%	39
June	10%	8%	0%	5%	77%	39
July	10%	8%	0%	5%	77%	39
August	21%	13%	5%	10%	51%	39
September	13%	5%	0%	5%	77%	39
October	13%	5%	0%	5%	77%	39
November	10%	5%	0%	3%	82%	39
December	10%	5%	0%	8%	77%	39

Respondents indicated that natural gas consumption is highest during the time intervals from 10:00 to 16:00 from Monday to Friday, Table 39. During weekends, most participants report a reduced natural gas consumption. We note that no responses were received for the time interval from 23:00 – 06:00.

It is noted that in the UCM calculations presented in Section 4.1, we assumed a constant sector dependence on natural gas 24 hours a day, 7 hours a week. A reduced utilisation to accommodate the finding of the MHC approach was assessed in the context of the sensitivity analysis carried out in Section 4.1.5 however the effect was only minor.

Table 39: Industrial Sector - Hourly dependency on natural gas

Weekday	Hourly dependence on natural gas consumption
Monday	
Tuesday	
Wednesday	
Thursday	
Friday	
Saturday	
Sunday	



Sector dependence on natural gas curtailment level and duration of disruption

Table 40 shows that more than 60 % of the eSurvey participants indicated that the level production drops to 0-10% for a gas loss of 100%. The number of participants acknowledging a reduction of production to 0-10% increased to over 75% for a disruption duration of 8-24h. Loss of production was acknowledged by over 85% of the participants for disruptions exceeding 24 h.

Curtailments of the order of 30-70% of the peak day demand also lead to reductions in the production of 0-10% as acknowledged by more 40-50% of the participants. The duration of curtailment does not seem to have a significant effect in maintaining production activity.

Table 40: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration

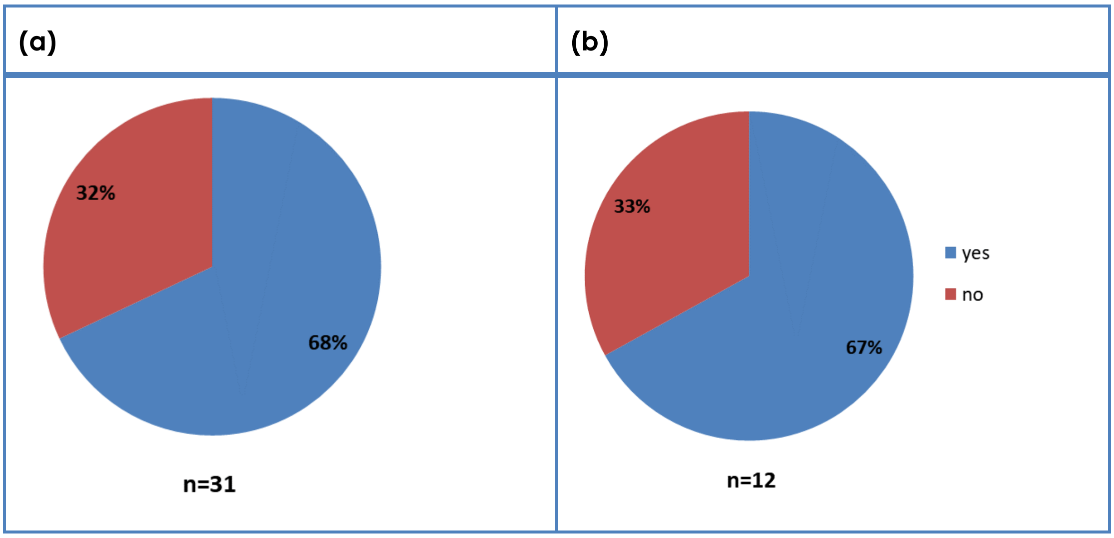
<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	60%	13%	10%	5%	8%	5%	40
	4-8h	63%	13%	8%	13%	0%	5%	40
	8-16h	73%	10%	8%	5%	3%	3%	40
	16-24h	78%	8%	5%	3%	3%	5%	40
	24-48h	85%	3%	3%	3%	0%	8%	40
	48-96h	83%	5%	3%	0%	5%	5%	40
70	2-4h	40%	10%	18%	8%	8%	18%	40
	4-8h	43%	5%	23%	10%	8%	13%	40
	8-16h	50%	8%	20%	10%	5%	8%	40
	16-24h	50%	10%	15%	13%	5%	8%	40
	24-48h	55%	10%	15%	8%	5%	8%	40
	48-96h	55%	10%	18%	5%	8%	5%	40
30	2-4h	28%	13%	13%	13%	20%	15%	40
	4-8h	30%	13%	13%	18%	18%	10%	40
	8-16h	33%	13%	18%	15%	15%	8%	40
	16-24h	43%	8%	15%	13%	15%	8%	40
	24-48h	50%	8%	10%	10%	15%	8%	40
	48-96h	50%	8%	10%	10%	18%	5%	40

Respondents reaction to the proposed CoDG methodology and values

Figure 43 shows that the majority of respondents did not object the proposed methodology.

Figure 43: Industrial Sector – Agreement with our approach - a) Gas as a fuel, b) Gas-as-feedstock



A number of comments and suggestions were received in relation to the improvement of the UCM methodology. One participant stressed that a method that considers the cost of sourcing alternative fuels such as the one proposed here is a useful exercise to show the importance of supply continuity. However, the alternative fuel option shouldn't necessarily be seen as a viable alternative to secure supplies. The participant also pointed out that practical considerations related to the actual implementation of an alternative fuel approach should be taken into account (such as regulatory approvals for fuel storage tanks, physical space to accommodate such changes etc). Another participant commented that the approach should be further refined by discounting the CAPEX as per a specified depreciation rate, regardless of utilisation or the lifetime. A third participant cautioned that the approach is based on a cost of delivery (based on an alternative fuel for gas) and not cost of gas disruption. Finally, a fourth participant indicated that care is needed in the selection of appropriate technologies and fuels to be used in the UCM calculations towards a CoDG. As an example, it was noted "*it is not possible to use electricity as an alternative to temporarily heat a gas fired kiln, either the technology does not exist, or substantial modification would be required. While oil fired options could be possible it would be expensive to install, maintain and implement such a system for back-up firing*".

Table 41 and Table 42 present the respondents reaction to the proposed UCM values and their proposals for a potential CoDG. It is useful to note that proposals are well within the order of magnitude of the proposed UCM values. The Tables are drawn for the cases of continuous operation. Participants were also asked to provide CoDG values in case facilities are operated in an intermittent mode. Results are summarised in Table 43 and Table 44.

Finally, Table 45 presents the participants proposals for a feedstock CoDG. It can be seen that with the exception of Italian and Greek respondents, the remaining participants propose values similar to the feedstock UCMs calculated in the previous section.

It is stressed again that findings in this section should be treated with caution due to the limited sample size and geographical biasing.

Table 41: Industrial Sector – Gas as a Fuel Participants reaction on the UCM values and CoDG proposals (continuous operation – oil fired boiler)

MS	Responses	Industrial UCM value (oil fired boiler) (€/MWh)	Realistic values		Proposed UCM value (€/MWh)				
			Yes	No	1	2	3	4	5
CZ	2	9	2	0	-	-	-	-	-
FR	2	18	2	0	-	-	-	-	-
DE	1	16	0	1	18-23	-	-	-	-
GR	1	14	1	0	-	-	-	-	-
HU	1	12	1	0	-	-	-	-	-
IE	1	14	1	0	-	-	-	-	-
IT	11	13	6	5	12-14	14-18	18-24	24-36	36-72
PT	1	28	1	0	-	-	-	-	-
ES	2	7	2	0	-	-	-	-	-
UK	4	8	2	2	0	16-24	-	-	-

Table 42: Industrial Sector – Gas as a Fuel, Participants reaction on the UCM values and CoDG proposals (continuous operation - electric boiler)

MS	Responses	Calculated UCM value (electric boiler) (€/MWh)	Realistic values		Proposed UCM value (€/MWh)				
			Yes	No	1	2	3	4	5
CZ	2	***49***	2	0	-	-	-	-	-
FR	2	***73***	2	0	-	-	-	-	-
DE	1	***127***	0	1	151-189	-	-	-	-
GR	1	***83***	1	0	-	-	-	-	-
HU	1	***51***	1	0	-	-	-	-	-
IE	1	***96***	1	0	-	-	-	-	-
IT	11	***125***	6	5	124-149	149-186	186-248	248-372	372-744
PT	1	***90***	1	0	-	-	-	-	-
ES	2	***81***	2	0	-	-	-	-	-
UK	4	***108***	2	2	0	216-324	-	-	-

Table 43: Industrial Sector – Gas as a Fuel, Comments of participants on proposed UCM as a proxy to the CoDG (intermittent operation - oil fired boiler)

MS	Responses	Calculated UCM value (oil fired boiler) (€/MWh)	Realistic values		Proposed UCM value (€/MWh)				
			Yes	No	1	2	3	4	5
AU	1	***8***	0	1	24-48	-	-	-	-
BG	1	***15***	0	1	45-90	-	-	-	-
CZ	1	***10***	1	0	-	-	-	-	-
DK	1	***45***	0	1	135-270	-	-	-	-
HU	1	***13***	0	1	13-16	-	-	-	-
IT	11	***14***	6	5	11-14	14-17	14-17	21-28	>84
UK	1	***9***	1	0	-	-	-	-	-

Table 44: Industrial Sector – Gas as fuel, Comments of participants on proposed UCM as a proxy to the CoDG (intermittent operation - electric boiler)

MS	Responses	Calculated UCM value (electric boiler) (€/MWh)	Realistic values		Proposed UCM value (€/MWh)				
			Yes	No	1	2	3	4	5
AU	1	***73***	0	1	219-438	-	-	-	-
BG	1	***59***	0	1	177-354	-	-	-	-
CZ	1	***52***	1	0	-	-	-	-	-
DK	1	***65***	0	1	195-390	-	-	-	-
HU	1	***55***	0	1	69-83	-	-	-	-
IT	11	***129***	6	5	103-129	129-155	129-155	194-258	>774
UK	1	***115***	1	0	-	-	-	-	-

Table 45: Industrial Sector – Gas as a Feedstock, Comments of participants on proposed UCM as a proxy to the CoDG

MS	Responses	Calculated UCM value (€/MWh)	Realistic values		Proposed UCM value (€/MWh)			
			Yes	No	Value 1	Value 2	Value 3	Value 4
AU	1	***228***	0	1	490-613	-	-	-
FR	1	***657***	0	1	558-697	-	-	-
DE	1	***388***	0	1	818-1023	-	-	-
GR	1	***140***	0	1	>2988	-	-	-
HU	2	***59***	0	2	448-538	448-538	-	-
IT	8	***337***	4	4	688-860	860-1032	12901720	1720-2580
PL	1	***63***	0	1	444-555	-	-	-
RO	1	***159***	0	1	632-791	-	-	-
ES	1	***807***	0	1	601-751	-	-	-
UK	1	***694***	0	1	791-989	-	-	-

Power Sector

Fuel switching

Participants to the survey indicated a per annum average utilization of natural gas firing equipment of up to 70%.

The majority of respondents indicated that they do not have fuel switching capabilities. For those with dual firing equipment, light fuel is used as alternative to natural gas. Storage capacity is of the order of 1-5 days of operation at full load. According to the responses received, the operating cost per annum for maintaining fuel switching facilities (not including the cost of the alternative fuel e.g. alternative fuel replacement fired during a planned maintenance procedure) is of the order of, or less than 5-10% of the overall OPEX of the facility. The additional operating cost for replacing alternative fuel fired during a planned maintenance is also of the order of 5-15%. All participants indicated that their decision to install a dual burner was unrelated to a supply disruption. Only two participants out of 17 indicated that they receive compensation when requested to switch to the alternative fuel.

Sector dependence on natural gas consumption by month and time of day

Respondents confirmed that with a minor exception during the summer months (May to September), overall natural gas consumption is to a good approximation constant throughout the year, Table 46.

We note that in the UCM of Section 4.1, we assumed utilisation of gas firing equipment in the power sector 51 weeks per year (i.e. almost 12 months). This assumption may need to be further refined in a future revision of the UCM values. Our sensitivity analysis of Section 4.1.5 indicated however that changes in the operating time have only a minor effect (up to 1.5%) in the UCM values.

Table 46: Power Sector - Monthly dependence on natural gas

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

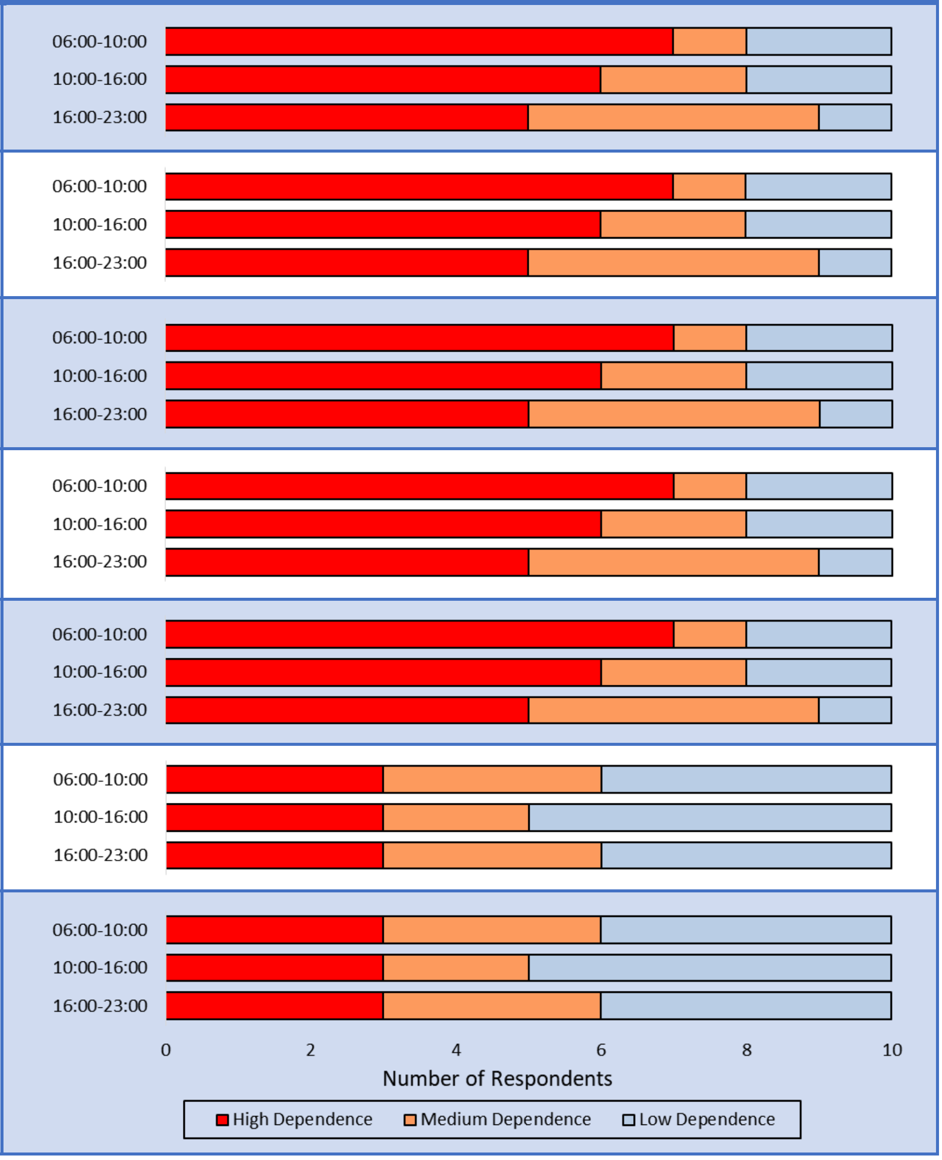
Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	12%	18%	6%	6%	59%	17
February	12%	18%	6%	6%	59%	17
March	18%	12%	12%	0%	59%	17
April	18%	6%	24%	0%	53%	17
May	18%	18%	18%	0%	47%	17
June	18%	6%	24%	6%	47%	17
July	18%	12%	18%	6%	47%	17
August	18%	18%	6%	18%	41%	17
September	24%	6%	12%	12%	47%	17
October	18%	12%	12%	6%	53%	17
November	12%	6%	12%	12%	59%	17
December	12%	6%	18%	6%	59%	17

Respondents indicated that natural gas consumption is highest during the time intervals from 06:00 to 10:00 from Monday to Friday, Table 47. During weekends, most participants report a reduced natural gas consumption.

We note that with the exception of a single participant, no responses were received for the time interval from 23:00 – 06:00. The single participant who responded to this question indicated that natural gas requirements in the night interval are low for all days of the week. As no other responses were received, we chose not to report this finding in the Table 47.

Table 47: Power Sector - Hourly dependency on natural gas

Weekday	Hourly dependence on natural gas consumption
Monday	
Tuesday	
Wednesday	
Thursday	
Friday	
Saturday	
Sunday	



Sector dependence on natural gas curtailment level and duration of disruption

Table 48 confirms that the level production drops to 0-10% for a gas loss of 100% as typically no alternative fuel burners are installed. Curtailments of the order of 30-70% of the peak day demand also lead to similar reductions in production. Responses are to a good approximation the same regardless the disruption duration

Table 48: Power sector - % of output activity continued as a function of level of curtailment and disruption duration

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	71%	0%	6%	12%	0%	12%	17
	4-8h	71%	0%	6%	12%	0%	12%	17
	8-16h	71%	6%	0%	12%	6%	6%	17
	16-24h	76%	0%	0%	6%	12%	6%	17
	24-48h	76%	0%	0%	6%	12%	6%	17
	48-96h	76%	0%	0%	6%	12%	6%	17
70	2-4h	35%	6%	6%	18%	6%	29%	17
	4-8h	35%	6%	12%	12%	6%	29%	17
	8-16h	35%	12%	12%	6%	6%	29%	17
	16-24h	35%	12%	12%	6%	12%	24%	17
	24-48h	35%	12%	12%	6%	12%	24%	17
	48-96h	35%	12%	12%	6%	12%	24%	17
30	2-4h	24%	12%	6%	18%	18%	24%	17
	4-8h	24%	18%	0%	24%	12%	24%	17
	8-16h	24%	18%	6%	18%	12%	24%	17
	16-24h	29%	12%	6%	18%	12%	24%	17
	24-48h	29%	12%	6%	18%	12%	24%	17
	48-96h	29%	18%	0%	18%	12%	24%	17

Respondents reaction to the proposed CoDG Methodology and values

Figure 44 shows that the majority of respondents do not object to the proposed methodology.

Table 49 presents the proposed CoDG values. These range from being equal to the UCM at circa 90 €-MWh to over 500 €-MWh.

Figure 44: Power Sector – Agreement with our approach

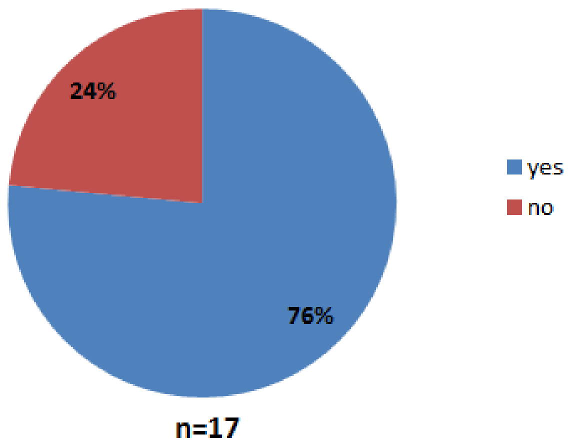


Table 49: Power Sector - Gas as a Fuel Participants reaction on the UCM values and CoDG proposals

Responses	Calculated UCM value (electric boiler) (€/MWh)	Realistic values		Proposed UCM value (€/MWh)								
		Yes	No	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Value 7	Value 8	Value 9
17	60	8	9	*71-89*	*107-134*	*134-178*	*178-267*	*267-534*	*267-534*	*>534*	*>534*	*N.A.*

4.3.2.3 Comments made by power and industrial sector interviewees

This section summarises the main points raised during the interviews. Findings are presented in terms of the following subtopics:

- General comments on the study and methodology and security of gas supply,
- Gas and electricity interdependence
- The conceptual difference between the solidarity price and the cost of gas disruption in the context of the CBA
- Proposed general rules for the estimation of the cost of disruption and potential values
- Proposed specific rules for the estimation of the solidarity price
- Alternative fuel approaches, dual Fuel facilities and CoDG values
- Consequential value approaches for estimating the cost of a disruption
- The CoDG as an administrative cap
- Monetary impact of a disruption in the context of a CBA methodology

General	Interviewees agree that, with the exception of the East/South East Europe which has been affected by the Russian-Ukrainian crises, customers elsewhere in the EU have received natural gas without any problems for at least over the last decade. Thus, there are no estimates on the cost of gas disruption. Interviewees also agree that a regulatory framework attempting to set the CoDG for a customer should be simple and transparent. Sophisticated approaches may lead to failure due to the subjective nature of the VoLL and the CoDG. Differences are expected between customer categories and Member States.
Gas and electricity interdependence	Interviewees agree that the growing interdependence between the gas and electricity sectors and markets in Europe makes the exercise of estimating the cost of gas disruption even more complex. Interviewees also highlight that is important to guarantee security of gas supply to gas fired power generators (through the critical installation option provided by Regulation (EU) 2017/1938) so that they are in turn able to provide security of electricity supply. Coordination between electricity and gas TSOs in neighbouring countries is equally important to address and limit the effects of a gas crisis.

Conceptual difference between the solidarity price and the cost of gas disruption in the context of the CBA	Interviewees share the view that the solidarity cost of gas disruption is not equal to the cost of gas disruption in the context of a CBA methodology and a TYNDP. The former addresses a comparatively short-term impact of a disruption while the latter aims to quantify the benefits of a new infrastructure which will be delivering gas over several decades.
Proposed general rules for the estimation of the cost of disruption and potential values	Interviewees acknowledge that CoDG values depend on numerous factors (duration of disruption, the day of the week, context of the crisis, industrial process or economic activity involved, etc). They agree that the Value of Lost Load for electricity (VoLL) or the CoDG should not interfere with the market functioning and should not hinder the emergence of scarcity values in case of tense situation on the supply-demand balance. In other words, estimates should not prevent spikes in commodity prices in case of adequacy issues. One interviewee proposes numerical values for natural gas (> 500 €/MWh) and electricity (> 3000 €/MWh). Another interviewee informed that national statistics have been used to derive some values of the CoDG. Calculations give results in the range from 100 to 20,000 €/MWh. Two interviewees note that detailed values by sector/country may not be possible but rather CoDG estimates should be reported in terms of orders of magnitude. It cannot certainly be set at an order of precision of 1 €. All agree that administratively set costs of disruption can play the role of a price caps in the commodity market (wholesale market) in both gas and electricity. To make sure that this is not the case, sufficiently high values should be pursued. Two interviewees note that CoDG values for protected consumers (vis-à-vis risk of disruption) should be in line with the underlying rational for protecting these consumers. This inherently implies that disruption cost estimates for protected customers should be higher than the respective estimates of non-protected customers.
Proposed specific rules for the estimation of the solidarity price	Interviewees agree that incentives need to remain in place so that voluntary demand reductions materialise. Voluntary

and potential values	demand reductions reduce the likelihood of involuntary supply interruptions and the associated economic costs. Interviewees share the common opinion that the cost of gas supply in the event of a disruption in the solidarity receiving Member State should be set by market value. An interviewee specifies that the cost of gas for the country receiving the solidarity (SR-MS) should depend on two things: (1) the market value of the cost of gas at the solidarity providing MS (SP-MS) and (2) a premium for the solidarity service delivered. This scenario assumes that the SP-MS is not in a crisis situation. Items (1) and (2) above should equal the value of the compensation to be paid to the forcibly disrupted consumer, with the premium essentially closing the gap between the value of lost load and the gas market price. Another interviewee proposes that the cost of gas disruption (CoDG) to be set as follows • In the event that a disruption of gas supply causes the market to stop functioning and requires solidarity arrangements to be implemented, the average market price of gas of the 30 days prior to the disruption could be used as a proxy. • In regions where there is no functioning gas market, the price of gas at a nearby functioning gas hub (NBP / TTF) could be used as a proxy. A third interviewee highlights that in case of isolated gas markets, illiquid markets or countries without functional hubs where Over-the-Counter (OTC) contracts are concerned, the price of the long-term contracts cannot be considered as representative to the price of gas in a crisis. According to the interviewee in such a case the value of gas at the nearest gas market (or any relevant approximation using the neighbouring market price) should be considered.
Alternative fuel approaches, dual Fuel facilities and CoDG values	One interviewee note that dual fuel facilities may be appropriate for cases where uninterrupted supply of energy is critical to a consumer. In such cases, the existence of dual fuel facilities would reduce the CoDG to zero, or to a value dependent on the difference in fuel efficiencies. For consumers that do not have dual fuel facilities installed, the CoDG could be very high.

Consequential value approaches for estimating the cost of a disruption	Interviewees agree that the value of natural gas should be limited to the value of the product and not the consequences of using the product. Consequential value approaches (such as the GVA approach or the GDP approach used by ENTSOG) have distinguishable drawbacks in their implementation in practical cases. It is not a simple task to estimate the level of consequential damage experienced by a certain sector/industry in the case of a gas disruption. Consequences such as loss of production and loss of reputation can lead to a massively high price. It is acknowledged that in some sectors the computed ratio (GVA to gas consumption) is large due to a large nominator (GVA) and a comparatively small denominator (limited gas consumption), Interviewees caution that the consequential damage approach, particularly in the context of solidarity arrangements could seriously undermine the concept of solidarity, as Member States requesting solidarity would have to pay a very high price. They further caution that such an approach (of high CoDG values due to the consequential damage approach) could introduce a perverse incentive to hold back voluntary demand reductions in anticipation of an emergency. This could increase the risk of involuntary supply interruptions and increase the associated economic costs.
The CoDG as an administrative cap	Participants caution that the VoLL (or CoDG) should not prevent (or be a barrier) to the emergence of scarcity prices that reveal a tense situation in the supply and demand balance. In general, it is noted that in gas, even if there is no particular crisis but merely a tense situation the balance between supply and demand is quite fragile. In such a case, the gas price in the commodity market will increase. In case however that the value of lost load is set at quite a low value, then this affects the marginal price in the gas market and it does not allow for the scarcity value to be revealed. Essentially such a disruption price acts as a price cap and can be detrimental to the functioning of the wholesale market. On the other hand, in the context of the solidarity mechanism, an over inflated solidarity price will act as a countermeasure. The solidarity receiving MS will never accept an over-inflated gas price and solidarity will be never realised.

	The introduction of administrative caps while markets are still functioning should be avoided.
Monetary impact of a disruption in the context of a CBA methodology	One interviewee considers that the current value of ENTSOG (as used in the CBA methodology and the 2017 TYNDP) maybe be an overestimate of the actual monetary impact of a disruption for the purposes of new infrastructure. Another interviewee claims that the value of 600 $€/MWh$ currently used by ENTSOG is not irrelevant. The interviewee stresses that it is important to note the difference that exists between a protected customer and a non-protected customer and that the value of lost load between the two consumer categories needs to be different to reflect the fact that the protected customer should be supplied with gas at all circumstances. Thus, for protected consumers the value of lost load can be even higher than the 600 $€/MWh$ estimated by ENTSOG. On the other hand, for the non-protected customer, the social welfare at a national level is not so critical and such customers may be interrupted. Thus, the CoDG can be lower than the value of the protected customers. The interviewee adds that this differentiation between protected and non-protected customers) may need to be taken into account in the evaluation of a new investment for the sake of the CBA. The approach to determine a CoDG on the basis of the consequences that a disruption could have on the user of gas is not acceptable. This is similar to a consequential damage approach. Another interviewee points that the ENTSOG value is inflated as it includes the GDP contribution of activities that do not use gas or for which gas is not essential. The interviewee proposes that a more sophisticated approach is adopted by distinguishing between different categories of gas consumers in different Member States

4.4 Recommended CoDG values

A cross-sectoral UCM value per Member State is finally estimated by taking into account the fuel UCM by sector and the feedstock UCM for the chemical/petrochemical subsectors, as described in Section 3.4.

Table 50 presents the MS UCM, and for the sake of completeness the respective sector values. A summary of the MS UCM is provided in Figure 45.

Estimates are:

- In the lowest range of just below 50 €/MWh for Bulgaria and Lithuania.
- Between 50 and 60 €/MWh for the Sweden, Estonia, Croatia, Hungary, Czech Republic, Finland and Latvia
- Between 61 and 70 €/MWh for Austria, Greece, Romania, the Netherlands, Luxembourg, Poland and Slovenia
- Between 71 and 80 €/MWh for Ireland and Portugal
- Between 81 and 90 €/MWh for France, Italy, Slovakia, Spain and the UK
- Between 91 and 114 €/MWh for Belgium (93 €/MWh), Denmark (102 €/MWh) and Germany (114 €/MWh).

The EU-26 value, calculated through the application of different averaging (simple average, GDP weighted, gas consumption weighted) is shown in Figure 46. As shown in the Figure 46, differences due to different averaging approaches do not exceed 61%.

Table 50: UCM Values at Sector and Member State Level [€/MWh]

	Total UCM (€/MWh)					
MS	**Residential**	**Services (P)**	**Services (NP)**	**Industrial (F+F)[37]**	**Power**	**Member State**
Austria	82	75	71	59	51	62
Belgium	147	136	127	71	52	93
Bulgaria	62	53	53	43	59	49
Croatia	76	68	65	40	66	58
Czech Republic	64	57	54	37	53	51
Denmark	157	145	133	53	87	102
Estonia	71	6171	61	34	47	51

[37] Fuel and feedstock

MS	Total UCM (€/MWh)					
	Residential	Services (P)	Services (NP)	Industrial (F+F)[37]	Power	Member State
Finland	80	71	66	39	75	60
France	75	68	64	109	62	82
Germany	146	140	127	111	60	114
Greece	104	97	94	69	58	67
Hungary	70	63	65	40	57	59
Ireland	118	107	98	57	58	71
Italy	119	109	105	89	57	87
Latvia	91	81	77	51	48	55
Lithuania	84	68	56	37	50	45
Luxembourg	107	95	82	34	57	69
Netherlands	62	52	51	53	75	63
Poland	83	74	66	48	54	62
Portugal	105	94	90	60	72	72
Romania	84	74	70	48	56	63
Slovakia	118	96	87	55	63	84
Slovenia	87	77	72	64	65	69
Spain	111	102	94	94	51	81
Sweden	66	44	41	36	80	55
United Kingdom	118	107	101	92	52	88
EU-26 average value	**96**	**85**	**80**	**59**	**60**	**701**
EU-26 median value	**85**	**76**	**71**	**53**	**58**	**65**
EU-26 max value	**157 (DK)**	**145 (DK)**	**133 (DK)**	**111 (DE)**	**87 (DK)**	**114 (DE)**
EU-26 min value	**62 (NL)**	**44 (SE)**	**41 (SE)**	**34 (LU)**	**47 (EE)**	**45 (LT)**

Figure 45 Proposed CoDG values calculated through their UCM proxies at Member State level [€/MWh]

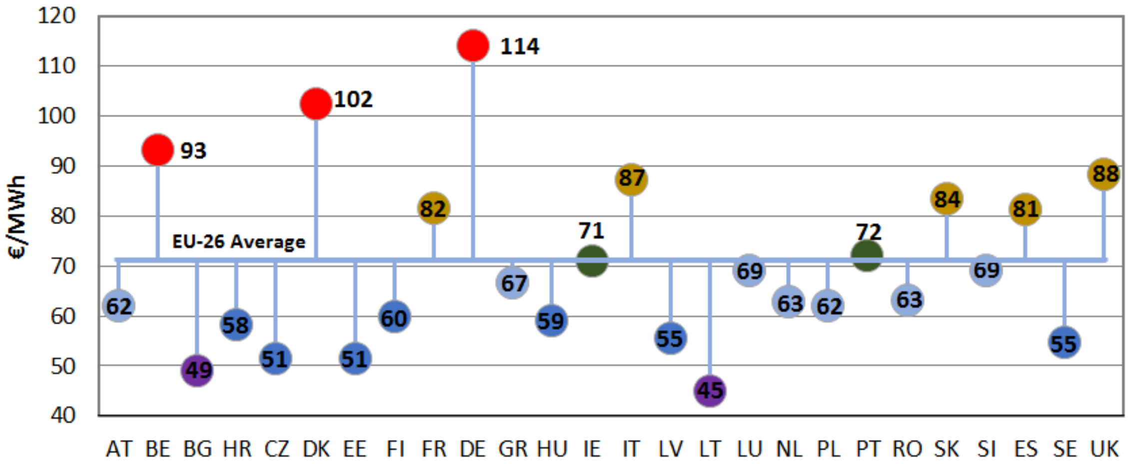
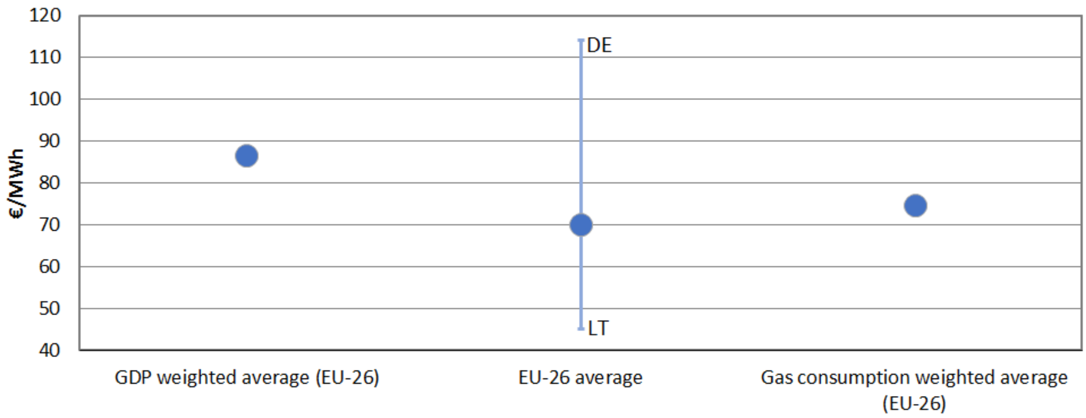


Figure 46: Average UCM value (EU-26)



In an effort to further assess dependencies of the UCM values on its input parameters but also on the Member State GDP and gas consumption, a number of correlation coefficients were calculated. Table 51 shows that the correlation between GDP and gas consumption is only week for the residential, services and power sectors. A comparatively strong correlation is identified for the industrial sector. As also shown in the Table 51, GDP and gas consumption are well correlated.

Table 51: Correlation assessments

Correlation values	Residential	Services (P / NP)		Industrial (F+F)	Power	Country level UCM
GDP/UCM	0,32	0,36	0,36	0,86	0,65	0,65
Gas Consumption/ UCM	0,32	0,36		0,81	-0,15	0,63
GDP/Gas Consumption	0,94	0,97		0,92	0,83	0,96

We note that throughout Sections 3 and 4 we refrained from using the term CoDG. The term UCM i.e. *unit cost measure* was used instead.

It is acknowledged that the fuel UCM calculated herein relates to the cost of substituting and operating, on a regular basis, an alternative appliance or equipment firing a fuel other than natural gas. As set by one respondent to our survey, the fuel UCM is rather a cost of delivery of a unit of energy by use of an alternative fuel, because natural gas is not available. This value may not necessarily coincide with a cost of a disruption. On the other hand, the GVA based approach for the chemical/petrochemical industry provides a measure of the consequential damage in the production chain in the case of a disruption, as it represents the value due to gas non-availability.

The methodology proposed in this study for both calculation streams (fuel and feedstock) is transparent, straightforward and does not discriminate between sectors and Member States. It sets for the first time in European level a base for the estimation on the cost of gas disruption by considering differences by sector and Member State.

Having said that, it may be argued that the UCM is only a proxy to the CoDG and further refinements may be necessary in the context of a future study.

We note for example that the UCM approach does not include:

(a) The subjective element of the value of gas to a customer. As brought forward by interviewees, the CoDG for a protected customer may be of a substantially larger value than the CoDG for non-protected customers to reflect the EU legal provisions for an uninterrupted supply to protected consumers. In this context, a weighted UCM value for residential and services-protected sectors calculated as the product of the fuel UCM by a large constant to reflect the sectoral dependence on gas and the social implications of a gas disruption may be more relevant.

(b) Assumptions on the probability of a disruption. The values for the fuel UCM estimated in this work relate to normal operation of an alternative appliance, i.e. they correspond to a unit cost as if the alternative appliance/fuel were used instead of the respective gas firing equipment. A cost of a disruption, however, may also need to reflect the fact that an alternative appliance will not be operated in a constant basis, but rather on the unlikely event of a disruption. Thus, the alternative appliance also includes a stranded cost due to non-use. The survey results, including the survey ran with the NRAs in the context of this study and results from ENTSOG'S 2017-Security of Supply Simulation Report show that with the exception of East/South-East Europe such disruptions are uncommon. Additional calculations taking into account revised operating hours may provide further insight towards the estimation of a CoDG. These calculations may reflect:

- A period of 2 weeks of disruption where the alternative equipment will function with a statistical probability of once in 20 years.
- One day of exceptionally high demand, (leading to a disruption) occurring with a statistical probability of once in 20 years.

In scenarios such as the ones above, the number of operating hours of the alternative equipment are expected to be substantially reduced from the values reported herein, leading to an increase in the UCM. A relevant CoDG value may then be calculated as the product of the fuel UCM multiplied by a constant to reflect the probability of a disruption.

5 Insights for a price methodology of solidarity gas

5.1 Proposed methods for monetizing the Solidarity Gas Price

This section highlights our proposed methodology for monetising the solidarity gas price. The approach uses some of the elements of the analysis of the previous sections.

Regulation (EU) 2017/1938 (Article 13, par. 8) sets that the compensation to be received by the Member State providing the solidarity (herein after Solidarity Provider, SP-MS) from the Member State requesting the mechanism (herein after Solidarity Recipient, SR-MS). According to the Regulation, the compensation should at least include the following items:

a) The gas delivered into the territory of the requesting Member State

b) All other relevant and reasonable costs incurred when providing solidarity including where appropriate costs of such measures that may have been established in advance.

c) Reimbursement for any compensation resulting from judicial proceedings, arbitration proceedings or similar proceedings and settlements involving the Member State providing the solidarity.

Based on the guidelines above, Figure 47 summarises the elements we consider to constitute the solidary price. These are the following

1. **The cost of using capacity at the interconnection point (IP) between the SP-MS and the SR-MS** This cost naturally involves the Exit tariff at the IP between the SP and the SR-MS.
   We distinguish here three possible options:
   - Solidarity gas is transferred from the SP-MS to the SR-MS through normal pipeline operation (e.g. without the need for the initiation of a physical reverse flow). The cost of using the IP capacity is determined by the existing transmission tariffs available on-line by all European TSOs and reported in the ENTSOG transparency platform
   - Solidarity gas is transferred from the SP-MS to the SR-MS through a physical reverse flow. However, physical reverse flow is offered as a commercial product and it is thus available during normal pipeline operation not just in the case of emergency. We note here that in cases where the realisation of the physical reverse flow was part of a PCI project, the related capital has already been split between the SP-MS and the SR-MS through the Cost Benefit-Cost-Allocation procedure (CBCA) and is funded through the transmission tariffs in both countries. Thus, also in this case the cost of reserving capacity at the IP can be calculated from the existing transmission tariffs. This tariff may or may

not be equal to the tariff above but in most cases, it is already available and published in the TSOs' websites. If tariffs for this case are still not available, regulators and TSOs' should be urged to make them available as soon as possible.

- Solidarity gas is transferred from the SP-MS to the SR-MS through a physical reverse flow initiated only in case of emergency (for the provision of solidarity). Tariffs in this case may not yet be determined. We will be looking further into this cost item further n Task B

2. **LNG regasification costs and costs of reserving capacity at an LNG entry point.** LNG regasification tariffs are published and generally available for both long term and short-term products which may be relevant for the case of a disruption. Tariffs for capacity booked at the regasified LNG entry point at the transmission system are also generally available by European TSOs.
3. **Costs related to the use of strategic storage**. We identify here three separate cost items
    a) The cost of the utilisation of withdrawal capacity for the provision of gas to the SR-MS.

    b) The cost of reserving capacity in the transmission system at the storage/transmission Entry point

    c) The cost of the quantity of gas withdrawn for solidarity purposes and

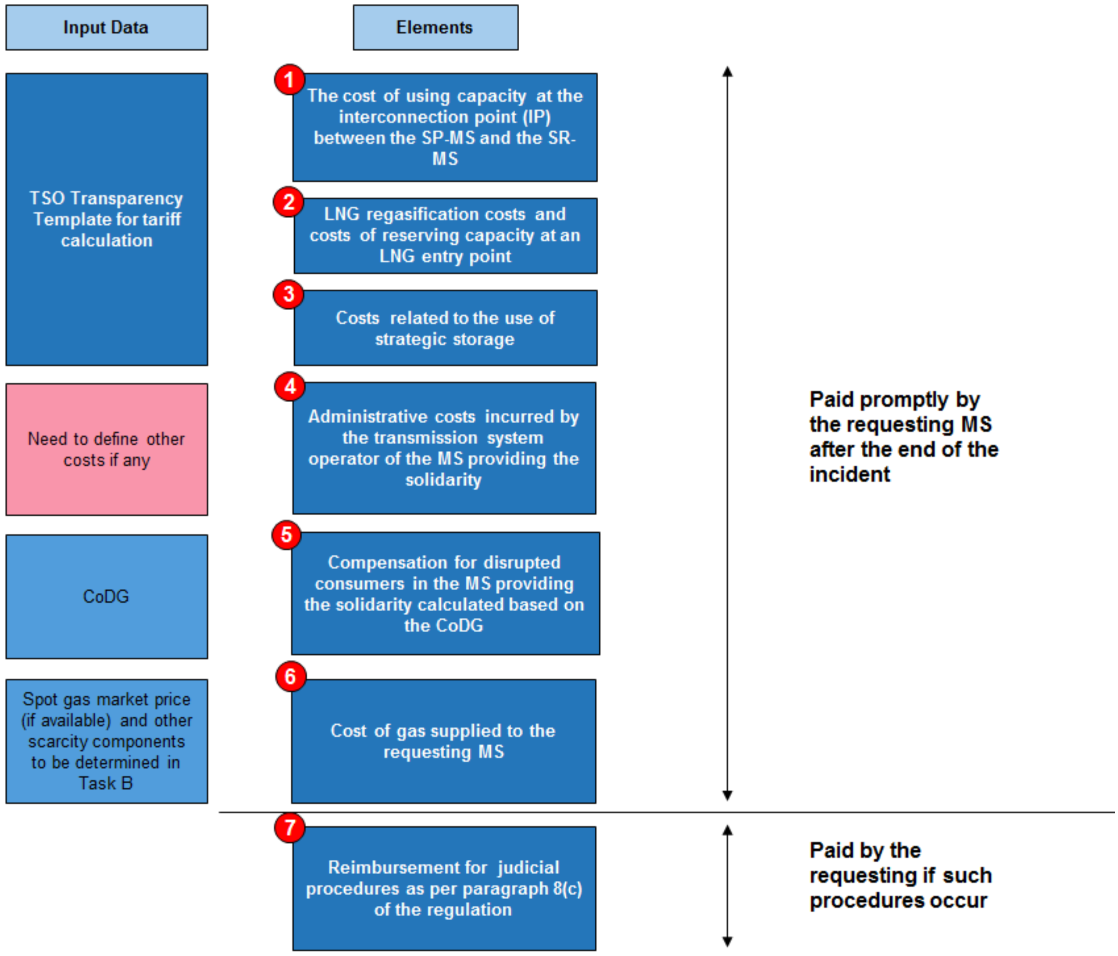
    d) The cost of the utilisation of injection capacity plus the cost of using any other additional transmission capacity to return the gas. This latter cost item is incurred by a SR-MS if there is a possibility of returning the gas withdrawn from the strategic storage after the end of the crisis rather than paying for the gas received. This means that the SR-MS returns the gas (commodity), In this case the SR-MS returns the gas then the cost item under (c) above also becomes relevant

4. **Administrative costs** incurred by the TSO, if any, for the provision of the solidarity transportation services. Such costs could be for example related to the actions necessary for the initiation of the emergency physical reverse such as
    - Fuel and electricity additional costs, if any, for the initiation of physical reverse flow
    - UFG and other system losses if any (and increased due to the provision of the physical reverse in comparison to normal flow direction)
    - Operational expenses for maintenance of the equipment to be used in physical reverse (if any and if not already included in the tariffs of the SR-MS as a result of the CBCA mechanism.

- Additional operational costs to support the physical reverse (extra shifts to be provided by the TSO, or the GSO, or the LSO -I doubt there is a need for the last 2 but I included them here for completeness)
- Other cost components

5. **A compensation** to be provided to the disrupted demand in the SP-MS if any. We will be using the CoDG value for the industrial sector developed in the first part of this study as a base for the compensation.
6. **The cost of gas** supplied to the SR MS. The discourse here is about remaining gas consumption that is so much valued by the consumers that it was not offered on the market, at least not at a price for which someone was willing to pay. If this would be the case, the system would not yet be in a solidarity stage and D/S could clear the missing gas.
7. **The reimbursement** for any compensation resulting from judicial proceedings, arbitration proceedings, sanction proceedings due to breaches of legal requirements in the SP-MS, for example, related to the obligation to keep strategic stocks, etc. as provided for in Article 8(c) of the Regulation. This is a clearly pass-through option for the SP party.

Figure 47: Methodology for the estimation of the solidarity gas price



5.2 Cost of gas supplied to the SR-MS

The European Commission recommendation 2018/177 on the mechanisms for solidarity gas state clearly that the price of the commodity gas should be reflective of market signals. This means that the cost of the gas should be directly set by market prices at the time the solidary request is activated. The market price may however not always be easy to establish. Particularly not in the case of a major supply disruption, where spot markets may be suspended (if spot market exists at all) or prices may be capped or frozen. It is therefore important to lay out the different price indicators that may be applied under different circumstances.

Applying one price indicator across all MS regardless of state of the gas market in the SP-MS at the time of the solidarity request would be too simplistic and not practical. We therefore provide ideas for five different price indicators that may be applied in the bilateral solidarity gas agreements depending on circumstance. These are:

- **Price indicator 1**: **spot market price** – Gas spot market price as and when solidarity gas is requested.
- **Price indicator 2**: **last observed spot market price** – Last observed gas spot market price in the SP-MS if the market is suspended at the time of the solidarity gas request.
- **Price indicator 3: skewed market price** – Gas price in the SP-MS market if government intervention in the market has skewed prices (e.g. frozen or capped prices).
- **Price indicator 4**: **bilateral contract price** – Highest bilateral contract price of non-protected customers interrupted as a result of solidarity gas request.
- **Price indicator 5**: **regional gas price** – Gas prices of a neighbouring market or regional hub where prices are most closely correlated with SP-MS market prices.

This section describes each of these methodologies and provides a range of scenarios under which each could apply. As part of the possible approach outlined, we propose a 'decision tree' to be applied during solidarity gas contract negotiations, which ensures that the most appropriate market price indicators apply for a range of possible scenarios.

The above price indicators and the decision tree could be revisited frequently during solidarity requests. A possible approach could be for the price indicators to change as and when the market conditions in the SP-MS change as well. This means that the choice of price indicators would be independent of the length of the interruption/solidarity request, but dependent on the conditions of the SP-MS.

This illustrated approach in this report cannot provide the fine details of each price indicator as these will result from the solidarity contract negotiations and be based on the nature of the SP-MS market. The objective of this section is to set out which pricing indicators could apply under each of the circumstances.

5.2.1 Price indicator 1: spot market price

If the SP-MS has a spot market, which continues to function effectively after the supply disruption, the spot market price at the time of the solidarity gas request should apply. Prices under such circumstances would reflect the supply shortages in neighbouring markets (providing the interconnector capacities are not restricted) allowing for a fair and adequate reflection of market conditions. Depending on the urgency required for gas supplies and the spot market structure in the sending market, the price could be set by day ahead prices or intraday settlement prices. For short term (within day) requirements the intraday prices should apply. For next day deliveries the day ahead, market price should apply. The details of timing on request for solidarity gas and delivery should be specified in the bilateral agreement between SP-MS and SR-MS. It is important to note that the additional demand from solidarity gas may result in a higher spot market price which essentially means that domestic consumers are charged for providing solidarity.

5.2.2 Price indicator 2: last observed market price

If the SP-MS has a spot market, but the market has broken down as a result of the supply disruption, the last observed market price – under specified circumstances – should apply. A number of reasons can be attributed to a breakdown or suspension of spot market trading. Most commonly however this will be because of a lack of liquidity on the market or a state entity acting as single buyer and redistributing gas at set prices. In such circumstances the spot market cannot provide an accurate price signal for solidarity gas.

A disruption of such severity that it leads to a suspension of spot market trading would in all likelihood need to be a sustained disruption of the majority of supply. The Initial supply shortages could still be sustained and would not require a complete suspension of the market. However, these initial signals will lead to increasing gas prices, reflecting the impending supply emergency. The increase in prices could be triggered by higher demand (e.g. customers maximizing load while it is still available) or the initial shortages of supply. Only under the most extreme scenario – a very sudden and unexpected disruption of all supply without alternative supply routes – may spot market prices not reflect circumstances of an emergency, as the emergency would occur at such short notice that markets would not have time to react. In such a scenario – the last observed spot prices would not be an accurate reflection of the market realities.

This means that the last observed market price should only apply when spot markets have reacted to supply shortages before the market was suspended. This could be measured by the European Commission's electricity price volatility index[38]. Concretely, solidarity gas contract parties should define a price volatility threshold above which spot market prices are deemed to have reflected the supply disruption. One possible measure that could be used would be to compare the weekly gas price volatility in

[38] European Commission document *Methodological description and interpretation of the volatility index for electricity markets.* Although only specified for electricity, the index can equally be used for gas market volatility measure as done by the GB energy regulator, Ofgem, for example

the, say, 5 trading days before the disruption of the market with average weekly volatilities over, say, 20 weeks before then. If the volatility index is above said, 5%, of the 20-week average, the last observed price is deemed to reflect the supply disruption and can be used as an adequate measure. Should the price volatility be under the agreed threshold, a separate price indicator should apply (see pricing option 4: bilateral contract pricing).

It is difficult to determine the threshold levels of gas price volatility that could apply across all European gas markets, as each market has its own dynamics and may be more or less volatile. Solidarity gas contract parties therefore need to negotiate the specific terms of (i) how to calculate the volatility, (ii) which volatility index applies and is compared to and (iii) the threshold above which market prices are deemed to reflect the supply disruption.

Another factor that should be considered when applying the last observed price is the duration of time between the solidarity request and the disruption of the spot market in the SP-MS. If a solidarity request is made two weeks after the spot market is disrupted (and remains disrupted), the last observed gas price may not be an adequate measure of market pricing. Conditions on the market may be very different after two weeks and the last observed price is unlikely to reflect the realities of new market conditions.

A possible idea could be to apply a maximum of five days after the suspension of the market to apply as a threshold value. If the request is done after five days, a separate price indicator should apply (see pricing option 4: bilateral contract pricing).

In conclusion therefore, two criteria need to be met in order for the last observed market price to serve as an adequate market price signal:

- *Volatility*: Gas spot prices in trading days (e.g. 5 days) before the market disruption need to display volatility of a pre-determined percentage (e.g. 10%) above the average price volatility observed in an extended period before (e.g. 20 weeks)
- *Time between request and market disruption*: the solidarity request should be within a pre-determined period of time (e.g. 5 days) after the spot market in the sending market is disrupted.

5.2.3 Price indicator 3: skewed market price

A supply disruption in the solidarity gas receiving market is likely to have knock-on effects on the sending market; at worst the sending market could be disrupted as well. This may – despite the European Commission recommendation stating that it should not – result in government intervention in the setting of prices, e.g. price caps or price freezes. Under such a circumstance spot market prices would not reflect market realities and would be skewed by government intervention. Theoretically two pricing options could apply:

- *Solidarity gas is priced at the theoretical spot market price* **–** as the spot market has not fully broken down and trades are still conducted (but at capped or frozen prices), the market operator should be in a position to identify the

competitive market price that would apply without government intervention on prices. Hence, domestic customers would face the capped or frozen price but receiving market customers would pay the full market price to be determined by the market operator on the basis of supply/demand conditions. This would be discriminatory pricing, which under normal market circumstances is not in line with European common market rules. However, the circumstances in this scenario are not normal and government intervention in gas prices – which is also illegal as it may constitute state aid – is only likely to be a last resort measure resulting from force majeure. To overcome this legal uncertainty, the bilateral agreement between the countries would need to specify the pricing methodology under such a scenario.
- *Solidarity gas is priced at the skewed market price* **–** under this pricing option, customers in the receiving market would pay the same price as customers in the sending market.

From an economic efficiency standpoint, the theoretical market price would seem sensible; however, a number of factors suggest that this may not be a viable and practical option:

- The intervention of the government in the SP-MS may result in **non-competitive trading behaviour by market actors**. So, even if the market operator was able to simulate a theoretical market price, this would be a skewed price that would not be representative of a pure competitive market outcome.
- The **legal implication** of discriminating between domestic and non-domestic customers may be too costly and uncertain. The combination of declaring force majeure first – to legitimize government intervention in pricing – and enforcing a price discrimination regime second – on the grounds that receiving market customers ought to pay a market reflective price – is contradictory and may not be in line with European legislation.
- **Difficulty in establishing the theoretical market price**. The market operator may find it difficult to establish the market price, as the system may not allow it to estimate these.

We conclude therefore, that if the spot market price is affected by government intervention, it would be advisable to set the price for the receiving market at the same level as the sending market. This would also disincentivise governments to meddle in price setting as their domestic customers/tax payers would cross-subsidize consumption in solidarity gas receiving markets.

5.2.4 Price indicator 4: bilateral contracts market

In a situation where no spot market exists in the sending market and the criteria for *pricing option 2: last observed prices* are not met, an alternative price indicator to spot market prices needs to apply. The best indicator for market prices in such a scenario is the Over the Counter Market (OTC) defined by bilateral contracts between suppliers and end-consumers. OTC markets remain a crucial component of European gas markets and will typically be set by long term gas contracts linked to oil price or increasingly European gas hub prices.

One approach could be to apply the highest priced bilateral contract price of the non-protected customers that is disrupted as a result of the solidarity request. This represents the marginal price of gas in the absence of a functioning spot market. It is a more accurate price indicator of the market conditions on the sending market than a regional gas hub price, which will be driven by supply and demand flows that may be irrelevant for the sending gas market.

A complication of this methodology however is that OTC prices are not readily available and not public. The Market Operator – when implementing a solidarity request on the basis of this pricing option – therefore will rely on the collaboration of non-protected customers (who are disrupted as a result of the solidarity request) in disclosing their bilateral contract prices. The willingness for these customers to do should be established during the solidarity gas contract negotiations. If they collaborate, this pricing option should feature in the contract. If not, another pricing option needs to apply (see *pricing option 5: regional gas hub prices*)

Non-protected customers however have an incentive to collaborate with the market operator and disclose their prices, as that would ensure that they receive their cost of gas (and more, since it is the highest price of disrupted customers) plus all other components featuring in the solidarity gas formula.

5.2.5 Price indicator 5: regional gas price

The last resort pricing option for solidarity gas price should be a regional gas price, i.e. a price of the most adequate functioning gas market at the time of the solidarity request. This should only apply for a SP-MS where either (i) no spot market is in place, (ii) last observed spot market price do not apply according to our set out criteria or (iii) bilateral contracts cannot be used as price indexation. Despite strong (and improving) interconnectedness of European gas markets, regional gas price differences still apply. This is particularly the case for localized supply disruptions. This means that the selection of regional gas markets to act as proxies for market conditions in a sending market may not be adequate and reflective of the market conditions in that market. This is likely to be used as a last resort price indicator.

This pricing option should not be restricted to the major regional gas hubs (e.g. NBP, ZEE, CEGH), but should include all European gas spot markets. The selection of an adequate regional gas price should be based on:

- Historical correlation of prices of the sending market with other gas markets over the space of a gas year. This analysis should be conducted for the sending market prior to negotiation solidarity gas agreements. It would result in a ranking of gas markets that can then be used in case of a market disruption in the sending market. It should be reviewed on an annual basis. The ranking is needed to guard against a breakdown of other spot markets. If the closest correlated spot market also breaks down, price should be set by the second closest correlated spot market. If that is broken down, it should go to the third closest and all the way until a functioning spot market is reached.
- For those MS with no spot market, the ranking of regional gas markets and applicable prices should be done on a measure of interconnectedness of the

market with surrounding markets and hubs. One possible way to estimate this is by assessing the physical flows into the sending market on the basis of interconnector capacity booking and usage of the last year (or the current year if data is available). ACER publishes the *Annual Report on the Results of Monitoring the Internal Electricity and Gas Markets* and has a dedicated *Gas Wholesale Markets Volume* including a chapter on interconnector capacity usage. This is mainly based on data received from the gas interconnector capacity booking platform PRISMA. Again, this analysis – done prior to solidarity gas contract agreements – should result in a ranking of prices that have the closest physical links with the sending market.

5.2.6 Scenarios and market pricing 'decision tree'

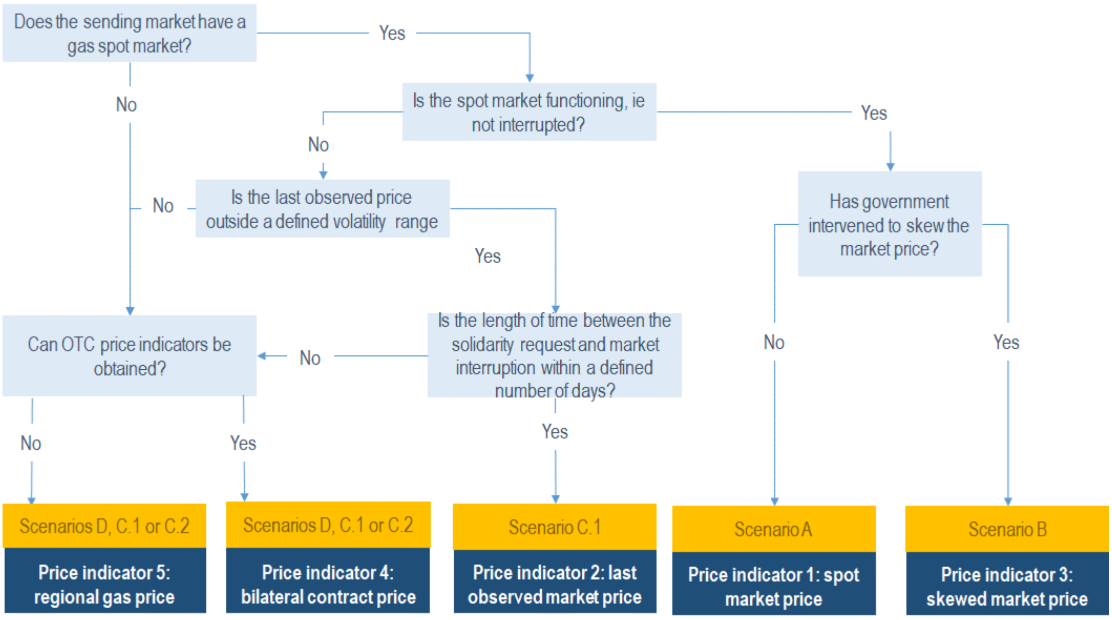
As described above, the solidarity gas contract should foresee different price indicators to apply to different market and disruption scenarios. Five distinct scenarios can be identified:

- **Scenario A:** The SP-MS has a spot market, where price signals have not been affected by the emergency situation
- **Scenario B:** The SP-MS has a spot market which has been affected – through government intervention - such that the price does not reflect market realities anymore
- **Scenario C:** The SP-MS has a spot market which has been suspended and provides no price signal at all at the time of the solidarity request. Two sub-scenarios can be further specified:
    - Scenario C.1: spot gas prices before the market breakdown reflect impending supply disruptions
    - Scenario C.2: spot gas prices before the market breakdown do not reflect impending supply disruptions
- **Scenario D:** The SP-MS has no spot market

The application of relevant gas prices for each of these scenarios is summarised in the decision tree below. We consider the decision tree to be a tool to be used during solidarity gas contract finalization to ensure all possible scenarios are covered and the most suitable price indicators are applied.

A possible approach could be for the solidarity gas price indicator to change as the situation in the sending market changes. So, if for example, the sending spot market has broken down for only 2 days and the solidarity requests lasts for 4 days, the applicable price should be *price indicator 2: last observable price* for the first 2 days and price *indicator 1: spot market price* for the last 2 days.

Figure 48: Scenarios and market pricing 'decision tree'



5.3 Transport and associated costs

Gas transmission, interconnection or LNG regasification costs (if not reflected in the spot market price) should not be different for solidarity gas than for any other gas supplies. The existing tariffs and their defined methodologies – as prescribed in the SP-MS tariff regulation - should apply. Transmission charges may vary by type of product - firm capacity, interruptible, short term or long term. The solidarity gas request should therefore specify the type of capacity product that will be needed.

5.4 Costs of release of strategic storage or having storage obligations

For the provision of solidarity gas, the SP-MS may, at some point, withdraw gas from its available gas stocks, maintained either subject to commercial considerations of market players (e.g. to take advantage of seasonal or other price differentials, provide balancing, etc.), or as a matter of security of supply related provisions.

When the spot market in the SP-MS continues to operate, while solidarity gas is provided, suppliers may decide to withdraw gas from storage sites voluntarily. In that case spot prices would reflect the cost of withdrawing gas from the storage sites, the provisions of Section 5.1 would apply, and no additional charges should be made for gas withdrawals.

When a spot market does not exist (or it is broken down, or suspended, as a result of the supply disruption), while solidarity gas is provided, gas stored for commercial purposes may be withdrawn by intervention of the TSO, which may be subject to provisions of emergency plans in the SP-MS. In such cases, the relevant price indicators discussed in Section 5.2 would not reflect additional costs associated with withdrawing gas from storage sites, and an additional charge to account for these costs should be added. That additional charge should be the gas withdrawal price associated with the specific storage site from where the gas was withdrawn.

Gas may be stored for security of supply purposes either centrally, as strategic storage, or through storage obligations imposed on suppliers. Such volumes are maintained for emergency conditions, and when they have to be withdrawn from storage sites they should be replaced as soon as possible, when the emergency conditions permit. When such gas volumes are withdrawn from storage for solidarity purposes, the following two options exist for covering the relevant extra costs associated with the withdrawal and replacement of stocks:

- **Option A:** The SP-MS to replace strategic storage, or volume of storage obligations withdrawn. Under this option the SR-MS is to be charged the price of gas as determined in section 5.1 plus the withdrawal and injection costs, or the Standard Bundled Unit (SBU), as applied to the storage sites concerned. The SR-MS can then decide when to replenish the storage and whether to use the proceeds of the solidarity gas transactions for this purpose or not.
- **Option B:** The SR-MS to replace strategic storage, or volume of storage obligations withdrawn. Under this option only the withdrawal and injection charges apply or the SBU of the storage sites concerned. In that case, the receiving state undertakes the procurement of the respective volumes and should not be charged by the SP-MS for the value of the gas.

Timing is a decisive factor for the above options. Either MS may time replenishment of storage, so as to gain from arbitrage. To avoid this, it should be assumed that replacement of strategic storage, or storage obligations, i.e. restoration of security of supply in the SP-MS, is implemented as soon as possible after conditions permit. If that holds the two states should be indifferent as to which of the two methods would apply, and they should agree to the preferred method in the bilateral agreement.

Timing for the replacement of the gas stock should relate to termination of the request for provision of solidarity gas, or inability of the SP-MS to maintain the provision of solidarity gas, due to depletion of its available resources. The two MS should agree to a period following the occurrence of either of the two events (or agree to other such suitable triggers), within which stocks should be fully replaced. The replacement period should relate to the technical conditions of each system, and its access to gas resources. An escalation should also apply, to disincentives delays in the implementation from the part of the SR-MS. The escalation should be designed in accordance with the replacement period and should be relative to the characteristics of the respective MS system and the volume to be replaced.

As security of supply margins and the corresponding strategic storage or storage obligations may vary over the year, there should be clear indication in the bilateral agreement of what is the volume of such stocks, or how they may be determined.

In all cases that the SR-MS will need to be charged for or replace gas stocks withdrawn from storage for solidarity purposes, the bilateral agreement between the two MS should also include a process for verifying the gas volumes withdrawn from storage sites for solidarity purposes.

5.5 Administrative costs for TSO

For the administration of the solidarity provision process, the SP-MS TSO would face the following costs.

- Costs for the setup of the solidarity process. This would mainly comprise the costs for the preparation of the bilateral agreement between the two MS. This might be a time-consuming process for the setup and negotiation of methodologies and other required procedures and would also comprise legal expenses. However, this would be a one-off process (with provision for periodic review), common for both MS, and should be considered sunk cost, therefore should not be part of the solidarity gas charge.
- Fixed, operation and maintenance expenses for the technical preparation of the system to provide solidarity gas. Where such expenses are not already accounted for under the CBCA mechanism, they would also comprise sunk costs and should not be part of the solidarity gas charge.
- Costs for the operation of the system for the provision of the solidarity gas. These should be part of the gas transportation costs applicable by the SP-MS TSO, in line with Network Codes, and should not comprise a separate charge to the SR-MS.

All the costs associated with solidarity gas could be absorbed into the overall regulated cost base of the TSO from the sending market. Although this means that sending market customers are charged for the solidarity gas, the additional costs are likely to be minor – other than the solidarity gas contract set –up costs, which are sunk costs anyway – and will probably not warrant a separate cost calculation methodology and procedure, which is likely to be even more administratively costly.

5.6 A compensation for non-protected customers in the country providing solidarity gas

A compensation for the non-solidarity protected customers, for example for the loss of production due to the disruption, could be linked to the Cost of Disrupted Gas (CoDG) established in previous sections of this report.

5.7 Cost of judicial proceedings in member state providing solidarity

Many legal questions may arise from a supply interruption of the non-protected customers in the sending market as a result of triggering the solidarity mechanism. The most important legal questions are:

- **The legality of the interruption**: The existing supply contracts with non-protected customers currently are unlikely to have a solidarity clause. There is therefore no legal underpinning for the market operator or TSO in interrupting supplies to these customers. Although this may qualify as a ‘force majeure’ incident, it is likely that customers would legally challenge this decision, which will incur costs to both the consumers as well as the suppliers in the sending market. To overcome this legal uncertainty, supplier contract would need to be renegotiated to include a ‘solidarity gas clause’, which should mirror the criteria for solidarity gas requests in the solidarity gas contract between the MS.
- **The level of compensation**: The compensation defined through the solidarity gas methodology would to a large extent (apart from the administrative cost and transportation costs) be given to the interrupted non-protective customers. However, this may not be sufficient for interrupted customers. The compensation may not capture the true costs incurred by disrupted suppliers because it may be (i) below the lost GVA as a result of the interruption, (ii) ignore the impact of disruptions on production equipment and (iii) underestimate the long-term effects of interruptions such as loss of customers.

It is highly likely that customers will challenge their suppliers and the associated compensation, which will incur legal fees and costs to suppliers for any settlement rulings, should the case be made that solidarity gas is not sufficient to cover losses.

This could be a very significant cost component of the solidarity gas mechanism. There is no single methodology that can be applied across the EU that would capture these costs accurately. The costs of judicial proceedings and final compensation are complicated and will depend on a case by case basis. The solidarity gas contracts therefore need to unambiguously assign the costs associated with arbitration proceedings and settlement of arbitration rulings to the parties involved.

The solidarity gas contracts will be established between MS and the Commission recommendation states that ‘*Member states should take ultimate responsibility for running the solidarity mechanism*’. It also makes it clear that the legal costs ‘*can be included in the compensation cost if the national legal framework provides for the obligation to pay damages to curtailed industry, including compensation for economic damage, on top of the gas price*’. This assigns the costs to the SR-MS government and/or receiving country customers if national laws allow it.

In conclusion, supplier contracts in the sending market need to be amended/renegotiated with a solidarity gas clause. The clause needs to mirror the conditions agreed in gas solidarity contract between MS. In particular, supplier contracts need to (i) specify under what conditions gas can be interrupted, (ii) specify the adequate level (or methodology) of compensation from the interruption, and (iii) assign the responsibility of costs for legal proceedings to the receiving market government.

5.8 Overarching themes

The cost components of the solidarity gas should be summed and in their solidarity gas contracts MS need to specify how costs are combined. Factors that will need to be considered are:

- **Timing of payments and interest rates –** As per the recommendations payments of the costs should be prompt. However, this may not always be possible as some costs may be incurred at a later stage. MS should therefore agree when payments are due and how to deal with late payments. It would certainly be economically sensible to apply the SP-MS's interest rate payments that are late, i.e. payments not provided within a pre-determined period of time after notification of the costs. The type of interest rate and payment terms need to be specified in the agreement.
- **Currency and exchange rates** - the agreement should also specify the applicable exchange rate and currency. An approach could be to apply the exchange rates at the time of supplying solidarity gas to ensure that the sending market has no incentive to delay or accelerate the invoicing of the payment on the basis of the exchange rate. As for the interest rate, a reliable source for exchange rates should be specified in the agreement.

Case study to illustrate how the concepts can be applied
Consider **two countries, A and B**, who have a bilateral solidarity gas agreement, the contract for which is structured according to the decision tree above. Both countries have an **interest rate of 2%** and B is a member of the Eurozone, while A is not; the **exchange rate** at the time of the supply of solidarity gas is 2 units of local currency (say ֏) to €1. **Country A's supply of gas is disrupted**, whereas county B's supply is not. As per the agreement B is required to send gas to A. Assume **B has a gas spot market** which is not interrupted, and government has not intervened in the market. The **current spot market price is €30/MWh**, which is the price applied to A. Now assume that the spot price market had been skewed, as the government had capped prices at €25/MWh, then **€25/MWh is the price A faces**, in order to prevent discrimination between customers in each country. Now suppose that, that B' **spot market has broken down**, because it has also been affected by the supply disruption. The last observed price is **€45/MWh** dated 2 days before the solidarity request. At the time, the price jumped from €28/MWh to €45/MWh in a matter of hours and remained at that level. As this is a **'recent'** (i.e. within a number of days - to be defined in the solidarity gas agreement) price

observations displaying **'unusual' levels of volatility** (i.e. outside a given volatility range – to be defined in the solidarity gas agreement), this can act as valid market indicator and this price applies. If, however the last observed price was 10 days before the solidarity request and set at €28/MWh without any unusual price movements, **bilateral contract price indicators** should be used if available. Suppose that non-protected customers are willing to reveal the OTC price they pay, because they will receive greater compensation by revealing their price. If the OTC prices that are revealed are €26/MWh, €27/MWh and €28/MWh, then the price of the solidarity gas should be set at the highest price of **€28/MWh**. This also applies if there is no spot market in B.

However, since the OTC prices are not public information, it might also be the case that **customers choose not to reveal them**. This means that B's solidarity gas price supplied to A is based on regional gas price markers. Countries C, D and E are other countries in the region. Suppose they all have spot markets, as does country A. C's spot market price is historically the most closely correlated to A followed by D, then E. The current spot market prices are €30/MWh in country C, €31/MWh in country D and €29/MWh in country E. The price applied for the gas sent by country B is €30/MWh. If country C's spot market had broken down, the price of solidarity gas would then be €31/MWh. Alternatively, if country A did not have a spot market, the ranking could then be based on interconnector capacity booking and usage, but the same process for setting the prices follows once the ranking is established.

Country B may incur some additional costs which have to be covered, for the transmission and replacement of gas. Assume that the main charge for the solidarity gas is paid promptly, but the additional costs of €5/MWh are not incurred immediately, and in the end are paid one period late, such that interest is paid on them. Under the first scenario, where B has a functioning spot market, A pays €60/MWh immediately and €10.20/MWh for the additional costs. In fact, payment would only have to be in the agreed time frame, rather than immediate, and the exchange rate applied would still be that from the time of supply of the solidarity gas.

6 Conclusions

The present study proposed a consistent methodology for the calculation of the cost of gas disruption across EU Member States, sectors and natural gas uses. The values proposed here may set a base for a more refined approach towards the evaluation of the benefits brought by proposed gas infrastructure projects, and particularly Projects of Common Interest.

6.1 Methodology, estimates and sensitivity of calculated values

Our recommended approach for the monetisation of the CoDG is summarized in the following four steps:

1. Estimate a cost measure per unit of energy (UCM in €/MWh) when natural gas firing equipment is substituted by alternative appliances/equipment and fuels. The approach is bottom up and relevant for all sectors where natural gas is used as fuel. Main inputs to the calculation are the capital costs of alternative appliances, their utilisation (operating time in year, lifetime) and the price difference between the alternative fuel and natural gas per unit of energy produced.

2. Estimate a UCM in the industrial sub-sectors where natural gas is used as feedstock, that is in the chemical and petrochemical sectors. An adjusted GVA-at-risk approach is used for this part of the methodology. The inputs to the calculation are the sector GVA, the natural gas consumption of the chemical/petrochemical subsectors, the non-energy natural gas consumption of the chemical/petrochemical subsectors and the overall fuel consumption.

3. Refine/assess the above estimates using a modified hypothetical-cost approach. The purpose of the MHC was to obtain additional understanding as to whether the UCM estimates can be used to represent the CoDG and if further refinements in the methodology are necessary. The approach involves sectoral surveys asking consumers about their estimates of CoDG under hypothetical scenarios with several granularity options (time of day, day of week, month, disruption duration, early warning)

4. Use the results from steps 1, 2 and 3 above to calculate sectoral CoDG values and values at country level for each Member State, Figure 49.

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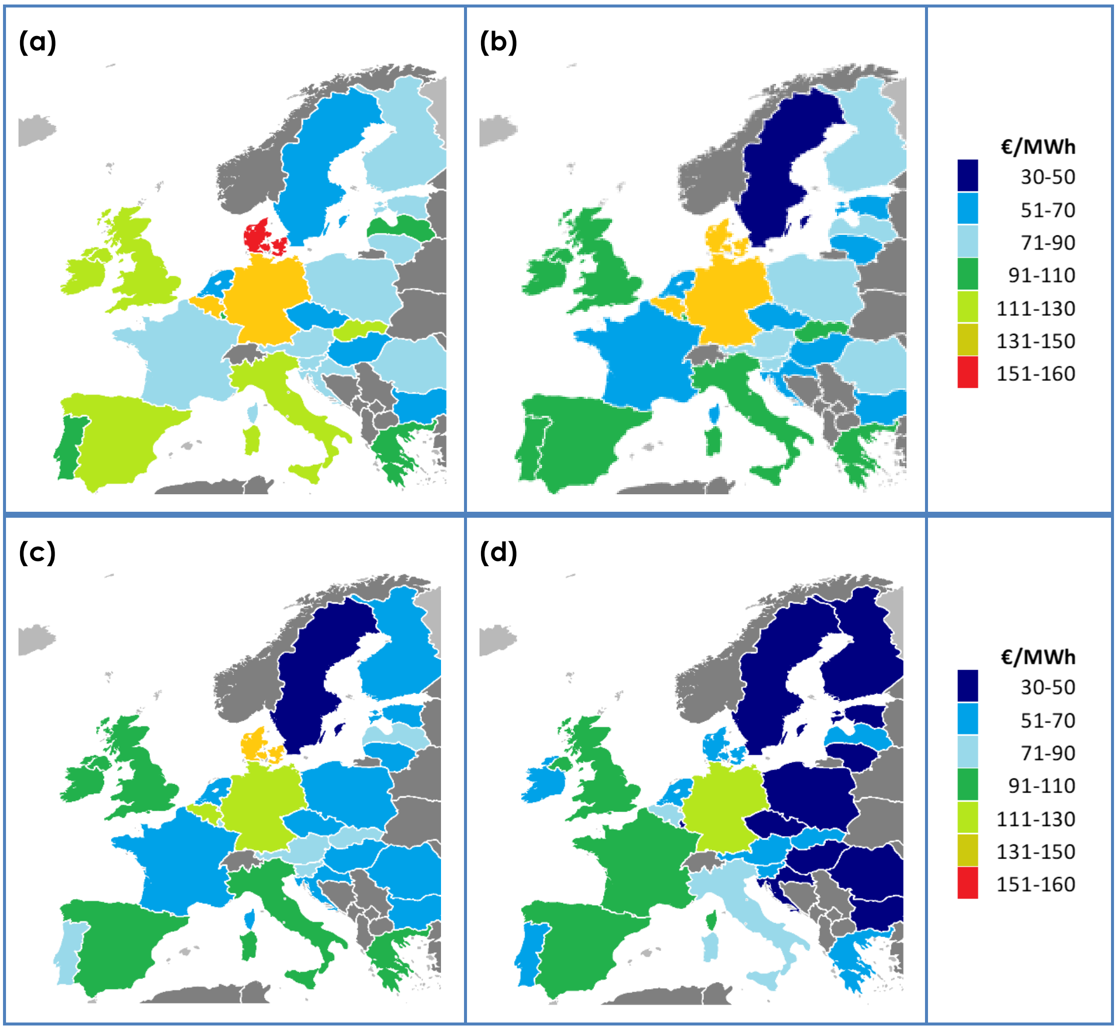
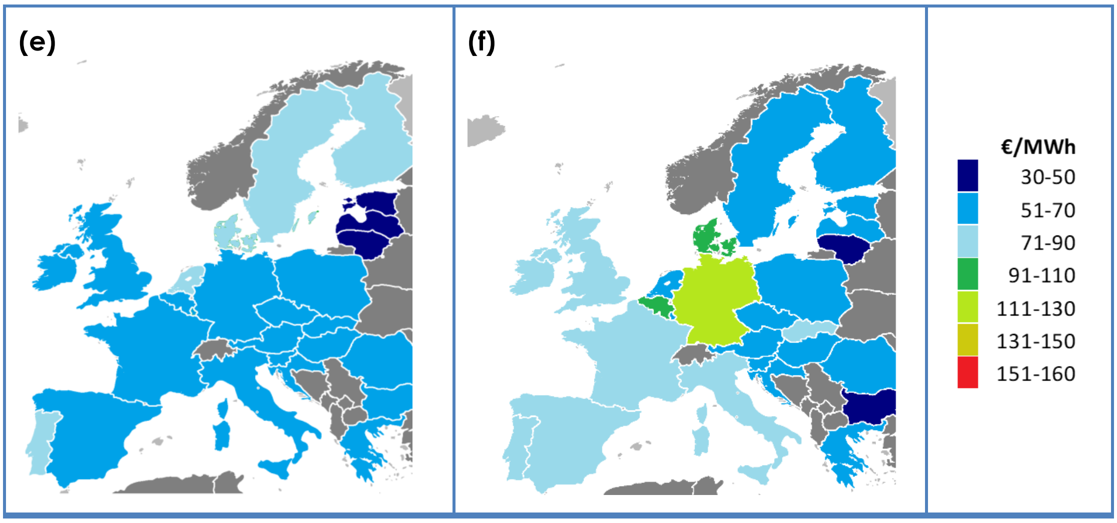
Figure 49 Summary of calculated UCM values by sector and Member State: (a) residential; (b) services (P); (c) services (NP); (d) Industrial (fuel and feedstock); (e) Power; (f) value at Member State level





We note that the fuel UCM approach is comparatively straightforward. However, it depends on a substantial number of input data and assumptions. A number of scenarios were explored in order to determine the model sensitivity to the input data. Results show that:

- UCM values are mostly dependent on the price difference between the alternative fuel and natural gas. The dependence on capital costs and operating times is only minor.
- An increase in the CAPEX of household appliances by 30% leads to an increase of up to 5% in the respective UCM values. Increases in the UCM values of the remaining sectors are lower, in the range of 1.5 to 3%.
- An increase or decrease in the operating weeks leads to a subsequent change (decrease/increase) in the fuel UCM that is only 1/10th of the change introduced.
- A change in the operational cost difference due to a change in fuel costs results in an almost proportional change in the UCM values.

6.2 Proposals for further research

The proposed approach can be refined further in a number of directions under a future research effort. A few examples are summarised below:

Weighting factors (RAA selection probability)	Under the approach adopted for this study, all Representative Alternative Appliances have equal probabilities to be selected by the gas user. An alternative approach would be to use specific assumptions for the share of each technology for each type of end-use.
Weighting factor for services subsectors	In the Services Sector, due to lack of suitable data, it is assumed that the contribution of each subsector to the overall sector gas consumption is equal. In a future refinement, data on the relative contribution of each subsector, if available to the Member State could be used.
Operating hours of each RAA within a day	The operating hours of the various RAA reflect assumptions and climatic data from Eurostat. These assumptions can be developed further (e.g. by compiling relevant data), in order to refine the granularity of the CoDG estimates. In all cases, the values estimated in this work, for the fuel UCM, relate to normal operation of an alternative appliance. A cost of a disruption may also need to reflect the fact that an alternative appliance will not be operated on a constant basis but rather on the unlikely event of a disruption. Potential scenarios may relate to the calculation of relevant UCM values considering as operating hours a period of 2 weeks of disruption once in 20 years, one day once in 20 years in the context of the scenarios considered in the may ENTSOG TYNDP.
Probability of disruption and CoDG for protected customers	The survey results, including the survey ran with the NRAs in the context of this study and results from ENTSOG'S 2017-Security of Supply Simulation Report show that with the exception of East/South-East Europe such disruptions are uncommon. The CoDG estimates may be further refined by taking into account the product of the MS UCM or sector UCM by a constant to reflect the probability of a disruption). Such a probability may differ across MS

eSurvey participation	Questionnaires in the context of this study were made available on-line and in English. A more systematic study for each Member State and at national languages targeting explicitly the domestic and services sector may provide further insights.

6.3 Specific conclusions on the solidarity price insight

As per the European Commission guidance, solidarity gas prices should be reflective of market conditions. Ideally, this means the price is determined through a competitive market in the SP-MS. However, country-specific factors and circumstances related to the supply disruption may make it difficult to observe gas prices at the time of the solidarity gas request. A variety of different price indicators can be taken as proxies for a competitive spot market. The objective of the possible approach outlined above is to provide MS with a methodology that could be applied to select the best proxy for solidarity gas pricing that (i) maintains flexibility to be applied across a range of situations, (ii) can be easily and quickly applied and (iii) is in line with basic economic principles.

A 'decision tree' for pricing gas could be used which could help MS to identify the best suited price indicator under different conditions. The indicators attempt to get as close to an accurate market price as possible. In the best-case scenario, the SP-MS spot market price is available, but it may be that a recent value, before spot market suspension, or a skewed value, due to government intervention, can be used. If neither of these are applicable, bilateral contract prices can be used (if shared). Since these are not public information, we also suggest ranking the relevance of neighbouring markets, to provide a last resort solidarity gas price indicator.

Applying this reasoning during solidarity gas contract negotiations, will help MS think through eventualities in advance thereby reducing potential uncertainty in pricing solidarity gas agreements at the time of the request. The principles can also be applied during solidarity gas request, as and when circumstances of a prolonged disruption change.

In addition to the cost of gas, other additional cost factors need to be recovered. Transport costs should not differ between solidarity and other gas supplies and many of the administrative costs of the TSO should be considered sunk; these do not require a separate charging methodology. Where strategic storage has been released for solidarity gas supplies, it should be replaced as soon as possible, such that it does not matter whether the receiving or SP-MS replaces it. Questions remain around the legality of the interruption and the level of compensation given to non-protected customers, so supplier contracts may need a solidarity clause in future.

Finally, practical issues around interest on late payments and the exchange rate applied, which should be the one at the time of supplying solidarity gas to avoid distorting incentives, should be specified in the contract.

Appendix 1 Examples of current approaches to estimating CoDG and VoLL

Table 52: Instances of case study approaches

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Corwin & Miles (1977)	Businesses Electricity generation Public services and government	Cost type (lost wages, restoration cost, overtime, etc.)	Secondary sources	Electricity
Serra & Fierro (1997)	Industrial users	Sector of economic activity	Business surveys/ interviews	Electricity
Zachariadis & Poullikkas (2012)	Electricity generation	None	Electricity generation costs before and after accident during the transitional period (which dealt with the supply disruption) Sales revenues of electricity producers before and after accident	Electricity

Table 53: Hypothetical cost studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Serra & Fierro (1997)	Industrial users	Curtailment levels (10%, 20%, 30%) Duration (1 month, 2 months, 10 months) Sector of economic activity	Business surveys/ interviews	Electricity
Balducci et al. (2002)	Sectors of economic activity Residential users	Duration (20 minutes, 1 hour, 4 hours)	Business surveys Consumer surveys	Electricity
Lawton, Eto, Katz, & Sullivan (2003)	Large commercial and industrial users SMEs	Geographic region Sector of economic activity Season Hour of day Day of week Duration Prior warning	Business surveys	Electricity
Kim & Cho (2017)	Industrial users	Damage type Season (spring, summer, autumn, winter)	Business surveys	Electricity

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
		Time of day (morning, afternoon, evening, dawn) Emergency generator (presence and capacity) Duration (one second, five seconds, one minute, 20 minutes, one hour, two hours, eight hours, 24 h, 48 h) Prior warning		
CRA International (2008)	Sector of economic activity Domestic users Public and social services	Duration (20 minutes, 1h, 2h, 4h, 8h, 24h)	Business and consumer surveys	Electricity
Leahy, Devitt, Lyons, & Tol (2012)	Electricity generation	Duration (1 day, 3 weeks, 3 months) Year (2008, 2020) Rationing scenario Wind penetration scenario Extent (partial, full) Season (Jan, July) Day of week (midweek, weekend)	Electricity model simulations VoLL of electricity estimates from secondary sources	Natural gas

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Concept Economics (2011) in Hoch & James (2011)	Large enterprises	Cost type	Business surveys	Electricity

Table 54: Revealed preference studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Serra & Fierro (1997)	Industrial users	None	Time series (1960-1986) on: Electricity demand Price of electricity GVA Wage index Investment	Electricity
DNV KEMA, REKK, & EIHP (2013)	Project level	30% reduction of gas deliveries on the interconnectors from Russia/Ukraine to the region in January in 2015 and 2020	Gas market model simulations	Natural gas
Leahy, Devitt, Lyons, & Tol (2012)	Domestic users	Duration (1 day, 3 weeks, 3 months) Year (2008, 2020) Demand elasticity sensitivity analysis Day of year	Daily profile of natural gas use Short-run elasticity of demand (from secondary sources) Natural gas prices Gas price growth projections (assumption)	Natural gas

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Zachariadis & Poullikkas (2012)	Industrial users Commercial users Domestic users	None	Time series on: • Electricity demand per sector • Price of electricity • GVA • Income • Degree-days	Electricity

Table 55: Contingent valuation studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
London Economics (2011)	Domestic users SMEs	Limited	Consumer surveys/ Choice experiments	Natural gas
Lawton, Eto, Katz, & Sullivan (2003)	Domestic users	Geographic region Season Hour of day Day of week Duration Prior warning	Consumer surveys	Electricity
Hartman, Doane, & Woo (1991)	Domestic users	Season (winter, summer, any) Time of day (morning, afternoon, evening, any) Duration (momentary, 1h, 4h, 12h) Prior warning	Consumer surveys	Electricity
MORI (1999)	Domestic users Businesses	Electricity supply improvement type Demographics	Consumer and business surveys	Electricity

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Accent Marketing & Research (2004)	Domestic users Businesses	Electricity supply improvement scenarios Demographics	Consumer and business surveys	Electricity
Carlsson, Martinsson, & Akay (2011)	Domestic users	Duration (1h, 4h, 8h, 24h, uncertain) Prior warning	Consumer surveys	Electricity

Table 56: Choice experiment studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
London Economics (2011)	Domestic users SMEs	Duration (3 levels) Frequency (3 levels) Season (winter/summer) Sector (services, non-services) SME size (2 levels) Geography (urban/rural)	Consumer surveys	Natural gas
Layton & Moeltner (2005)	Domestic users	Season (summer, winter) Time of day (8am, 3pm, 7pm, midnight) Duration (moment, 1h, 4h, 12h)	Consumer surveys	Electricity
Carlsson & Martinsson (2008)	Domestic users	Day of week (working day, weekend) Duration (4h, 8h, 24h) Season (winter, rest of the year) Number of outages over 5 years (0,1,2)	Consumer surveys	Electricity

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
KPMG (2002) in Hoch & James (2011)	Domestic users Businesses	17 non-price service attributes, regarding service reliability (unplanned and planned outages, voltage fluctuations, etc.)	Consumer and business surveys	Electricity
Concept Economics (2011) in Hoch & James (2011)	Domestic users SMEs	Season (winter, summer) Time of day (8am, 6pm) Frequency (0, 1, 2, 3 and 4 outages per year) Duration (10m, 1h, 4h and 8h)	Consumer and business surveys	Electricity
Reichl, Schmidthaler, & Schneider (2013)	Domestic users	Season (winter, summer) Time of day (working, non-working hours) Duration of outage (1h, 12h) Region Prior warning	Consumer surveys	Electricity

Table 57: GDP-at-risk studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Booz & Company et al., (2013)	Country level	Curtailment level (linear) Curtailment duration (linear)	Share of NG in total gross inland consumption of energy GDP	Natural gas
DNV KEMA, REKK, & EIHP (2013)	Country level	None	GDP Electricity consumption	Natural gas

Table 58: GVA-at-risk studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Oxera (2007)	Sectors of economic activity Country	Curtailment at country level (non-linear, 1 level per sector)	GVA per sector NG consumption per sector	Natural gas
Growitsch, Malischek, Nick, & Wetzel (2013)	Sectors of economic activity	Regional level (states in Germany) Timing (per hour in a day within a year)	Electricity consumption per sector and state Value added per sector and state Load profile per sector	Electricity
de Nooij, Koopmans, & Bijvoet (2007)	Sectors of economic activity	Time of day (day, evening, night) Day of week (weekdays, Saturdays, Sundays)	Electricity demand per sector Value added per sector Working hours per year per sector (assumption)	Electricity
Linares & Rey (2013)	Sectors of economic activity	Regions Time of day (hours)	Electricity demand per sector and regions Value added per sector and region Load per hour and sector	Electricity
Praktiknjo, Hähnel, & Erdmann (2011)	Sectors of economic activity	None	Electricity demand per sector Value added per sector	Electricity

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Leahy & Tol, (2011)	Sectors of economic activity	Year (2000-2007) Day of week (midweek, weekend) Time of day (day, evening, night) Season (winter, spring, summer, autumn)	Electricity demand per sector Value added per sector Working hours per year per sector (assumption)	Electricity
Coll-Mayor, Pardo, & Perez-Donsion (2012)	Sectors of economic activity	Regions	Value added per sector and region Energy consumption per region	Electricity
Castro, Faias, & Esteves (2016)	Sectors of economic activity	None	Value added per sector Energy consumption per sector	Electricity
Zachariadis & Poullikkas (2012)	Sectors of economic activity	None	Value added per sector Energy consumption per sector	Electricity

Table 59: Adjusted GVA-at-risk studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
London Economics (2011)	Non-electricity industrial and commercial users	Sector of economic activity	GVA per sector NG consumption per sector Interviews/qualitative analysis	Natural gas
Linares & Rey (2013)	Sectors of economic activity	Regions Time of day (hours)	Electricity demand per sector and regions Value added per sector and region Load per hour and sector Substitutability per sector (assumption)	Electricity
Reichl, Schmidthaler, & Schneider (2013)	Non-household consumers	Season (winter, summer) Time of day (working, non-working hours) Duration of outage (1h, 12h) Region	Annual turnover per sector Staff costs per sector Input expenses per sector Synthetic electricity load profiles per sector and region Dependence on interruption-free supply (based on business survey)	Electricity

Table 60: GVA-at-risk studies with Input-Output analysis

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
ILEX (2006)	Gas-consuming sectors Their upstream sectors	Duration (3 levels)[39]	GVA per sector NG consumption per sector Input-output tables	Natural gas
Praktiknjo (2016)	Sectors of economic activity	Year	GVA per sector Electricity consumption per sector Input-output tables	Electricity

[39] ILEX (2006) report results on GVA impact at 3 levels of emergency interruptions – one day, 3 weeks and 6 weeks. It seems that the results are linear – the 6-weeks impact is twice as high as the 3-weeks impact. Thus, it seems that they have the same €/MWh for all three durations.

Table 61: Tax-at-risk studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Praktiknjo, Hähnel, & Erdmann (2011)	Public administration	None	Tax income Electricity consumption of public administration sector	Electricity
Leahy, Devitt, Lyons, & Tol (2012)	Public administration	Duration (1 day, 3 weeks, 3 months) Year (2008, 2020) Day of year Wind penetration scenario	VAT rate Daily profile of gas consumption	Natural gas

Table 62: Leisure-at-risk studies

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Growitsch, Malischek, Nick, & Wetzel (2013)	Domestic users	Regional level (states in Germany) Timing (per hour in a day within a year)	Electricity consumption per state Residential load profile Number of employed persons per state Number of unemployed persons per state Number of actual hours worked per employee per year per state Labour cost per hour per state Employers' average rate of social security contributions Employees' average rate of income tax social security contributions Substitutability between electricity-based and non-electricity-based leisure activities (assumption)	Electricity

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
de Nooij, Koopmans, & Bijvoet (2007)	Domestic users	Time of day (day, evening, night) Day of week (weekdays, Saturdays, Sundays)	Electricity consumption Loss of leisure time per time of day and day of week (assumption) Average gross hourly wage Net marginal income as percentage of average gross hourly wage (assumption) Number of employed Total population size	Electricity
Linares & Rey (2013)	Domestic users	Regions Time of day (hours)	Electricity consumption Average gross hourly wage Net marginal income as percentage of average gross hourly wage (assumption) Number of employed Total population size Substitutability (assumption)	Electricity
Praktiknjo, Hähnel, & Erdmann (2011)	Domestic users	Frequency distribution of VoLL (with Monte Carlo methods)	Microdata on time use, electricity expenses and wages	Electricity

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
Leahy & Tol (2011)	Domestic users	Year (2000-2007) Day of week (midweek, weekend) Time of day (day, evening, night) Season (winter, spring, summer, autumn)	Average earnings Number of hours worked Tax rates Number of employed Total population Consumer price index Electricity profiles per hour Time use data	Electricity
Castro et al. (2016)	Domestic users	None	Percentage of people performing each activity Duration of each activity Average hourly wage Average tax rate Active and inactive population size Electricity consumption	Electricity
Shivakumar et al. (2017)	Domestic users	EU member state	Annual household electricity consumption per MS Hourly wage per MS Number of employed per MS Number of unemployed per MS Number of hours worked per MS Hours spent on personal care per day (assumption)	Electricity

Study	Estimation scope	Dimensions and granularity	Data input	Energy source (Electricity or Gas)
			Substitutability factor (assumption)	
Zachariadis & Poullikkas (2012)	Domestic users	None	Number of employed Total population Total working hours Gross hourly wage Net hourly income as percentage of gross wage (assumption) Leisure time per week and employment status Average weekly time spent for domestic activities (assumption) Electricity consumption	Electricity

Appendix 2 VoLL and CoDG estimates from the literature

Table 63: Corwin & Miles (1977) study – Summary of Economic Impacts ($ m)

Impact areas	Direct		Indirect	
Businesses	Food Spoilage	1.0	Small Businesses	155.4
	Wages Lost	5.0	Emergency Aid (Private sector)	5.0
	Securities Industry	15.0		
		13.0		
Government			Federal Assistance programs	11.5
			New York State Assistance Program	1.0
Consolidated Edison	Restoration Costs	10.0	New Capital Equipment (program and installation)	65.0
	Overtime Payments	2.0		
Insurance			Federal Crime Insurance	3.5
			Fire Insurance	19.5

Impact areas	Direct		Indirect	
			Private Property Insurance	10.5
Public health Services			Public Hospitals – overtime, emergency room charges	1.5
Other Public Services	Metropolitan Transportation Authority (MTA) Revenue Losses	2.6	MTA Vandalism	0.2
	MTA overtimes and Unearned Wages	6.5	MTA New capital equipment requires	11.0
			Red Cross	0.01
			Fire Department overtime and damaged equipment	0.05
			Police Department overtime	4.4
			State courts overtime	0.05
			Prosecution and Correction	1.1
Westchester Country	Food Spoilage	0.25[3]		
	Public Services equipment damage, overtime payments	0.19		
TOTALS		**55.54**		**290.16**

Table 64: Serra & Fierro (1997) study – Mean outage costs for the industry with a selective restriction (Us cents/MWh)

	Depth of the fault		
Duration	**10%**	**20%**	**30%**
1 month	3,150	5,460	17,570
2 months	4,240	5,990	20,530
10 months	3,890	6,530	21,960

Table 65: Balducci, Roop, Schienbein, Desteese, & Weimar (2002) study – Interruption cost in 1996 US$/MW by sector

Sector	Duration of Interruption		
	20 minutes	1.0 Hour	4.0 Hour
Industrial	6,290	13,930	29,940
Commercial	4,740	12,870	44,370
Residential	30	150	1,640
Transportation	8,910	16,420	45,950
Weighted average	3,590	8,760	2,490

Table 66: Layton, Moelthner (2005) study – Cross-study comparison of cost estimates

	This study	Doane et al. (1988)	Doane et al. (1988b)	Woo et al., (1991)
Data Year:	1998	1986	1986	1989
Timing:	winter evening	winter evening/ morning	winter evening/ morning	winter
Method:		2-stage Heckman	self-stated	OLS
Duration	**Cost (1998 $)**			
1 hr	13.45	16.33	13.66	9.83
4 hrs	25.17	29.16	26.79	13.1
8 hrs	34.49	N/A	N/A	19.65
12 hrs	41.51	49.39	58.11	30.13
	Cost ($/MWh unserved)			
1 hr	5,340	14,610	N/A	12,710
4 hrs	2,660	5,290	N/A	7,340
8 hrs	2,290	N/A	N/A	4,980
12 hrs	2,060	3,380	N/A	3,280

Table 67: Leahy, Devitt, Lyons, & Tol (2012) study - Loss of consumer surplus as a result of residential gas outages

Elasticity=-0.16	€s	€s	€s
2008	ROI	NI	Total 2008[a]
1 day			
Midweek winter	8,237,231	1,656,415	9,893,645
Weekend winter	6,256,090	1,258,030	7,514,120
Midweek summer	1,489,279	299,477	1,788,756
Weekend summer	1,629,835	327,741	1,957,576
3 weeks			
Winter	160,511,007	32,276,961	192,787,969
Summer	34,196,207	6,876,473	41,072,680
3 months			
Winter	680,020,558	136,744,499	816,765,056
Summer	152,181,154	30,601,921	182,783,076

Elasticity=-0.16	€s	€s	€s
2008	ROI	NI	Total 2008[a]
2020	**ROI**	**NI**	**Total 2020[a]**
1 day			
Midweek winter	16,575,412	3,333,129	19,908,541
Weekend winter	12,588,852	2,531,477	15,120,329
Midweek summer	2,977,725	598,787	3,576,512
Weekend summer	3,258,758	655,300	3,914,058
3 weeks			
Winter	322,989,148	64,949,491	387,938,640
Summer	68,373,299	12,749,103	82,122,402
3 months			
Winter	1,368,375,068	275,164,862	1,643,539,930
Summer	304,277,247	61,186,738	365,463,985

Table 68: London Economics (2011) - VoLL estimates for I&C customers (range p/MWh)

Sector	Low	High
Electricity (1hr interruption)	3,686	4,607
Electricity (24hr interruption)	1,638	2,014
Non-Ferrous Metals	29,146	38,872
Iron and Steel	44,776	58,530
Chemicals	9,283	12,354
Petroleum Refineries	10,341	12,901
Agriculture	-	5,051
Mineral Products	14,505	21,774
Textiles, Leather etc.	12,628	21,023
Other industries	61,397	81,840
Food Beverages etc.	23,241	34,845
Paper, printing etc.	16,723	25,084
Vehicles	58,291	77,710
Electrical Engineering etc.	28,122	37,507
Mechanical Engineering etc.	38,292	63,820
Construction	-	31,501
Fertilizers	10,989	10,989

Table 69: Coll-Mayor, Pardo, & Perez-Donsion (2012) - VoLL for the Netherlands industry

Activity	VoLL	
	€ (2007)/MWh	€ (current)/MWh
Agriculture	3,900	2,650
Energy sector	-320	-220
Manufacturing	1,870	1,270
Construction	33,050	22,480
Transport	12,420	8,450
Services	7,940	5,400
Government	33,500	22,790
Firms and government	5,970	4,060
Households	16,380	11,140
Firms, government and households	8,560	5,820

Table 70: Zachariadis & Poullikkas (2012) study – Economic output, electricity use and value of lost load in Cyprus in 2009

	Electricity Consumption		Value		Value of lost load
Sector	GWh	% of total	(mil €)	% of total	(€/MWh)
Agriculture	151	3.2	346	1.1	2300
Mining and quarrying	27	0.6	52	0.2	1,900
Manufacturing	546	11.6	1043	3.4	1,910
Cement industry	133	2.8	120	0.4	900
Gas and water supply	249	5.3	51	0.2	200
Construction	11	0.2	1249	4.1	118,060
Services	1999	42.5	12243	40.0	6,120
Public administration	135	2.9	1570	5.1	11,630
Private offices	397	8.4	5551	18.1	13,970
Health	94	2.0	628	2.1	6,650
Trade	467	9.9	1872	6.1	4,000
Hotels and restaurants	485	10.3	915	3.0	1,890

	Electricity Consumption		Value		Value of lost load
Sector	GWh	% of total	(mil €)	% of total	(€/MWh)
Education	38	0.8	960	3.1	25,480
Other	382	8.1	747	2.4	1,960
Residential	1722	36.3	15614	51.0	9,070
Total	**4706**	**100.0**	**30,598**	**100.0**	**6,500**

Table 71: Oxera (2007) study – Costs of gas interruption, excluding demand-size response (£m/day)

Interruption size (mcm/day)	Cost (£m/day)
10	95
20	127
30	184
40	296
50	347
60	413
70	472
80	522
90	589
100	684
110	1143
120	1517
130	1891
130.4	1906

Table 72: Castro et al. (2016) study – Comparison with other European countries VoLL €/kWh

Country	PT	ES	DE	DE	CY	RO	NL
Year	2010	2008	2007	2008-2010	2009	2008	2001
Agriculture and fisheries	3.38	4.4	2.49	2.2	2.3	NA	3.9
Manufacturing	1.28	1.38	2.19	2.81	1.91	4	1.87
Const. and public works	15.52	33.37	102.9	NA	118.0	NA	33.05
Transportation	6.03	8.53	NA	7.61	NA	NA	12.42
Services	6.67	8.47	11.04	15.37	6.12	14	7.49
Total without household	4.2	5.13	5.74	NA	NA	NA	5.97
Household	7.43	8.11	11.92	15.05	9.07	24.6	16.38
Total	5.12	5.98	7.41	12.51	6.5	12.9	8.56

Table 73: ILEX (2006) study

	Range £/MWh	
1-day emergency (involuntary) interruption		
3-6 weeks emergency (involuntary) interruption	186.7	815.0
Self-interruption	65.2	284.6

Table 74: Praktiknjo (2016) – Results for the VoLL I in the 12 sector division in EUR/MWh

Sector	VoLL in EUR/MWh			
	2000	2005	2006	2007
Agriculture and forestry	4,620	3,070	3,110	3,530
Mining, energy and water	670	720	780	830
Chemical and petroleum products	870	890	940	890
Metalworking	1,170	1,110	1,210	1,260
Machinery, vehicles, electronics	4,870	4,900	5,210	5,130
Textiles, wood, paper	1,810	1.520	1,510	1,560
Food and beverages	2,130	1,830	1,790	1,790
Construction word	29,860	24,160	22,920	23,940
Commerce, traffic, communication, restaurants	5,640	5,620	5,660	5,830
Banks, insurances, housing industry	39,590	38,390	39,570	41,220

	VoLL in EUR/MWh			
Healthcare and social work services	15,470	17,060	15,530	16,000
Public administration, culture, private household services	12,550	13,170	12,810	13,570

Table 75: Praktiknjo (2016) – Results for the VoLL II in the 12 sector division in EUR/MWh

Sector	VoLL in EUR/kWh			
	2000	2005	2006	2007
Agriculture and forestry	6,970	4,850	4,930	5,460
Mining, energy and water	2,350	1,680	1,680	1,780
Chemical and petroleum products	1,650	1,550	1,630	1,610
Metalworking	2,060	1,880	2,070	2,160
Machinery, vehicles, electronics	5,860	5,820	6,120	6,050
Textiles, wood, paper	2,770	2,390	2,330	2,410
Food and beverages	2,760	2,370	2,280	2,310
Construction word	41.810	33.500	31,890	33,530
Commerce, traffic, communication, restaurants	8.150	7.620	7,600	7,910
Banks, insurances, housing industry	59,840	56,470	57,420	59,440

	VoLL in EUR/kWh			
Healthcare and social work services	16,380	18,200	16,510	17,070
Public administration, culture, private household services	14,970	16,040	15,630	16,590

Table 76: Shivakumar et al. (2017) - VoLL by country using production - function approach

Country	Electricity-based leisure activity (hours/ year)	Value of leisure (total) (million €/year)	Electricity consumption (households) (GWh/year)	VoLL (PPPa adjusted (€/kWh)
Austria	1,497.90	176,619	17,641	9.49
Belgium	1,405.30	291,517	19,756	13.58
Bulgaria	1,314.30	16,568	10,510	3.20
Croatia	1,337.70	24,986	6,213	5.90
Cyprus	1,337.70	8,690	1,434	6.50
Czech Republic	1,319.50	65,621	14,677	6.55
Denmark	1,498.90	161,665	10,280	11.38
Estonia	1,363.70	7,926	1,861	5.71
Finland	1,413.10	117,332	21,460	4.46
France	1,397.50	1,490,576	167,470	8.28

Country	Electricity-based leisure activity (hours/ year)	Value of leisure (total) (million €/year)	Electricity consumption (households) (GWh/year)	VoLL (PPPa adjusted (€/kWh)
Germany	1,454.70	1,768,204	135,649	12.64
Greece	1,280.50	88,706	17,401	5.68
Hungary	1,345.50	46,834	10,553	7.47
Ireland	1,452.10	92,828	7,927	9.71
Italy	1,413.10	1,112,956	66,810	16.29
Latvia	1,363.70	8,049	1,778	6.43
Lithuania	1,381.90	12,168	2,584	7.49
Luxembourg	1,407.90	12,846	875	12.20
Malta	1,374.10	3,391	607	6.87
Netherlands	1,592.50	431,322	25,068	15.80
Poland	1,314.30	192,110	28,369	12.15
Portugal	1,350.70	85,808	12,282	8.42

Country	Electricity-based leisure activity (hours/ year)	Value of leisure (total) (million €/year)	Electricity consumption (households) (GWh/year)	VoLL (PPPa adjusted (€/kWh)
Romania	1,332.50	56,618	11,866	8.97
Slovakia	1,314.30	30,383	4,917	9.01
Slovenia	1,342.90	20,081	3,220	7.51
Spain	1,384.50	596,244	72,326	8.70
Sweden	1,428.70	250,300	38,105	5.03
United Kingdom	1,423.50	914,742	113,160	6.94

Appendix 3 Data sources for the estimation of capital costs

	Description	Link
Austria		
Stoves		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.at
Air Condition		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.at
Other electric appliances		

	Description	Link
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.at
Electric water heaters		
Badshop	Badshop is an Austrian online shop for bathroom and heating	• https://www.badshop-austria.at
Hornbach	The HORNBACH Group is one of the leading DIY companies in Europe, with branches in Germany, Luxembourg, the Netherlands, Austria, Romania, Slovakia, Sweden, Switzerland and the Czech Republic.	• https://www.hornbach.at
Oil burners		
HTS	N/A	• https://www.hts-heiztechnik.at/
Belgium		

	Description	Link
Stoves		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://www.mediamarkt.be
Vandenborre	N/A	• https://www.vandenborre.be
Air Condition		
Brico	Brico is the first in Belgium to offer a wide range of products directly related to DIY, dedicated to the layout and renovation of the house and garden.	• https://www.brico.be
Gamma	GAMMA is in the top 3 DIY stores in Belgium.	• https://www.gamma.be
Electrolux	N/A	• https://www.electrolux.be
Other electric appliances		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://www.mediamarkt.be

	Description	Link
Electric water heater		
Vaillant	N/A	• https://www.vaillant.be
Hubo	Hubo is a 100% Belgian organization with 145 stores across the country and holds a strong second place in the DIY sector.	• https://www.hubo.be
Bulgaria		
Stoves		
Zora	N/A	• https://zora.bg
Air Condition		
Zora	N/A	• https://zora.bg
Other electric appliances		
Zora	N/A	• https://zora.bg

	Description	Link
Electric water heaters		
Zora	N/A	• https://zora.bg
Heat pumps		
Termo-klima	THERMO-CLIMA Ltd. specializes in the field of air conditioning and heating equipment.	• https://www.termo-klima.com/bg
Pellet burners		
Daricclima	Darik Clima was established with the business of design and construction of heating and air conditioning systems, service activities, trade activities in Bulgaria and abroad, import and export of goods.	• https://www.daricclima.bg
Croatia		
Stoves		

	Description	Link
Elipso	N/A	• https://www.elipso.hr
Air Condition		
klimatizacija	klimatizacija is a leader in air conditioning in the domestic market	• http://klimatizacija.hr
Other electric appliances		
Elipso	N/A	• https://www.elipso.hr
Pellet burners		
Ikoma	N/A	• https://www.ikoma.hr
Njuskalo	N/A	• https://www.njuskalo.hr
Czech Republic		
Stoves		

	Description	Link
Alza	N/A	• https://www.alza.cz
Heureka	Heureka is the largest shopping guide on the Czech Internet.	• https://sporaky.heureka.cz
Air Condition		
Heureka	Heureka is the largest shopping guide on the Czech Internet.	• https://klimatizace.heureka.cz/
Exasoft	ExaSoft Holding as is a purely Czech company and has been operating on the market since 2004. It started as a local computer sales and computer service provider called ComputerPoint. In 2008, the company transformed into a joint stock company and renamed ExaSoft. ExaSoft expanded to a retail store with a retail space of more than 800 m2, and white goods, home appliances and televisions were added to the sales portfolio.	• https://www.exasoft.cz

	Description	Link
Baxx	A purely Czech specialist company for everything about cooling, ventilation and air conditioning	• https://baxx.cz/
Other electric appliances		
Alza	N/A	• https://www.alza.cz
Heureka	Heureka is the largest shopping guide on the Czech Internet.	• https://cisticky-vzduchu-a-zvlhcovace.heureka.cz
Electric water heaters		
Alza	N/A	• https://www.alza.cz
Heat pumps		
Ekologicke-kotle	N/A	• http://www.ekologicke-kotle.cz
Pellet burners		

	Description	Link
Heureka	Heureka is the largest shopping guide on the Czech Internet.	• https://kotle.heureka.cz
Denmark		
Stoves		
Skousen	Skousen is Denmark's leading and most experienced consumer of white goods.	• https://www.skousen.dk
Wupti	N/A	• https://www.wupti.com
Air Condition		
Punkt1	Punkt1 is Denmark's largest white goods chain with stores distributed throughout the country.	• https://www.punkt1.dk
Wupti	N/A	• https://www.wupti.com

	Description	Link
Whiteaway	WhiteAway offers a wide range of quality white goods, vacuum cleaners and other home appliances.	• https://www.whiteaway.com
Other electric appliances		
Punkt1	Punkt1 is Denmark's largest white goods chain with stores distributed throughout the country.	• https://www.punkt1.dk
Power	N/A	• https://www.power.dk
Electric water heaters		
Bauhaus	N/A	• https://www.bauhaus.dk
Harald-Nyborg	N/A	• https://www.harald-nyborg.dk
Billigvvs	BilligVVS supplies quality plumbing products at cheap prices to all of Denmark.	• https://www.billigvvs.dk
Lavprisvvs	N/A	• https://www.lavprisvvs.dk

	Description	Link
Heat pumps		
Wupti	N/A	• https://www.wupti.com
Whiteaway	WhiteAway offers a wide range of quality white goods, vacuum cleaners and other home appliances.	• https://www.whiteaway.com
Power	N/A	• https://www.power.dk
Oil burners		
VVS-Eksperten	N/A	• https://www.vvs-eksperten.dk
VVS-Netto	N/A	• https://www.vvsnetto.dk
Multikøb	N/A	• https://www.multikoeb.dk
Estonia		
Stoves		

	Description	Link
1a.ee	N/A	• https://www.1a.ee
Air Condition		
1a.ee	N/A	• https://www.1a.ee
Kliimamarket	N/A	• https://www.kliimamarket.ee
Other electrical appliances		
1a.ee	N/A	• https://www.1a.ee
Electric water heaters		
1a.ee	N/A	• https://www.1a.ee
Heat pumps		
Kliimamarket	N/A	• https://www.kliimamarket.ee
ACkliima	N/A	• http://www.ackliima.eu

	Description	Link
Pellet burners		
Cerbos	OÜ Cerbos' field of activity includes selling, installing, maintaining and designing central heating components.	• https://www.cerbos.ee
Toru-Juri	Toru-Juri are selling, installing and maintaining heating and water systems.	• https://torujyri.ee
Küttesalong	N/A	• http://www.xn--kttesalong-9db.ee
Finland		
Stoves		
Gigantii	N/A	• https://www.gigantti.fi
Verkkokauppa	N/A	• https://www.verkkokauppa.com/fi
Power	N/A	• https://www.power.fi

	Description	Link
Other electric appliances		
Taloon	N/A	• https://www.taloon.com
Electric water heaters		
Huipputuotteet	N/A	• http://www.huipputuotteet.fi
Heat pumps		
Taloon	N/A	• https://www.taloon.com
Oil burners		
Lvitarvikkeet	N/A	• https://www.lvitarvikkeet.fi
Pellet burners		
Pl Eldfast	N/A	• http://shop.pleldfast.se/fi
France		

	Description	Link
Stoves		
Leroy Merlin	Leroy Merlin is a French headquartered home improvement and gardening retailer serving several countries in Europe, Asia, South America, and Africa.	• https://www.leroymerlin.fr/
Air Condition		
Leroy Merlin	Leroy Merlin is a French headquartered home improvement and gardening retailer serving several countries in Europe, Asia, South America, and Africa.	https://www.leroymerlin.fr
Other electric appliances		
Leroy Merlin	Leroy Merlin is a French headquartered home improvement and gardening retailer serving several countries in Europe, Asia, South America, and Africa.	• https://www.leroymerlin.fr/

	Description	Link
Electric water heaters		
Leroy Merlin	Leroy Merlin is a French headquartered home improvement and gardening retailer serving several countries in Europe, Asia, South America, and Africa.	• https://www.leroymerlin.fr
Heat pumps		
Leroy Merlin	Leroy Merlin is a French headquartered home improvement and gardening retailer serving several countries in Europe, Asia, South America, and Africa.	https://www.leroymerlin.fr
Pellet burners		
Leroy Merlin	Leroy Merlin is a French headquartered home improvement and gardening retailer serving several countries in Europe, Asia, South America, and Africa.	• https://www.leroymerlin.fr

	Description	Link
Germany		
Stoves		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.de
Air Condition		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.de
Other electric appliances		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.de
Electric water heaters		

	Description	Link
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.del
Heat pumps		
HeizungDiscount24.de	N/A	• https://www.heizungsdiscount24.de
Oil Burners		
Hansa Heiztechnik	N/A	• https://www.hansa-heiztechnik.de
Pellet Burners		
Gemashop	Gemashop is a heating and plumbing company in Germany with sales area extended Europe-wide.	• https://www.gemashop.de
Heizerschwaben	N/A	• https://heizerschwaben.de
Greece		

	Description	Link
Stoves		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.gr
Kotsovolos	Kotsovolos is the leading electrical and electronics chain in Greece.	• https://www.kotsovolos.gr
Air Condition		
Kotsovolos	Kotsovolos is the leading electrical and electronics chain in Greece.	• https://www.kotsovolos.gr
Other electric appliances		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.gr
Electric water heaters		

	Description	Link
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.gr
Heat pumps		
Kalogiropoulos	Kalogiropoulos offers complete solutions for heating, hydraulic installations, solar water heater, tiles and sanitary items.	• http://www.kalogiropoulos.gr
Abclima	AB CLIMA PPC is a company that operates in the area of Cooling and Heating.	• https://abclima.gr
Oil burners		
Abclima	AB CLIMA PPC is a company that operates in the area of Cooling and Heating.	• https://abclima.gr
Multiclima	MultiClima was founded with the task of heating and air conditioning, has expanded into the	• https://www.multiclima.gr

	Description	Link
	plumbing, solar, floor heating, renewable energy sectors and energy saving energy systems.	
Celsius	Celsius' main activity is natural gas and has a significant presence in heating with oil, in the air conditioning, in solar energy, in the interior heating and water supply/sewage.	• https://www.celsius.gr
Pellet burners		
Alphaclima		• https://www.alphaclimagr.gr
Proenergy	Proenergy is a technical office, commercial and construction company with collection points all over Greece, offering complete services for the Study and Construction of Electrical Installations, RES, Heating and Air Conditioning.	• https://www.proenergy.gr
Hungary		
Stoves		

	Description	Link
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.hu
Air Condition		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.hu
Other electric appliances		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.hu
Electric water heaters		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.hu

	Description	Link
Pellet burners		
Pelletkályha Webshop	N/A	• https://www.pelletkalyhawebshop.hu
Ireland		
Stoves		
Currys	Currys is a British electrical retailer operating in the United Kingdom and Republic of Ireland, and specialises in selling home electronics and household appliances.	• http://www.currys.ie
Harveynorman	Harvey Norman is the leading retailer of furniture, bedding, computer and electrical goods in Republic of Ireland and in Northern Ireland.	• http://www.harveynorman.ie
Air Condition		

	Description	Link
Slingsby	Slingsby is one of the UK's market leaders in the distance selling of industrial and commercial equipment.	• https://www.slingsby.ie
Huntoffice	Huntoffice is the largest Irish owned office supplies company and website providing customers with a one stop shop for all their office supplies needs, products from everyday stationery to furniture, warehouse products and canteen supplies.	• https://www.huntoffice.ie
Other electrical appliances		
Currys	Currys is a British electrical retailer operating in the United Kingdom and Republic of Ireland, and specialises in selling home electronics and household appliances.	• http://www.currys.ie
Electric water heaters		
Watersave	WaterSave is a small, closely held all Irish company.	• http://www.watersave.ie

	Description	Link
Screwfix	Screwfix is the UK's largest multi-channel supplier of trade tools, plumbing, electrical, bathrooms and kitchens.	• https://www.ie.screwfix.com
Heat pumps		
RVR	RVR Energy Technology Ltd is a leading producer and distributor of heating equipment for commercial, residential and residential buildings.	• https://www.rvr.ie
Oil burners		
Plumbing products	Plumbing products expertise in dealing with Heating & Plumbing Supplies & Accessories	• https://www.plumbingproducts.ie
Pellet burners		
Natural Green energy	Natural Green energy specialises in Plumbing, Heating, Solar, Stoves and Fireplaces.	• https://www.naturalgreenenergy.ie
Italy		

	Description	Link
Stoves		
Media world	Media Markt (Media world in Italy) is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://www.mediaworld.it
Air Condition		
Leroy Merlin	Leroy Merlin is a French headquartered home improvement and gardening retailer serving several countries in Europe, Asia, South America, and Africa.	• https://www.leroymerlin.it
Electric water heaters		
Media World	Media Markt (Media world in Italy) is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://www.mediaworld.it

	Description	Link
Latvia		
Stoves		
Xnet	N/A	• https://www.xnet.lv
1a	N/A	• https://www.1a.lv
Air Condition		
Commodus	N/A	• https://commodus.lv
1a	N/A	• https://www.1a.lv
Prof	N/A	• https://prof.lv
Other electric appliances		
Rdveikals	N/A	• http://www.rdveikals.lv
Prof	N/A	• https://prof.lv

	Description	Link
Electric water heaters		
1a	N/A	• https://www.1a.lv
Prof	N/A	• https://prof.lv
Heat pumps		
Commodus	N/A	• https://commodus.lv
SB Siltumtechica	N/A	• https://www.sbsiltumtehnika.lv
Prof	N/A	• https://prof.lv
Oil burners		
Buvbaze	N/A	• https://www.buvbaze.lv
Pellet burners		
Commodus	N/A	• https://commodus.lv

	Description	Link
Buvbaze	N/A	• https://www.buvbaze.lv
Lithuania		
Stoves		
Avitela	N/A	• https://www.avitela.lt
Bigbox	N/A	• http://www.bigbox.lt
Rde	N/A	• http://www.rde.lt
Air Condition		
Elektromarkt	N/A	• https://www.elektromarkt.lt
Topo centras	N/A	• https://www.topocentras.lt
Geri katilai	N/A	• https://www.gerikatilai.lt
Other electric appliances		

	Description	Link
Avitela	N/A	• https://www.avitela.lt
Elektromarkt	N/A	• https://www.elektromarkt.lt
Electric water heaters		
Rde	N/A	• http://www.rde.lt
Senukai	N/A	• https://www.senukai.lt
Ermitazas	N/A	• https://www.ermitazas.lt
Heat pumps		
Topo centras	N/A	• https://www.topocentras.lt
E-Silumossiurbliai	N/A	• http://www.e-silumossiurbliai.lt
Katiluturgus	N/A	• https://www.katiluturgus.lt
Pellet burners		

	Description	Link
Skelbiu	N/A	• https://www.skelbiu.lt
Katiluturgus	N/A	• https://www.katiluturgus.lt
Geri katilai	N/A	• https://www.gerikatilai.lt
Technica jums	N/A	• http://www.technikajums.lt
Luxembourg		
Stoves		
Hornbach	The HORNBACH Group is one of the leading DIY companies in Europe, with branches in Germany, Luxembourg, the Netherlands, Austria, Romania, Slovakia, Sweden, Switzerland and the Czech Republic.	• https://www.hornbach.lu
Conforama	N/A	• http://www.conforama.lu
Air Condition		

	Description	Link
Hifi	N/A	• https://www.hifi.lu
Other electrical appliances		
Hornbach	The HORNBACH Group is one of the leading DIY companies in Europe, with branches in Germany, Luxembourg, the Netherlands, Austria, Romania, Slovakia, Sweden, Switzerland and the Czech Republic.	• https://www.hornbach.lu
Electric water heaters		
Hornbach	The HORNBACH Group is one of the leading DIY companies in Europe, with branches in Germany, Luxembourg, the Netherlands, Austria, Romania, Slovakia, Sweden, Switzerland and the Czech Republic.	• https://www.hornbach.lu
Pellet burners		
Hornbach	The HORNBACH Group is one of the leading DIY companies in Europe, with branches in Germany,	• https://www.hornbach.lu

	Description	Link
	Luxembourg, the Netherlands, Austria, Romania, Slovakia, Sweden, Switzerland and the Czech Republic.	
Netherlands		
Stoves		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.nl
Air Condition		
Coolblue	Coolblue is a fast-growing e-commerce company in the Netherlands and Belgium.	• https://www.coolblue.nl
Koelklimaattechniek	N/A	• https://www.koelklimaattechniekwebwinkel.nl
Other electric appliances		

	Description	Link
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.nl
Electric water heaters		
Boilermarkt	N/A	• https://www.boilermarkt.nl
De Groene Hoed	N/A	• http://www.groenehoedduurzaam.nl
Oil burners		
AltecParts	N/A	• https://www.altecparts.nl
Pellet burners		
Ecoportaal	N/A	• http://www.ecoportaal.nl
Poland		
Stoves		

	Description	Link
al.to	N/A	• https://www.al.to
Mediaexpert	N/A	• https://www.mediaexpert.pl
Allegro	N/A	• http://allegro.pl
Zadowolenie	N/A	• https://www.zadowolenie.pl
Air Condition		
Skep klimman	N/A	• https://sklep.klimman.com.pl
Other electric appliances		
Domsary	N/A	• https://domsary.eu
Neo24	N/A	• https://www.neo24.pl
Sferis	SFERIS is a dynamically growing specialist retail network offering consumer electronics product.	• https://www.sferis.pl

	Description	Link
Ceneo	Ceneo.pl is the second largest e-commerce website in Poland.	• https://www.ceneo.pl
eMag	N/A	• https://www.emag.pl
Electric water heaters		
Bridom	N/A	• http://www.bridom.pl
e-Term	e-Term is now one of the largest online stores offering heating and sanitary equipment in Poland.	• http://www.e-term.pl
Instalacje-grzewcze	N/A	• http://instalacje-grzewcze.eu
Heat pumps		
Grzanie plus	N/A	• http://grzanieplus.pl
Bridom	N/A	• http://www.bridom.pl
Oil burners		

	Description	Link
2heat	N/A	• http://2heat.pl
Pellet burners		
499	499 is dealing in the heating devices market.	• https://499.com.pl
Fuego	Fuego has experience in the field of trade and assembly of installation materials.	• https://www.fuego.pl
Auroks	N/A	• https://sklep.auroks.pl
Portugal		
Stoves		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://mediamarkt.pt
Air Condition		

	Description	Link
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://mediamarkt.pt
Other electric appliances		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://mediamarkt.pt
Electric water heaters		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://mediamarkt.pt
Heat pumps		
ATD-RM	N/A	• http://atd-rm.pt
Worten	Worten offers a wide range of products and brands - not only as a supplier, but also as exclusive brands	• https://www.worten.pt

	Description	Link
	in the home appliances, consumer electronics and entertainment sectors.	
Obras360	Obras360 offers a wide range of products for construction and rehabilitation of home.	• https://www.obras360.pt
Oil burners		
Electronic star	N/A	• https://www.electronic-star.pt
Shopping	N/A	• https://shopping.pt
Pellet burners		
Leroy Merlin	Leroy Merlin is a French headquartered home improvement and gardening retailer serving several countries in Europe, Asia, South America, and Africa.	• http://www.leroymerlin.pt
Romania		
Stoves		

	Description	Link
eMag	eMag is a company in Romania dealing with online sale of equipment and components, IT, electronics, personal care items, automotive products, sporting goods, books, music, movies, products for home and garden, pet shops, goods for children.	• https://www.emag.ro
Air Condition		
eMag	eMag is a company in Romania dealing with online sale of equipment and components, IT, electronics, personal care items, automotive products, sporting goods, books, music, movies, products for home and garden, pet shops, goods for children.	• https://www.emag.ro
Other electrical appliances		
eMag	eMag is a company in Romania dealing with online sale of equipment and components, IT, electronics, personal care items, automotive products, sporting goods, books, music, movies, products for home and garden, pet shops, goods for children.	• https://www.emag.ro

	Description	Link
Electric water heaters		
eMag	eMag is a company in Romania dealing with online sale of equipment and components, IT, electronics, personal care items, automotive products, sporting goods, books, music, movies, products for home and garden, pet shops, goods for children.	• https://www.emag.ro
Heat pumps		
eMag	eMag is a company in Romania dealing with online sale of equipment and components, IT, electronics, personal care items, automotive products, sporting goods, books, music, movies, products for home and garden, pet shops, goods for children.	• https://www.emag.ro
Oil burners		
Scule Unelte	N/A	• https://www.magazindesculesiunelte.ro
Brico Tools	N/A	• https://www.ebricotools.ro

	Description	Link
Detop	N/A	• https://www.scule.detop.ro
Pellet burners		
eMag	eMag is a company in Romania dealing with online sale of equipment and components, IT, electronics, personal care items, automotive products, sporting goods, books, music, movies, products for home and garden, pet shops, goods for children.	• https://www.emag.ro
Slovakia		
Stoves		
Hej	N/A	• https://www.hej.sk
Mall	N/A	• https://www.mall.sk
Air Condition		
Dobra Klima	N/A	• https://www.dobraklima.sk

	Description	Link
Chladenie a klimatizacie	N/A	• https://chladenieaklimatizacie.sk
Heureka	N/A	• https://klimatizacie.heureka.sk
Other electric appliances		
Bonusko	N/A	• http://www.bonusko.sk
K24	N/A	• https://www.k24.sk
Electric water heaters		
Andrea Shop Sala	N/A	• https://www.andreashop-sala.sk
Hej	N/A	• https://www.hej.sk
Heat pumps		
Gas-TM	N/A	• https://www.gas-tm.sk

	Description	Link
Pellet burners		
Kotol Lacno	N/A	• http://www.kotollacno.sk
Heureka	N/A	• https://kotly.heureka.sk
Instalater shop	N/A	• http://www.instalatershop.sk
Slovenia		
Stoves		
Mimovrste	N/A	• https://www.mimovrste.com
Air Condition		
Mimovrste	N/A	• https://www.mimovrste.com
Other electric appliances		
Mimovrste	N/A	• https://www.mimovrste.com

	Description	Link
Big Bang	N/A	• https://www.bigbang.si
Electric water heaters		
Big Bang	N/A	• https://www.bigbang.si
Ceneje	N/A	• https://www.ceneje.si
Heat pumps		
Mimovrste	N/A	• https://www.mimovrste.com
Oil burners		
Merkur	N/A	• https://www.merkur.si
Lontech	N/A	• http://www.lontech.si
Pellet burners		
Lontech	N/A	• http://www.lontech.si

	Description	Link
Spain		
Air Condition		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://tiendas.mediamarkt.es
Electric water heaters		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• https://tiendas.mediamarkt.es
Sweden		
Stoves		
Mediamarkt	Media Markt is a German multinational chain of stores selling consumer electronics with numerous branches throughout Europe and Asia.	• http://www.mediamarkt.se

	Description	Link
Air Condition		
Clas ohlson	N/A	• https://www.clasohlson.com
Other electric appliances		
VVSbutiken	N/A	• http://www.vvsbutiken.nu
Electric water heaters		
Nordkapp	N/A	• https://www.nordkapp.nu
VVSbutiken	N/A	• http://www.vvsbutiken.nu
Ahlsell	N/A	• https://www.ahlsell.se
PriceRunner	N/A	• https://www.pricerunner.se
Heat pumps		
VVSbutiken	N/A	• http://www.vvsbutiken.nu

	Description	Link
VVS	N/A	• http://www.vvsobadrum.se
Oil burners		
Armatec	N/A	• https://www.armatec.com
Pellet burners		
Pricerunner	N/A	• https://www.pricerunner.se
Velltra	Velltra is a family company that has been trading in Construction, Plumbing, Electricity, Gardening, Hobby and Crafts since 1991.	• https://www.velltra.se
United Kingdom		
Stoves		
Currys	Currys is a British electrical retailer operating in the United Kingdom and Republic of Ireland, and	• https://www.currys.co.uk

	Description	Link
	specialises in selling home electronics and household appliances.	
Argos	Argos is one of the UK's leading digital retailers offering more than 60,000 products online and in-store	• http://www.argos.co.uk
Air Condition		
Cooleasy	Cooleasy is one of the UK's top trade air conditioning suppliers.	• https://www.cooleasy.co.uk
Airconditioner.me	N/A	• http://www.airconditioner.me.uk
Qstore24	Qstore24 is London based company which specialises in supplying gas and electrical appliances for domestic, commercial and industrial properties across the UK.	• https://www.qstore24.co.uk
Other electric appliances		

	Description	Link
Currys	Currys is a British electrical retailer operating in the United Kingdom and Republic of Ireland, and specialises in selling home electronics and household appliances.	• https://www.currys.co.uk
Electric water heaters		
Cnm online	N/A	• https://www.cnmonline.co.uk
Ehc	The Electric Heating Company ("EHC") has been one of the foremost suppliers of electric heating and hot water products in the UK for over 10 years.	• https://www.electric-heatingcompany.co.uk
Heat pumps		
Dream Heat Pumps	Dreamheatpumps is a fully internet-based business, which offers to the customer heat pumps at bargain prices.	• http://www.dreamheatpumps.co.uk
Oil burners		

	Description	Link
DirectHeatingSupplies	Direct Heating Supplies is one of the UK's leading plumbing and heating retailers.	• https://www.directheatingsupplies.co.uk
PlumbNation	PlumbNation is one of the leading Suppliers of Plumbing and Heating products in the UK.	• https://www.plumbnation.co.uk
Pellet burners		
Wood Pellet Stove	Wood Pellet Stove is a UK agent for Artel stoves which are made in Northern Italy	• http://woodpelletstove.co.uk

Appendix 4 Capital costs of Representative Alternative Appliances

Table 77 and Table 78 present the Capital costs of representative alternative appliances. We used the average EU cost for the countries and the appliances that we could not find any available values.

Table 77: Capital costs by Member State, sector and type of appliance

MS	Appliances [€/MW]								
	Residential and Services Sectors							Industrial Sector	
	Stove	A/C	Other electric	Electric Water heater	Heat pump	Oil Burner	Burner (Pellet, wood)	Oil fired boiler	Electric boiler
Austria	125,290	139,808	25,193	20,345	352,299	35,580	150,921	121,000	578,000
Belgium	253,663	175,594	11,613	139,846	256,139	21,337	-	98,500	470,500
Bulgaria	161,842	128,259	19,601	45,145	512,669	245,446	35,218	45,000	215,000
Croatia	157,428	159,156	14,785	43,028	371,867	16,063	47,554	90,460	432,160
Cyprus	N/A (no gas)								

MS	Appliances [€/MW]								
	Residential and Services Sectors							Industrial Sector	
	Stove	A/C	Other electric	Electric Water heater	Heat pump	Oil Burner	Burner (Pellet, wood)	Oil fired boiler	Electric boiler
Czech Republic	78,555	57,718	5,838	39,769	403,333	9,550	75,655	314,000	-
Denmark	208,043	132,372	47,730	78,067	256,139	21,337	-	148,000	707,500
Estonia	59,571	192,856	10,800	75,970	308,332	-	46,677	71,000	339,000
Finland	167,778	192,856	74,277	42,899	240,299	14,919	70,072	108,500	518,500
France	213,275	82,275	23,177	57,834	180,332	12,185	150,921	118,500	567,000
Germany	132,298	98,000	23,486	32,281	123,973	22,437	131,819	120,000	572,500
Greece	185,000	109,064	29,502	30,080	466,677	6,260	14,554	72,500	346,000
Hungary	134,611	119,359	9,909	61,825	370,713	16,987	117,940	61,500	295,000

MS	Appliances [€/MW]								
	Residential and Services Sectors							Industrial Sector	
	Stove	A/C	Other electric	Electric Water heater	Heat pump	Oil Burner	Burner (Pellet, wood)	Oil fired boiler	Electric boiler
Ireland	176,568	266,352	17,933	46,917	408,343	43,429	190,334	102,500	489,500
Italy	272,667	137,665	21,910	73,670	-	43,429	-	79,000	376,500
Latvia	124,284	167,492	52,831	51,372	360,681	9,550	73,291	83,000	395,500
Lithuania	276,550	125,959	13,772	54,396	331,796	-	58,064	73,500	352,000
Luxembourg	185,860	165,877	11,160	17,499	578,491	245,446	159,344	102,000	487,500
Malta	N/A (no gas)								
Netherlands	212,383	170,598	6,660	95,980	370,713	18,891	159,767	128,500	613,000
Poland	138,795	56,742	7,075	26,931	578,491	245,446	113,007	71,000	339,500

MS	Appliances [€/MW]								
	Residential and Services Sectors							Industrial Sector	
	Stove	A/C	Other electric	Electric Water heater	Heat pump	Oil Burner	Burner (Pellet, wood)	Oil fired boiler	Electric boiler
Portugal	172,927	143,957	18,433	71,778	371,867	16,063	260,225	59,000	282,000
Romania	117,747	89,179	10,752	59,708	243,765	39,007	58,902	45,500	218,000
Slovakia	197,203	111,175	30,864	87,502	472,470	-	73,784	69,500	331,500
Slovenia	113,089	107,295	18,983	42,972	370,713	13,737	119,968	75,500	362,000
Spain	172,927	101,128	14,425	41,067	-	-	-	82,000	390,500
Sweden	408,889	211,348	19,094	243,352	714,914	11,156	84,133	144,500	689,500
United Kingdom	168,115	201,485	20,240	40,341	223,464	54,505	167,378	116,000	554,000

Table 78: Power and District Heating sector: Capital costs by technology

Member state	Appliances [€/MW]	
	Gas turbine - New dual fuel burner	Gas turbine - Modification of existing gas burner to dual fuel
EU28	10,175	46,428

Appendix 5 Assumptions on the utilization and lifetime of Representative Alternative Appliances

Table 79 and Table 80 present our assumptions on the utilisation of each appliance in hours per week W_H and number of weeks in year, N_w, as required by equation (1). Assumptions in relation to the appliance lifetime, *TL*, are also shown. No differentiation across MS has been made.

Table 79: Residential and Services Sectors: Assumptions on utilization and lifetime for each alternative appliance

Sector	Subsector	Variable	Type of End-Use						
			Cooking	Water Heating	Space heating/Space cooling				
			Stove	Electric Water heater	A/C	Heat Pump	Oil Burner	Pellet Burner	Other Electrical Appliances
Residential	n.a.	D_H [hours in day]	1	1	4	4	4	4	4
Residential	n.a.	N_D [days]	7	7	7	7	7	7	7
Residential	n.a.	N_w [weeks]	52	52	34	34	34	34	34
Residential	n.a.	TL [years]	10	10	10	15	20	20	7

Sector	Subsector	Variable	Type of End-Use						
			Cooking	Water Heating	Space heating/Space cooling				
			Stove	Electric Water heater	A/C	Heat Pump	Oil Burner	Pellet Burner	Other Electrical Appliances
Services (P)[40]	Healthcare	D_H $[hours\ in\ day]$	4	24	24	24	24	24	24
Services (P)	Healthcare	N_D $[days]$	7	7	7	7	7	7	7
Services (P)	Healthcare	N_w $[weeks]$	52	52	52	34	34	34	34
Services (P)	Education	D_H $[hours\ in\ day]$	3	8	8	8	8	8	8
Services (P)	Education	N_D $[days]$	5	5	5	5	5	5	5
Services (P)	Education	N_w $[weeks]$	38	38	34	34	34	34	34

40 Services Protected

Sector	Subsector	Variable	Type of End-Use						
			Cooking	Water Heating	Space heating/Space cooling				
			Stove	Electric Water heater	A/C	Heat Pump	Oil Burner	Pellet Burner	Other Electrical Appliances
Services (P)	Emergency	D_H $[hours\ in\ day]$	1	24	24	24	24	24	24
Services (P)	Emergency	N_D $[days]$	7	7	7	7	7	7	7
Services (P)	Emergency	N_w $[weeks]$	52	52	52	34	34	34	34
Services (P)	Security	D_H $[hours\ in\ day]$	1	24	24	24	24	24	24
Services (P)	Security	N_D $[days]$	7	7	7	7	7	7	7
Services (P)	Security	N_w $[weeks]$	52	52	52	34	34	34	34
Services (P)	Essential social care	D_H $[hours\ in\ day]$	4	24	24	24	24	24	24

Sector	Subsector	Variable	Type of End-Use						
			Cooking	Water Heating	Space heating/Space cooling				
			Stove	Electric Water heater	A/C	Heat Pump	Oil Burner	Pellet Burner	Other Electrical Appliances
Services (P)	Essential social care	N_D $[days]$	7	7	7	7	7	7	7
Services (P)	Essential social care	N_w $[weeks]$	52	52	52	34	34	34	34
Services (P)	Public administration	D_H $[hours\ in\ day]$	-	8	8	8	8	8	8
Services (P)	Public administration	N_D $[days]$	-	5	5	5	5	5	5
Services (P)	Public administration	N_w $[weeks]$	-	52	34	34	34	34	34

Sector	Subsector	Variable	Type of End-Use						
			Cooking	Water Heating	Space heating/Space cooling				
			Stove	Electric Water heater	A/C	Heat Pump	Oil Burner	Pellet Burner	Other Electrical Appliances
Services (P)	all	$TL\ [years]$	10	10	10	15	20	20	7
Services (NP)	Commercial	$D_H\ [hours\ in\ day]$	8	8	8	8	8	8	8
Services (NP)	Commercial	$N_D\ [days]$	7	7	7	7	7	7	7
Services (NP)	Commercial	$N_w\ [weeks]$	52	52	52	34	34	34	34
Services (NP)	Retail stores	$D_H\ [hours\ in\ day]$	-	10	12	10	10	10	10

Sector	Subsector	Variable	Type of End-Use						
			Cooking	Water Heating	Space heating/Space cooling				
			Stove	Electric Water heater	A/C	Heat Pump	Oil Burner	Pellet Burner	Other Electrical Appliances
Services (NP)	Retail stores	$N_D\ [days]$	-	6	6	6	6	6	6
Services (NP)	Retail store	$N_w\ [weeks]$	-	52	52	34	34	34	34
Services (NP)	Private offices	$D_H\ [hours\ in\ day]$	-	8	8	8	8	8	8
Services (NP)	Private offices	$N_D\ [days]$	-	5	5	5	5	5	5
Services (NP)	Private offices	$N_w\ [weeks]$	-	52	52	34	34	34	34

Sector	Subsector	Variable	Type of End-Use						
			Cooking	Water Heating	Space heating/Space cooling				
			Stove	Electric Water heater	A/C	Heat Pump	Oil Burner	Pellet Burner	Other Electrical Appliances
Services (NP)	all	$TL\ [years]$	10	10	10	15	20	20	7

Table 80: Industrial and Power Sectors: Assumptions on utilization and lifetime for each alternative appliance

Sector	Subsector	Variable	Type of utilisation	Type of End-Use			
				Oil fired boiler	Electric boiler	New dual fuel burner	Modification of existing gas burner to dual fuel
Industrial	n.a.	D_H $[hours\ in\ day]$	Continuous	24	24	n.a.	n.a.
Industrial	n.a.	N_D $[days]$	Continuous	7	7	n.a.	n.a.
Industrial	n.a.	N_w $[weeks]$	Continuous	52	52	n.a.	n.a.
Industrial	n.a.	D_H $[hours\ in\ day]$	Intermittent	12	12	n.a.	n.a.
Industrial	n.a.	N_D $[days]$	Intermittent	7	7	n.a.	n.a.
Industrial	n.a.	N_w $[weeks]$	Intermittent	52	52	n.a	n.a
Industrial	n.a.	TL $[years]$	all	10	10	n.a	n.a
Power	n.a.	D_H $[hours\ in\ day]$	n.a.	n.a.	n.a.	16	16

Sector	Subsector	Variable	Type of utilisation	Type of End-Use			
				Oil fired boiler	Electric boiler	New dual fuel burner	Modification of existing gas burner to dual fuel
Power	n.a.	N_D $[days]$	n.a.	n.a.	n.a.	5	5
Power	n.a.	N_w $[weeks]$	all	n.a.	n.a.	51	51[41]
Power	n.a.	TL $[years]$	n.a	20	n.a	20	20

41 Assuming 1 week of planned maintenance

Appendix 6 Fuel prices and Operating cost difference values due to the use of alternative fuels.

Table 81 presents the fuel prices and Table 82 the resulting $\Delta OPEX$ values used in the UCM calculations.

Table 81: Fuel prices (excl. VAT)

MS	Natural Gas price (Euro/kWh)		Electricity price (Euro/kWh)		Heating Oil price Euro/kWh	Fuel oil Euro/kWh	Pellet/ Wood price Euro/kWh
	Households	Non - Households	Households	Non - Households			
Austria	0,056	0,034	0,163	0,093	0,082	0,039	0,042
Belgium	0,043	0,024	0,235	0,113	0,069	0,032	0,049
Bulgaria	0,028	0,022	0,080	0,076	0,104	0,032	0,032
Croatia	0,029	0,025	0,106	0,087	0,075	0,046	0,045
Czech Republic	0,045	0,024	0,119	0,069	0,074	0,032	0,027
Denmark	0,065	0,033	0,244	0,082	0,142	0,074	0,045
Estonia	0,036	0,028	0,108	0,087	0,083	0,049	0,045
Finland	-	0,046	0,128	0,067	0,107	0,049	0,045
France	0,055	0,033	0,144	0,099	0,093	0,049	0,042
Germany	0,051	0,032	0,256	0,152	0,073	-	0,044
Greece	0,050	0,028	0,174	0,107	0,108	0,042	0,055
Hungary	0,028	0,026	0,089	0,074	0,129	0,038	0,045

MS	Natural Gas price (Euro/kWh)		Electricity price (Euro/kWh)		Heating Oil price Euro/kWh	Fuel oil Euro/kWh	Pellet/ Wood price Euro/kWh
	Households	Non - Households	Households	Non - Households			
Ireland	0,056	0,033	0,203	0,124	0,073	0,046	0,056
Italy	0,060	0,027	0,194	0,148	0,133	0,039	0,056
Latvia	0,031	0,027	0,131	0,118	0,071	0,030	0,045
Lithuania	0,030	0,025	0,092	0,084	0,072	0,030	0,045
Luxembourg	0,039	0,032	0,150	0,078	0,067	0,044	0,045
Netherlands	0,063	0,037	0,129	0,082	0,113	0,066	0,045
Poland	0,034	0,027	0,119	0,088	0,082	0,036	0,045
Portugal	0,063	0,028	0,186	0,115	0,119	0,055	0,045
Romania	0,025	0,026	0,101	0,077	0,102	0,036	0,045
Slovakia	0,035	0,028	0,120	0,115	0,098	0,046	0,045
Slovenia	0,045	0,031	0,132	0,078	0,098	0,051	0,045
Spain	0,055	0,030	0,190	0,106	0,076	0,036	0,045
Sweden	0,097	0,041	0,155	0,065	0,121	0,076	0,045
United Kingdom	0,045	0,025	0,168	0,127	0,069	0,076	0,047

Table 82: Operating cost difference values due to the use of alternative fuels

MS	Δ (electricity price - gas price) (Euro/kWh)		Δ (heating oil price - gas price) (Euro/kWh)	Δ (fuel oil price - gas price) (Euro/kWh)	Δ (pellet/wood price - gas price) (Euro/kWh)
	Households	Non - Households			
Austria	0,106	0,059	0,026	0,005	-0,014
Belgium	0,192	0,088	0,026	0,007	0,006
Bulgaria	0,052	0,055	0,077	0,010	0,005
Croatia	0,077	0,063	0,047	0,021	0,016
Czech Republic	0,073	0,045	0,029	0,008	-0,019
Denmark	0,179	0,049	0,077	0,041	-0,020
Estonia	0,071	0,059	0,046	0,022	0,009
Finland	0,128	0,020	0,107	0,003	0,045
France	0,089	0,067	0,039	0,017	-0,013
Germany	0,205	0,120	0,021	-0,032	-0,007
Greece	0,124	0,079	0,058	0,013	0,006
Hungary	0,061	0,048	0,101	0,012	0,017
Ireland	0,147	0,091	0,017	0,013	-0,000
Italy	0,134	0,121	0,073	0,012	-0,004
Latvia	0,100	0,091	0,040	0,003	0,014
Lithuania	0,062	0,059	0,041	0,005	0,015
Luxembourg	0,111	0,046	0,029	0,012	0,006

MS	Δ (electricity price - gas price) (Euro/kWh)		Δ (heating oil price - gas price) (Euro/kWh)	Δ (fuel oil price - gas price) (Euro/kWh)	Δ (pellet/wood price - gas price) (Euro/kWh)
	Households	Non - Households			
Netherlands	0,066	0,046	0,050	0,030	-0,018
Poland	0,085	0,060	0,048	0,009	0,011
Portugal	0,123	0,087	0,056	0,027	-0,018
Romania	0,075	0,051	0,076	0,011	0,020
Slovakia	0,085	0,087	0,063	0,018	0,010
Slovenia	0,087	0,048	0,053	0,020	-0,000
Spain	0,135	0,076	0,021	0,006	-0,010
Sweden	0,058	0,024	0,024	0,035	-0,052
United Kingdom	0,123	0,102	0,024	0,051	0,002

Appendix 7 Weighting factors quantifying the contribution of each type of end-use of energy to the gas consumption of the sub-sector (SERVICES ONLY).

Table 83 presents the Weighting factors, $WF^{f}_{sub-EULk}$ as used in equation (3) for the estimation of the UCM at subsector levels. We used the average EU weighting factors for the countries (Czech Republic, Finland, Poland, Spain) that we could not find any available data.

Table 83: Weighting factors, $WF^{f}_{sub-EULk}$ as used in equation (3) for the estimation of the UCM at sub-sector level

Member State	Sector	Subsectors	Cooking [%]	Water heating [%]	Space heating [%]
Austria	Services (P)	all excluding Public Administration	1	14	85
	Services (NP)	Commercial			
Austria	Services (P)	Public Administration	n.a.	14	86
	Services (NP)	Retail Stores, Private Offices			
Belgium	Services (P)	all excluding Public Administration	1	14	85
	Services (NP)	Commercial			
Belgium	Services (P)	Public Administration	n.a.	14	86
	Services (NP)	Retail Stores, Private Offices			
Bulgaria	Services (P)	all excluding Public Administration	6	15	79
	Services (NP)	Commercial			
Bulgaria	Services (P)	Public Administration	n.a.	16	84
	Services (NP)	Retail Stores, Private Offices			
Croatia	Services (P)	all excluding Public Administration	7	17	75
	Services (NP)	Commercial			

Member State	Sector	Subsectors	Cooking [%]	Water heating [%]	Space heating [%]
Croatia	Services (P)	Public Administration	n.a.	19	81
	Services (NP)	Retail Stores, Private Offices			
Czech Republic	Services (P)	all excluding Public Administration	9	20	71
	Services (NP)	Commercial			
Czech Republic	Services (P)	Public Administration	n.a.	23	77
	Services (NP)	Retail Stores, Private Offices			
Denmark	Services (P)	all excluding Public Administration	11	23	66
	Services (NP)	Commercial			
Denmark	Services (P)	Public Administration	n.a.	26	74
	Services (NP)	Retail Stores, Private Offices			
Estonia	Services (P)	all excluding Public Administration	2	25	74
	Services (NP)	Commercial			
Estonia	Services (P)	Public Administration	n.a.	25	75
	Services (NP)	Retail Stores, Private Offices			
Finland	Services (P)	all excluding Public Administration	9	20	71
	Services (NP)	Commercial			
Finland	Services (P)	Public Administration	n.a.	23	77
	Services (NP)	Retail Stores, Private Offices			
France	Services (P)	all excluding Public Administration	2	20	79
	Services (NP)	Commercial			

Member State	Sector	Subsectors	Cooking [%]	Water heating [%]	Space heating [%]
France	Services (P)	Public Administration	n.a.	20	80
	Services (NP)	Retail Stores, Private Offices			
Germany	Services (P)	all excluding Public Administration	6	10	84
	Services (NP)	Commercial			
Germany	Services (P)	Public Administration	n.a.	11	89
	Services (NP)	Retail Stores, Private Offices			
Greece	Services (P)	all excluding Public Administration	0.4	18	82
	Services (NP)	Commercial			
Greece	Services (P)	Public Administration	n.a.	18	82
	Services (NP)	Retail Stores, Private Offices			
Hungary	Services (P)	all excluding Public Administration	1	6	93
	Services (NP)	Commercial			
Hungary	Services (P)	Public Administration	n.a.	6	94
	Services (NP)	Retail Stores, Private Offices			
Ireland	Services (P)	all excluding Public Administration	7	11	83
	Services (NP)	Commercial			
Ireland	Services (P)	Public Administration	n.a.	11	89
	Services (NP)	Retail Stores, Private Offices			
Italy	Services (P)	all excluding Public Administration	2	26	72
	Services (NP)	Commercial			

Member State	Sector	Subsectors	Cooking [%]	Water heating [%]	Space heating [%]
Italy	Services (P)	Public Administration	n.a.	26	74
	Services (NP)	Retail Stores, Private Offices			
Latvia	Services (P)	all excluding Public Administration	8	14	77
	Services (NP)	Commercial			
Latvia	Services (P)	Public Administration	n.a.	16	84
	Services (NP)	Retail Stores, Private Offices			
Lithuania	Services (P)	all excluding Public Administration	29	19	52
	Services (NP)	Commercial			
Lithuania	Services (P)	Public Administration	n.a.	27	73
	Services (NP)	Retail Stores, Private Offices			
Luxembourg	Services (P)	all excluding Public Administration	24	11	65
	Services (NP)	Commercial			
Luxembourg	Services (P)	Public Administration	n.a.	15	85
	Services (NP)	Retail Stores, Private Offices			
Netherlands	Services (P)	all excluding Public Administration	3	9	89
	Services (NP)	Commercial			
Netherlands	Services (P)	Public Administration	n.a.	9	91
	Services (NP)	Retail Stores, Private Offices			
Poland	Services (P)	all excluding Public Administration	9	20	71
	Services (NP)	Commercial			

Member State	Sector	Subsectors	Cooking [%]	Water heating [%]	Space heating [%]
Poland	Services (P)	Public Administration	n.a.	23	77
	Services (NP)	Retail Stores, Private Offices			
Portugal	Services (P)	all excluding Public Administration	2	20	78
	Services (NP)	Commercial			
Portugal	Services (P)	Public Administration	n.a.	21	79
	Services (NP)	Retail Stores, Private Offices			
Romania	Services (P)	all excluding Public Administration	20	25	54
	Services (NP)	Commercial			
Romania	Services (P)	Public Administration	n.a.	32	68
	Services (NP)	Retail Stores, Private Offices			
Slovakia	Services (P)	all excluding Public Administration	35	62	3
	Services (NP)	Commercial			
Slovakia	Services (P)	Public Administration	n.a.	95	5
	Services (NP)	Retail Stores, Private Offices			
Slovenia	Services (P)	all excluding Public Administration	19	23	59
	Services (NP)	Commercial			
Slovenia	Services (P)	Public Administration	n.a.	28	72
	Services (NP)	Retail Stores, Private Offices			
Spain	Services (P)	all excluding Public Administration	9	20	71
	Services (NP)	Commercial			

Member State	Sector	Subsectors	Cooking [%]	Water heating [%]	Space heating [%]
Spain	Services (P)	Public Administration	n.a.	23	77
	Services (NP)	Retail Stores, Private Offices			
Sweden	Services (P)	all excluding Public Administration	5	19	76
	Services (NP)	Commercial			
Sweden	Services (P)	Public Administration	n.a.	20	80
	Services (NP)	Retail Stores, Private Offices			
United Kingdom	Services (P)	all excluding Public Administration	11	43	46
	Services (NP)	Commercial			
United Kingdom	Services (P)	Public Administration	n.a.	48	52
	Services (NP)	Retail Stores, Private Offices			

Appendix 8 Weighting factors quantifying contribution of each type of end-use of energy to the gas consumption of the Residential sector.

Table 84 presents the Weighting factors, $\boldsymbol{WF^{f}_{s-EULk}}$as used in equations (4) for the estimation of the UCM at Residential sector level. We used the average EU weighting factors for the countries (Czech Republic, Finland, Poland, Spain) that we could not find any available data.

Table 84: Weighting factorsWF^{f}_{s-EULk} as used in equation (4) for the estimation of the UCM for the residential sector

Member State	Cooking [%]	Water heating [%]	Space heating [%]
Austria	1	14	85
Belgium	1	14	85
Bulgaria	6	15	79
Croatia	7	17	75
Czech Republic	9	20	71
Denmark	11	23	66
Estonia	2	25	74
Finland	9	20	71
France	2	20	79
Germany	6	10	84
Greece	0.4	18	82
Hungary	1	6	93
Ireland	7	11	83
Italy	2	26	72

Member State	Cooking [%]	Water heating [%]	Space heating [%]
Latvia	8	14	77
Lithuania	29	19	52
Luxembourg	24	11	65
Netherlands	3	9	89
Poland	9	20	71
Portugal	2	20	78
Romania	20	25	54
Slovakia	35	62	3
Slovenia	19	23	59
Spain	9	20	71
Sweden	5	19	76
United Kingdom	11	43	46

Appendix 9 Weighting factor which quantifies contribution of each type of sector to the overall gas consumption.

Table 85: Weighting factors WF_{SLk}^{f} as used in equation (6) for the estimation of the UCM at Member state Level

Member State	Residential [%]	Services [%]	Industrial [%]	Power [%]
Austria	20	7	45	28
Belgium	27	15	30	28
Bulgaria	3	5	55	37
Croatia	32	13	25	30
Czech Republic	33	19	34	14
Denmark	31	9	33	27
Estonia	23	31	42	5
Finland	2	2	40	55
France	35	20	28	17
Germany	33	15	29	23
Greece	10	5	17	68
Hungary	42	19	20	19
Ireland	14	11	18	57
Italy	31	12	15	42
Latvia	10	9	11	70
Lithuania	18	8	35	39
Luxembourg	31	19	39	11
Netherlands	29	13	20	37

Member State	Residential [%]	Services [%]	Industrial [%]	Power [%]
Poland	34	19	33	14
Portugal	6	6	28	60
Romania	30	10	27	32
Slovakia	38	19	28	15
Slovenia	17	10	62	12
Spain	16	14	31	38
Sweden	5	14	44	37
United Kingdom	39	11	12	38

Appendix 10 Weighting factors quantifying contribution of each use of gas consumption to the total industry gas consumption.

Table 86 presents the Weighting factors, $\boldsymbol{WF^{f}_{Industry}}$ and $\boldsymbol{WF^{CP}_{Industry}}$ as used in equation (8) for the estimation of the total Industry UCM (gas-as-fuel and gas-as-feedstock).

Table 86: Weighting factors $WF^{f}_{Industry}$ and $WF^{CP}_{Industry}$ as used in equation (8) for the estimation of the total Industry UCM

Member State	Fuel use [%]	Feedstock use [%]
Austria	89	11
Belgium	81	19
Bulgaria	76	24
Croatia	48	52
Czech Republic	95	5
Denmark	100	0
Estonia	100	0
Finland	94	6
France	90	10
Germany	88	12
Greece	79	21
Hungary	73	27
Ireland	100	0
Italy	93	7
Latvia	100	0
Lithuania	25	75

Member State	Fuel use [%]	Feedstock use [%]
Luxembourg	100	0
Netherlands	71	29
Poland	62	38
Portugal	100	0
Romania	88	12
Slovakia	70	30
Slovenia	99	1
Spain	94	6
Sweden	75	25
United Kingdom	95	5

Appendix 11 Appliance Level, EU-26 Average, $CAPEX$ Part of the UCM

Table 87: Residential and Services Sector - Appliance Level – $CAPEX$ Part of the UCM (EU-26 average)

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Residential	n.a.	cooking	Stove [Electric]	49	47	16	-66	Estonia	112	130	Sweden
Residential	n.a.	water heating	Hot Water Heater [Electric]	17	14	5	-72	Luxembourg	67	290	Sweden
Residential	n.a.	space heating	A/C [Electric]	15	14	6	-60	Poland	28	89	Ireland

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Residential	n.a.	space heating	Heat Pump [Electric]	26	26	9	-66	Germany	50	96	Sweden
Residential	n.a.	space heating	Burner [Heating Oil]	2	2	0,3	-82	Greece (Italy, Spain)	13	621	Poland
Residential	n.a.	space heating	Burner [Pellet]	6	6	1	-86	Greece	14	147	Portugal
Residential	n.a.	space heating	Other [Electric]	3	3	1	-73	Czech Republic	11	245	Finland
Services (P)	Healthcare Essential Social Care	cooking	Stove [Electric]	12	12	4	-66	Estonia	28	130	Sweden

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Healthcare Emergency Security Essential Social Care	water heating	Hot Water Heater [Electric]	1	1	0,2	-72%	Luxembourg	3	290	Sweden
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	A/C [Electric]	2	2	1	-60	Poland	3	89	Ireland
Services (P)	Healthcare Emergency Security	space heating	Heat Pump [Electric]	4	4	1	-66	Germany	8	96	Sweden

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
	Essential Social Care										
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	Burner [Heating Oil]	0,3	0,3	0,1	-82	Greece (Italy, Spain)	2	621	Poland
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	Burner [Pellet]	1	1	0,1	-86	Greece	2	147	Portugal

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	Other [Electric]	1	0,5	0,1	-73%	Czech Republic	2	245	Finland
Services (P)	Education	Cooking	Stove [Electric]	32	30	10	-67	Estonia	72	125	Sweden
Services (P)	Education	water heating	Hot Water Heater [Electric]	4	3	1	-72	Luxembourg	16	290	Sweden
Services (P)	Education	space heating	A/C [Electric]	10	10	4	-60	Poland	20	89	Ireland

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Education Public Administration	space heating	Heat Pump [Electric]	18	18	6	-66	Germany	35	96	Sweden
Services (P)	Education Public Administration	space heating	Burner [Heating Oil]	1	1	0,23	-82	Greece (Italy, Spain)	9	621	Poland
Services (P)	Education Public Administration	space heating	Burner [Pellet]	4	4	1	-86	Greece	10	147	Portugal
Services (P)	Education Public Administration	space heating	Other [Electric]	2	2	1	-73	Czech Republic	8	245	Finland

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Emergency Security	cooking	Stove [Electric]	49	47	16	-66	Estonia	112	130	Sweden
Services (P)	Public Administration	water heating	Hot Water Heater [Electric]	3	2	1	-72	Luxembourg	12	290	Sweden
Services (P)	Public Administration	space heating	A/C [Electric]	7	6	3	-60	Poland	13	89	Ireland
Services (NP)	Commercial	cooking	Stove [Electric]	6	6	2	-66	Estonia	14	130	Sweden
Services (NP)	Commercial	water heating	Hot Water Heater [Electric]	2	2	1	-72	Luxembourg	8	290	Sweden

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Commercial	space heating	A/C [Electric]	5	5	2	-60	Poland	9	89	Ireland
Services (NP)	Commercial	space heating	Heat Pump [Electric]	13	13	4	-66	Germany	25	96	Sweden
Services (NP)	Commercial	space heating	Burner [Heating Oil]	1	1	0,2	-82	Greece (Italy, Spain)	6	621	Poland
Services (NP)	Commercial	space heating	Burner [Pellet]	3	3	0,4	-86	Greece	7	147	Portugal
Services (NP)	Commercial	space heating	Other [Electric]	2	1	0,4	-73	Czech Republic	6	245	Finland

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Retail Stores	water heating	Hot Water Heater [Electric]	2	2	1	-72	Luxembourg	8	290	Sweden
Services (NP)	Retail Stores	space heating	A/C [Electric]	4	4	2	-60	Poland	7	89	Ireland
Services (NP)	Retail Stores	space heating	Heat Pump [Electric]	12	12	4	-66	Germany	23	96	Sweden
Services (NP)	Retail Stores	space heating	Burner [Heating Oil]	1	1	0,2	-82	Greece (Italy, Spain)	6	621	Poland

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Retail Stores	space heating	Burner [Pellet]	3	3	0,4	-86	Greece	6	147	Portugal
Services (NP)	Retail Stores	space heating	Other [Electric]	2	1	0,4	-73	Czech Republic	5	245	Finland
Services (NP)	Private Offices	water heating	Hot Water Heater [Electric]	3	2	1	-72	Luxembourg	12	290	Sweden
Services (NP)	Private Offices	space heating	A/C [Electric]	7	6	3	-60	Poland	13	89	Ireland

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Private Offices	space heating/ cooling	Heat Pump [Electric]	18	18	6	-66	Germany	35	96	Sweden
Services (NP)	Private Offices	space heating	Burner [Heating Oil]	1	1	0,2	-82	Greece (Italy, Spain)	9	621	Poland
Services (NP)	Private Offices	space heating	Burner [Pellet]	4	4	1	-86	Greece	10	147	Portugal
Services (NP)	Private Offices	space heating	Other [Electric]	2	2	1	-73	Czech Republic	8	245	Finland

Sector	Subsector	End-Use	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country

Table 88: Power and Industrial Sector - Appliance Level – $CAPEX$ Part of the UCM (EU-26 average)

Sector	End-Use	Type of utilisation	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Industrial	Fuel	Continuous	Oil fired boiler [Fuel Oil]	1	1	1	-50	Bulgaria	2	64%	Denmark
Industrial	Fuel	Continuous	Electric boiler [Electric]	5	4	2	-50	Bulgaria	8	64%	Denmark
Industrial	Fuel	Intermittent	Oil fired boiler [Fuel Oil]	2	2	1	-50	Bulgaria	3	64%	Denmark
Industrial	Fuel	Intermittent	Electric boiler [Electric]	10	9	5	-50	Bulgaria	16	64%	Denmark
Power	Fuel	n.a.	new dual fuel burner [Fuel Oil]	0,12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Sector	End-Use	Type of utilisation	RAA type	CAPEX Part of the $UCM^{f}_{ATj,MSi}$							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Power	Fuel	n.a.	modification of existing gas burner to dual fuel [Fuel Oil]	0,57	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Appendix 12 Appliance Level EU-26 Average, - $\Delta OPEX$ Part of the UCM

Table 89: Residential and Services Sector - Appliance Level - $\Delta OPEX_{MSi}$ (EU-26 average)

Fuel	RAA type	$\Delta OPEX_{MSi}$ Part of the $UCM^{f}_{ATj,MSi}$							
		Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
				Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Electricity	Stove	104	88	52	-50	Bulgaria	205	97	Germany
Electricity	Hot water heater	104	88	52	-50	Bulgaria	205	97	Germany
Electricity	A/C Heat Pump Other electric Appliances	104	88	52	-50	Bulgaria	205	97	Germany

Fuel	RAA type	$\Delta OPEX_{MSi}$ Part of the $UCM^{f}_{ATj,MSi}$							
		Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
				Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Heating Oil	Burner	47	47	17	-64	Ireland	101	115	Hungary
Pellet	Burner	-2	1	-52	3161	Sweden	20	-1329	Romania

Table 90: Power and Industrial Sector - Appliance Level - $\Delta OPEX_{MSi}$ (EU-26 average)

Alternative Fuel	Sector	RAA type	$\Delta OPEX_{MSi}$ Part of the $UCM^{f}_{ATj,MSi}$							
			Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
					Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Electricity	Industrial	Electric boiler	67	60	20	-70	Finland	121	80	Italy
Fuel Oil	Industrial	Oil fired boiler	15	12	2	-86	Estonia	41	175	Denmark
Fuel Oil	Power	New dual fuel burner	15	12	2	-86	Estonia	41	175	Denmark
Fuel Oil	Power	Modification of existing gas burner to dual fuel	15	12	2	-86	Estonia	41	175	Denmark

Appendix 13 Appliance Level – EU-26 Average, Min, Max and Median UCM values

Table 91: Residential and Services Sector - Appliance Level UCM_{AT}^{f} (EU-26 average)

Sector	Subsector	End-Use	RAA type	UCM_{AT}^{f}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Residential	n.a.	cooking	Stove [Electric]	153	140	88	-43	Estonia	261	71	Belgium
Residential	n.a.	water heating	Hot Water Heater [Electric]	121	110	65	-47	Bulgaria	230	90	Belgium
Residential	n.a.	space heating	A/C [Electric]	119	100	66	-45	Bulgaria	215	81	Germany

Sector	Subsector	End-Use	RAA type	UCM^{f}_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Residential	n.a.	space heating	Heat Pump [Electric]	129	121	85	-34	Lithuania	217	68	Belgium
Residential	n.a.	space heating	Burner [Heating Oil]	49	48	19	-60	Ireland	102	109	Hungary
Residential	n.a.	space heating	Burner [Pellet]	4	7	-48	-1311	Sweden	23	498	Hungary
Residential	n.a.	space heating	Other [Electric]	107	92	55	-49	Bulgaria	208	94	Germany

Sector	Subsector	End-Use	RAA type	UCM^{f}_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Healthcare Essential Social Care	cooking	Stove [Electric]	116	101	63	-46	Bulgaria	214	84	Germany
Services (P)	Healthcare Emergency Security Essential Social Care	water heating	Hot Water Heater [Electric]	105	89	53	-50	Bulgaria	205	96	Germany
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	A/C [Electric]	105	89	54	-49	Bulgaria	206	95	Germany

Sector	Subsector	End-Use	RAA type	UCM^{f}_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	Heat Pump [Electric]	108	91	58	-46	Bulgaria	206	91	Germany
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	Burner [Heating Oil]	47	47	17	-63	Ireland	101	114	Hungary
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	Burner [Pellet]	-1	3	-51	7507	Sweden	20	-3085	Romania

Sector	Subsector	End-Use	RAA type	UCM^f_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	Other [Electric]	104	89	53	-50	Bulgaria	205	97	Germany
Services (P)	Education	Cooking	Stove [Electric]	135	124	80	-40	Bulgaria	236	75	Belgium
Services (P)	Education	water heating	Hot Water Heater [Electric]	108	92	55	-49	Bulgaria	207	92	Germany
Services (P)	Education Public Administration	space heating	A/C [Electric]	114	96	62	-46	Bulgaria	212	86	Germany

Sector	Subsector	End-Use	RAA type	UCM^{f}_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Education Public Administration	space heating	Heat Pump [Electric]	122	110	77	-37	Bulgaria	211	73	Germany
Services (P)	Education Public Administration	space heating	Burner [Heating Oil]	48	48	19	-61	Ireland	102	110	Hungary
Services (P)	Education Public Administration	space heating	Burner [Pellet]	2	6	-49	-2253	Sweden	22	858	Romania
Services (P)	Education Public Administration	space heating	Other [Electric]	106	90	54	-49	Bulgaria	207	95	Germany
Services (P)	Emergency Security	cooking	Stove [Electric]	153	140	88	-43	Estonia	261	71	Belgium

Sector	Subsector	End-Use	RAA type	UCM^f_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Public Administration	water heating	Hot Water Heater [Electric]	107	90	54	-49	Bulgaria	206	93	Germany
Services (NP)	Commercial	cooking	Stove [Electric]	110	94	58	-48	Bulgaria	209	90	Germany
Services (NP)	Commercial	water heating	Hot Water Heater [Electric]	106	90	54	-49	Bulgaria	206	94	Germany
Services (NP)	Commercial	space heating	A/C [Electric]	109	91	57	-48	Bulgaria	208	91	Germany

Sector	Subsector	End-Use	RAA type	UCM^{f}_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Commercial	space heating	Heat Pump [Electric]	117	103	70	-40	Bulgaria	209	79	Germany
Services (NP)	Commercial	space heating	Burner [Heating Oil]	48	48	18	-62	Ireland	101	112	Hungary
Services (NP)	Commercial	space heating	Burner [Pellet]	1	5	-50	-4365	Sweden	21	1712	Romania
Services (NP)	Commercial	space heating	Other [Electric]	105	90	54	-49	Bulgaria	206	96	Germany

Sector	Subsector	End-Use	RAA type	UCM^{f}_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Retail Stores	water heating	Hot Water Heater [Electric]	106	90	54	-49	Bulgaria	206	94	Germany
Services (NP)	Retail Stores	space heating	A/C [Electric]	108	91	56	-48	Bulgaria	207	93	Germany
Services (NP)	Retail Stores	space heating	Heat Pump [Electric]	116	102	69	-41	Bulgaria	209	80	Germany
Services (NP)	Retail Stores	space heating	Burner [Heating Oil]	48	47	18	-62	Ireland	101	112	Hungary

Sector	Subsector	End-Use	RAA type	UCM^{f}_{AT}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Retail Stores	space heating	Burner [Pellet]	1	5	-50	-5179	Sweden	21	2040	Romania
Services (NP)	Retail Stores	space heating	Other [Electric]	105	89	53	-49	Bulgaria	206	96	Germany
Services (NP)	Private Offices	water heating	Hot Water Heater [Electric]	107	90	54	-49	Bulgaria	206	93	Germany
Services (NP)	Private Offices	space heating	A/C [Electric]	111	93	58	-47	Bulgaria	209	89	Germany
Services (NP)	Private Offices	space heating	Heat Pump [Electric]	122	110	77	-37	Bulgaria	211	73	Germany

Sector	Subsector	End-Use	RAA type	UCM_{AT}^{f}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Private Offices	space heating	Burner [Heating Oil]	48	48	19	-61	Ireland	102	110	Hungary
Services (NP)	Private Offices	space heating	Burner [Pellet]	2	6	-49	-2253	Sweden	22	858	Romania
Services (NP)	Private Offices	space heating	Other [Electric]	106	90	54	-49	Bulgaria	207	95	Germany

Table 92: Power and Industrial Sector - Appliance Level UCM_{AT}^{f} (EU-26 average)

Sector	End-Use	Type of utilisation	RAA type	UCM_{AT}^{f}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Industrial	Fuel	Continuous	Oil fired boiler [Fuel Oil]	16	14	3	-82	Estonia	43	167	Denmark
Industrial	Fuel	Continuous	Electric boiler [Electric]	72	65	26	-63	Finland	127	76	Germany
Industrial	Fuel	Intermittent	Oil fired boiler [Fuel Oil]	17	15	4	-78	Estonia	45	161	Denmark
Industrial	Fuel	Intermittent	Electric boiler [Electric]	77	70	32	-58	Finland	133	74	Germany

Sector	End-Use	Type of utilisation	RAA type	UCM_{AT}^{f}							
				Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
						Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Power	Fuel	n.a.	new dual fuel burner [Fuel Oil]	60	57	47	-22	Estonia	86	44	Denmark
Power	Fuel	n.a.	modification of existing gas burner to dual fuel [Fuel Oil]	60	58	48	-21	Estonia	87	43	Denmark

Appendix 14 End Use Level –UCM average values EU-26 (natural gas-as-fuel)

Table 93: Residential and Services Sector - End Use Level UCM^{f}_{EUL} (EU-26 average)

Sector	Subsector	End-Use	UCM^{f}_{EUL}							
			Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
					Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Residential	n.a.	cooking	149	139	88	-41	Estonia	261	75	Belgium
Residential	n.a.	water heating	118	109	65	-45	Bulgaria	230	95	Belgium
Residential	n.a.	space heating	80	76	45	-43	Sweden	132	66	Belgium
Services (P)	Healthcare Essential Social Care	cooking	116	101	63	-46	Bulgaria	214	84	Germany
Services (P)	Healthcare Emergency Security	water heating	105	89	53	-50	Bulgaria	205	96	Germany

Sector	Subsector	End-Use	UCM_{EUL}^{f}							
			Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
					Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
	Essential Social Care									
Services (P)	Healthcare Emergency Security Essential Social Care	space heating	73	66	32	-57	Sweden	127	74	Germany
Services (P)	Education	Cooking	135	124	80	-40	Bulgaria	236	75	Belgium
Services (P)	Education	water heating	108	92	55	-49	Bulgaria	207	92	Germany

Sector	Subsector	End-Use	UCM_{EUL}^{f}							
			Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
					Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Education Public Administration	space heating	79	72	40	-49	Sweden	130	65	Germany
Services (P)	Emergency Security	cooking	153	140	88	-43	Estonia	261	71	Belgium
Services (P)	Public Administration	water heating	107	90	54	-49	Bulgaria	206	93	Germany
Services (NP)	Commercial	cooking	110	94	58	-48	Bulgaria	209	90	Germany
Services (NP)	Commercial	water heating	106	90	54	-49	Bulgaria	206	94	Germany

Sector	Subsector	End-Use	UCM_{EUL}^{f}							
			Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
					Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Commercial	space heating	76	70	36	-52	Sweden	128	69	Germany
Services (NP)	Retail Stores	water heating	106	90	54	-49	Bulgaria	206	94	Germany
Services (NP)	Retail Stores	space heating	68	65	30	-56	Sweden	109	60	Belgium
Services (NP)	Private Offices	water heating	107	90	54	-49	Bulgaria	206	93	Germany
Services (NP)	Private Offices	space heating	71	68	34	-52	Sweden	112	58	Belgium

Appendix 15 Subsector Level –UCM average values EU-26 (natural gas-as-fuel)

Table 94: Services Sector - Subsector Level UC^{f}_{s-SL} (EU-26 average)

Sector	Subsector	Mean	Median	UCM^{f}_{s-SL}					
				Minimum			Maximum		
				Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (P)	Healthcare Essential Social Care	83	74	40	-52	Sweden	142	72	Denmark
Services (P)	Education	89	80	51	-43	Sweden	149	68	Denmark
Services (P)	Emergency Security	86	79	44	-49	Sweden	147	71	Denmark
Services (P)	Public Administration	85	77	46	-46	Sweden	140	66	Denmark

Sector	Subsector	Mean	Median	UCM^{f}_{s-SL}					
				Minimum			Maximum		
				Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Services (NP)	Commercial	84	76	44	-48	Sweden	144	72	Denmark
Services (NP)	Retail Stores	76	69	37	-52	Sweden	127	66	Denmark
Services (NP)	Private Offices	79	71	41	-48	Sweden	129	64	Denmark

Appendix 16 End use and subsector level - UCM values by Member State (natural gas-as-fuel)

Table 95: End use and subsector level $UCM^{f}_{EUL,MSi}$ and $UCM^{f}_{s-SL,MSi}$

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Austria	Services (P)	Healthcare, Essential Social Care	115	107	68	74	-11
Austria	Services (P)	Education	128	108	73	79	-12
Austria	Services (P)	Emergency, Security	141	107	68	74	-14
Austria	Services (P)	Public Administration	n.a.	107	73	78	-8
Austria	Services (NP)	Commercial	111	107	71	76	-9
Austria	Services (NP)	Retail Stores	n.a.	107	61	67	-12
Austria	Services (NP)	Private Offices	n.a.	107	63	70	-11
Belgium	Services (P)	Healthcare, Essential Social Care	209	193	123	134	62
Belgium	Services (P)	Education	236	201	129	140	57
Belgium	Services (P)	Emergency, Security	261	193	123	134	56
Belgium	Services (P)	Public Administration	n.a.	198	129	138	63

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Belgium	Services (NP)	Commercial	200	196	126	136	63
Belgium	Services (NP)	Retail Stores	n.a.	196	109	121	58
Belgium	Services (NP)	Private Offices	n.a.	198	112	124	57
Bulgaria	Services (P)	Healthcare, Essential Social Care	63	53	49	51	-39
Bulgaria	Services (P)	Education	80	55	55	57	-36
Bulgaria	Services (P)	Emergency, Security	97	53	49	53	-39
Bulgaria	Services (P)	Public Administration	n.a.	54	55	55	-35
Bulgaria	Services (NP)	Commercial	58	54	53	53	-37
Bulgaria	Services (NP)	Retail Stores	n.a.	54	52	52	-32
Bulgaria	Services (NP)	Private Offices	n.a.	54	55	55	-30
Croatia	Services (P)	Healthcare, Essential Social Care	88	78	60	65	-21
Croatia	Services (P)	Education	105	80	66	71	-20
Croatia	Services (P)	Emergency, Security	120	78	60	68	-21
Croatia	Services (P)	Public Administration	n.a.	79	66	68	-19

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Croatia	Services (NP)	Commercial	83	79	63	67	-20
Croatia	Services (NP)	Retail Stores	n.a.	78	59	63	-18
Croatia	Services (NP)	Private Offices	n.a.	79	61	65	-18
Czech Republic	Services (P)	Healthcare, Essential Social Care	79	74	47	56	-33
Czech Republic	Services (P)	Education	87	76	52	60	-33
Czech Republic	Services (P)	Emergency, Security	95	74	47	57	-34
Czech Republic	Services (P)	Public Administration	n.a.	75	52	57	-32
Czech Republic	Services (NP)	Commercial	76	75	50	57	-32
Czech Republic	Services (NP)	Retail Stores	n.a.	75	44	51	-33
Czech Republic	Services (NP)	Private Offices	n.a.	75	46	53	-33
Denmark	Services (P)	Healthcare, Essential Social Care	193	180	120	142	72
Denmark	Services (P)	Education	216	184	125	149	68
Denmark	Services (P)	Emergency, Security	236	180	120	147	71

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Denmark	Services (P)	Public Administration	n.a.	183	125	140	66
Denmark	Services (NP)	Commercial	186	182	123	144	72
Denmark	Services (NP)	Retail Stores	n.a.	182	108	127	66
Denmark	Services (NP)	Private Offices	n.a.	183	110	129	64
Estonia	Services (P)	Healthcare, Essential Social Care	75	72	55	60	-28
Estonia	Services (P)	Education	82	76	61	65	-27
Estonia	Services (P)	Emergency, Security	88	72	55	60	-30
Estonia	Services (P)	Public Administration	n.a.	75	61	64	-24
Estonia	Services (NP)	Commercial	73	74	58	62	-26
Estonia	Services (NP)	Retail Stores	n.a.	74	54	59	-23
Estonia	Services (NP)	Private Offices	n.a.	75	56	61	-22
Finland	Services (P)	Healthcare, Essential Social Care	92	81	61	68	-18
Finland	Services (P)	Education	110	83	67	74	-17
Finland	Services (P)	Emergency, Security	126	81	61	71	-17

Member State	Sector	Subsector	$UCM^f_{EUL,MSi}$ [€/MWh]			$UCM^f_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Finland	Services (P)	Public Administration	n.a.	82	67	71	-16
Finland	Services (NP)	Commercial	86	82	64	70	-17
Finland	Services (NP)	Retail Stores	n.a.	82	58	64	-16
Finland	Services (NP)	Private Offices	n.a.	82	61	66	-16
France	Services (P)	Healthcare, Essential Social Care	104	90	60	67	-20
France	Services (P)	Education	127	93	63	70	-21
France	Services (P)	Emergency, Security	148	90	60	67	-22
France	Services (P)	Public Administration	n.a.	92	63	69	-18
France	Services (NP)	Commercial	97	91	62	68	-19
France	Services (NP)	Retail Stores	n.a.	91	54	62	-19
France	Services (NP)	Private Offices	n.a.	92	56	63	-20
Germany	Services (P)	Healthcare, Essential Social Care	214	205	127	139	69
Germany	Services (P)	Education	228	207	130	143	61
Germany	Services (P)	Emergency, Security	241	205	127	141	64

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Germany	Services (P)	Public Administration	n.a.	206	130	138	63
Germany	Services (NP)	Commercial	209	206	128	141	68
Germany	Services (NP)	Retail Stores	n.a.	206	108	119	56
Germany	Services (NP)	Private Offices	n.a.	206	110	120	53
Greece	Services (P)	Healthcare, Essential Social Care	137	125	89	96	16
Greece	Services (P)	Education	157	126	94	100	13
Greece	Services (P)	Emergency, Security	175	125	89	96	11
Greece	Services (P)	Public Administration	n.a.	126	94	100	18
Greece	Services (NP)	Commercial	131	125	92	98	17
Greece	Services (NP)	Retail Stores	n.a.	125	83	91	19
Greece	Services (NP)	Private Offices	n.a.	126	85	93	18
Hungary	Services (P)	Healthcare, Essential Social Care	70	62	62	62	-25
Hungary	Services (P)	Education	85	65	67	67	-25
Hungary	Services (P)	Emergency, Security	98	62	62	62	-28

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Hungary	Services (P)	Public Administration	n.a.	64	67	67	-21
Hungary	Services (NP)	Commercial	66	63	64	64	-23
Hungary	Services (NP)	Retail Stores	n.a.	63	65	64	-16
Hungary	Services (NP)	Private Offices	n.a.	64	67	67	-15
Ireland	Services (P)	Healthcare, Essential Social Care	160	148	94	104	26
Ireland	Services (P)	Education	178	150	102	112	26
Ireland	Services (P)	Emergency, Security	196	148	94	107	24
Ireland	Services (P)	Public Administration	n.a.	150	102	107	27
Ireland	Services (NP)	Commercial	153	149	98	107	28
Ireland	Services (NP)	Retail Stores	n.a.	149	84	92	20
Ireland	Services (NP)	Private Offices	n.a.	150	88	95	21
Italy	Services (P)	Healthcare, Essential Social Care	153	135	96	107	29
Italy	Services (P)	Education	182	139	101	113	26
Italy	Services (P)	Emergency, Security	209	135	96	108	26

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Italy	Services (P)	Public Administration	n.a.	138	101	111	31
Italy	Services (NP)	Commercial	143	137	99	109	30
Italy	Services (NP)	Retail Stores	n.a.	136	89	101	33
Italy	Services (NP)	Private Offices	n.a.	138	91	103	32
Latvia	Services (P)	Healthcare, Essential Social Care	108	100	72	79	-4
Latvia	Services (P)	Education	122	103	78	85	-4
Latvia	Services (P)	Emergency, Security	134	100	72	81	-5
Latvia	Services (P)	Public Administration	n.a.	102	78	82	-3
Latvia	Services (NP)	Commercial	104	102	75	82	-3
Latvia	Services (NP)	Retail Stores	n.a.	101	68	73	-4
Latvia	Services (NP)	Private Offices	n.a.	102	70	75	-4
Lithuania	Services (P)	Healthcare, Essential Social Care	81	63	50	61	-26
Lithuania	Services (P)	Education	111	66	55	73	-18
Lithuania	Services (P)	Emergency, Security	138	63	50	78	-10

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Lithuania	Services (P)	Public Administration	n.a.	65	55	57	-32
Lithuania	Services (NP)	Commercial	71	64	52	60	-28
Lithuania	Services (NP)	Retail Stores	n.a.	64	49	53	-31
Lithuania	Services (NP)	Private Offices	n.a.	65	51	55	-30
Luxembourg	Services (P)	Healthcare, Essential Social Care	124	111	75	91	10
Luxembourg	Services (P)	Education	143	112	81	100	12
Luxembourg	Services (P)	Emergency, Security	162	111	75	100	16
Luxembourg	Services (P)	Public Administration	n.a.	112	81	86	1
Luxembourg	Services (NP)	Commercial	117	111	78	91	9
Luxembourg	Services (NP)	Retail Stores	n.a.	111	69	76	-1
Luxembourg	Services (NP)	Private Offices	n.a.	112	72	78	-1
Netherlands	Services (P)	Healthcare, Essential Social Care	81	67	48	50	-39
Netherlands	Services (P)	Education	103	72	53	56	-37
Netherlands	Services (P)	Emergency, Security	124	67	48	51	-40

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Netherlands	Services (P)	Public Administration	n.a.	71	53	55	-35
Netherlands	Services (NP)	Commercial	73	69	51	53	-37
Netherlands	Services (NP)	Retail Stores	n.a.	69	46	48	-37
Netherlands	Services (NP)	Private Offices	n.a.	71	49	51	-35
Poland	Services (P)	Healthcare, Essential Social Care	94	85	65	71	-14
Poland	Services (P)	Education	109	86	72	78	-12
Poland	Services (P)	Emergency, Security	123	85	65	74	-14
Poland	Services (P)	Public Administration	n.a.	86	72	75	-11
Poland	Services (NP)	Commercial	89	86	69	57	-32
Poland	Services (NP)	Retail Stores	n.a.	85	64	69	-9
Poland	Services (NP)	Private Offices	n.a.	86	68	72	-8
Portugal	Services (P)	Healthcare, Essential Social Care	135	124	83	92	12
Portugal	Services (P)	Education	153	128	90	98	11
Portugal	Services (P)	Emergency, Security	170	124	83	93	8

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Portugal	Services (P)	Public Administration	n.a.	126	90	97	15
Portugal	Services (NP)	Commercial	129	125	87	95	14
Portugal	Services (NP)	Retail Stores	n.a.	125	77	87	14
Portugal	Services (NP)	Private Offices	n.a.	126	80	89	14
Romania	Services (P)	Healthcare, Essential Social Care	83	76	65	72	-13
Romania	Services (P)	Education	96	79	69	77	-14
Romania	Services (P)	Emergency, Security	108	76	65	77	-11
Romania	Services (P)	Public Administration	n.a.	78	69	72	-15
Romania	Services (NP)	Commercial	79	77	67	72	-14
Romania	Services (NP)	Retail Stores	n.a.	77	65	69	-10
Romania	Services (NP)	Private Offices	n.a.	78	67	70	-11
Slovakia	Services (P)	Healthcare, Essential Social Care	98	86	67	89	8
Slovakia	Services (P)	Education	119	90	73	100	12
Slovakia	Services (P)	Emergency, Security	139	86	67	104	20

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Slovakia	Services (P)	Public Administration	n.a.	89	73	88	4
Slovakia	Services (NP)	Commercial	91	88	70	88	5
Slovakia	Services (NP)	Retail Stores	n.a.	87	66	86	13
Slovakia	Services (NP)	Private Offices	n.a.	89	69	88	12
Slovenia	Services (P)	Healthcare, Essential Social Care	94	87	64	75	-9
Slovenia	Services (P)	Education	106	89	69	81	-9
Slovenia	Services (P)	Emergency, Security	118	87	64	79	-8
Slovenia	Services (P)	Public Administration	n.a.	89	69	75	-12
Slovenia	Services (NP)	Commercial	90	88	67	76	-9
Slovenia	Services (NP)	Retail Stores	n.a.	88	61	69	-10
Slovenia	Services (NP)	Private Offices	n.a.	89	64	71	-10
Spain	Services (P)	Healthcare, Essential Social Care	147	135	84	100	21
Spain	Services (P)	Education	165	137	89	106	19
Spain	Services (P)	Emergency, Security	182	135	84	103	20

Member State	Sector	Subsector	$UCM^f_{EUL,MSi}$ [€/MWh]			$UCM^f_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
Spain	Services (P)	Public Administration	n.a.	137	89	100	18
Spain	Services (NP)	Commercial	141	136	87	102	21
Spain	Services (NP)	Retail Stores	n.a.	136	74	89	16
Spain	Services (NP)	Private Offices	n.a.	137	77	91	15
Sweden	Services (P)	Healthcare, Essential Social Care	86	61	32	40	-52
Sweden	Services (P)	Education	130	74	40	51	-43
Sweden	Services (P)	Emergency, Security	170	61	32	44	-49
Sweden	Services (P)	Public Administration	n.a.	69	40	46	-46
Sweden	Services (NP)	Commercial	72	66	36	44	-48
Sweden	Services (NP)	Retail Stores	n.a.	66	30	37	-52
Sweden	Services (NP)	Private Offices	n.a.	69	34	41	-48
United Kingdom	Services (P)	Healthcare, Essential Social Care	135	124	81	105	27
United Kingdom	Services (P)	Education	153	126	87	111	24
United Kingdom	Services (P)	Emergency, Security	170	124	81	109	27

Member State	Sector	Subsector	$UCM^{f}_{EUL,MSi}$ [€/MWh]			$UCM^{f}_{s-SL,MSi}$	
			Cooking	Water Heating	Space heating	Value [€/MWh]	Difference from EU mean [%]
United Kingdom	Services (P)	Public Administration	n.a.	125	87	105	24
United Kingdom	Services (NP)	Commercial	129	125	84	106	27
United Kingdom	Services (NP)	Retail Stores	n.a.	125	73	98	28
United Kingdom	Services (NP)	Private Offices	n.a.	125	76	99	27

Appendix 17 Sector Level – UCM average values EU-26 (natural gas-as-fuel)

Table 96: Sector Level UCM_{SL}^{f} - (EU-26 average)

Sector	UCM_{SL}^{f}							
	Mean [€/MWh]	Median [€/MWh]	Minimum			Maximum		
			Value [€/MWh]	Difference from Mean [%]	Country	Value [€/MWh]	Difference from Mean [%]	Country
Residential	96	85	62	-36	Bulgaria	157	64	Denmark
Services (P)	85	76	44	-48	Sweden	145	70	Denmark
Services (NP)	80	71	41	-49	Sweden	133	67	Denmark
Industrial	45	45	30	-35	Czech Republic	73	61	Germany
Power	60	58	47	-22	Estonia	87	44	Denmark

Appendix 18 End use and sector level – UCM values by Member State (natural gas as a fuel)

Table 97: End use level $UCM^{f}_{EUL,MSi}$

Member State	Sector	$UCM^{f}_{EUL,MSi}$ [€/MWh]		
		Cooking	Water Heating	Space heating
Austria	Residential	141	112	76
Austria	Services (P)	128	107	70
Austria	Services (NP)	111	107	65
Belgium	Residential	261	230	132
Belgium	Services (P)	235	195	125
Belgium	Services (NP)	200	197	115
Bulgaria	Residential	97	65	59
Bulgaria	Services (P)	80	53	51
Bulgaria	Services (NP)	58	54	53
Croatia	Residential	120	89	69
Croatia	Services (P)	104	78	62
Croatia	Services (NP)	83	79	61
Czech Republic	Residential	95	84	54
Czech Republic	Services (P)	87	74	49
Czech Republic	Services (NP)	76	75	46
Denmark	Residential	236	201	128
Denmark	Services (P)	215	181	122

Member State	Sector	$UCM^{f}_{EUL,MSi}$ [€/MWh]		
		Cooking	Water Heating	Space heating
Denmark	Services (NP)	186	182	114
Estonia	Residential	88	92	63
Estonia	Services (P)	82	73	57
Estonia	Services (NP)	73	74	56
Finland	Residential	126	92	71
Finland	Services (P)	109	81	63
Finland	Services (NP)	86	82	61
France	Residential	148	105	65
France	Services (P)	126	91	61
France	Services (NP)	97	92	57
Germany	Residential	241	214	132
Germany	Services (P)	228	206	128
Germany	Services (NP)	209	206	116
Greece	Residential	175	133	97
Greece	Services (P)	156	125	91
Greece	Services (NP)	131	125	87
Hungary	Residential	98	78	69
Hungary	Services (P)	84	63	63
Hungary	Services (NP)	66	63	65
Ireland	Residential	196	160	106
Ireland	Services (P)	178	149	97

Member State	Sector	$UCM^{f}_{EUL,MSi}$ [€/MWh]		
		Cooking	Water Heating	Space heating
Ireland	Services (NP)	153	149	90
Italy	Residential	209	154	104
Italy	Services (P)	181	136	97
Italy	Services (NP)	143	137	93
Latvia	Residential	134	114	82
Latvia	Services (P)	121	101	74
Latvia	Services (NP)	104	102	71
Lithuania	Residential	138	77	57
Lithuania	Services (P)	110	63	51
Lithuania	Services (NP)	71	64	51
Luxembourg	Residential	162	116	84
Luxembourg	Services (P)	143	111	77
Luxembourg	Services (NP)	117	111	73
Netherlands	Residential	124	92	57
Netherlands	Services (P)	103	69	50
Netherlands	Services (NP)	73	70	49
Poland	Residential	123	92	76
Poland	Services (P)	109	85	67
Poland	Services (NP)	89	86	67
Portugal	Residential	170	143	93
Portugal	Services (P)	153	125	85

Member State	Sector	$UCM^{f}_{EUL,MSi}$ [€/MWh]		
		Cooking	Water Heating	Space heating
Portugal	Services (NP)	129	126	81
Romania	Residential	108	92	71
Romania	Services (P)	96	77	66
Romania	Services (NP)	79	77	66
Slovakia	Residential	139	109	76
Slovakia	Services (P)	119	87	69
Slovakia	Services (NP)	91	88	68
Slovenia	Residential	118	98	72
Slovenia	Services (P)	106	88	66
Slovenia	Services (NP)	90	88	64
Spain	Residential	182	146	92
Spain	Services (P)	165	136	86
Spain	Services (NP)	141	136	79
Sweden	Residential	170	125	45
Sweden	Services (P)	128	64	34
Sweden	Services (NP)	72	67	33
United Kingdom	Residential	170	134	90
United Kingdom	Services (P)	152	124	83
United Kingdom	Services (NP)	129	125	77

Table 98: Sector Level $UCM^{f}_{SL,MSi}$

Member State	Sector	UCM^{f}_{SLMSi} [€/MWh]	Difference from EU Mean [%]
Austria	Residential	82	-14
Austria	Services (P)	75	-12
Austria	Services (NP)	71	-11
Austria	Industrial	38	-16
Austria	Power	51	-16
Belgium	Residential	147	54
Belgium	Services (P)	136	59
Belgium	Services (NP)	127	59
Belgium	Industrial	53	16
Belgium	Power	52	-13
Bulgaria	Residential	62	-35
Bulgaria	Services (P)	53	-38
Bulgaria	Services (NP)	53	-33
Bulgaria	Industrial	37	-19
Bulgaria	Power	59	-1
Croatia	Residential	76	-21
Croatia	Services (P)	68	-21
Croatia	Services (NP)	65	-19
Croatia	Industrial	47	2
Croatia	Power	66	10

Member State	Sector	UCM^{f}_{SLMSi} [€/MWh]	Difference from EU Mean [%]
Czech Republic	Residential	64	-33
Czech Republic	Services (P)	57	-33
Czech Republic	Services (NP)	54	-33
Czech Republic	Industrial	30	-35
Czech Republic	Power	53	-12
Denmark	Residential	157	64
Denmark	Services (P)	145	70
Denmark	Services (NP)	133	67
Denmark	Industrial	53	16
Denmark	Power	87	44
Estonia	Residential	71	-26
Estonia	Services (P)	61	-28
Estonia	Services (NP)	61	-24
Estonia	Industrial	34	-25
Estonia	Power	47	-22
Finland	Residential	80	-16
Finland	Services (P)	71	-17
Finland	Services (NP)	66	-17
Finland	Industrial	30	-33
Finland	Power	75	24
France	Residential	75	-22

Member State	Sector	UCM^{f}_{SLMSi} [€/MWh]	Difference from EU Mean [%]
France	Services (P)	68	-20
France	Services (NP)	64	-19
France	Industrial	48	5
France	Power	62	3
Germany	Residential	146	53
Germany	Services (P)	140	65
Germany	Services (NP)	127	59
Germany	Industrial	73	61
Germany	Power	60	-1
Greece	Residential	104	9
Greece	Services (P)	97	14
Greece	Services (NP)	94	18
Greece	Industrial	50	9
Greece	Power	58	-3
Hungary	Residential	70	-27
Hungary	Services (P)	63	-26
Hungary	Services (NP)	65	-18
Hungary	Industrial	33	-28
Hungary	Power	57	-5
Ireland	Residential	118	23
Ireland	Services (P)	107	25

Member State	Sector	UCM^{f}_{SLMSi} [€/MWh]	Difference from EU Mean [%]
Ireland	Services (NP)	98	23
Ireland	Industrial	57	25
Ireland	Power	58	-3
Italy	Residential	119	25
Italy	Services (P)	109	28
Italy	Services (NP)	105	31
Italy	Industrial	70	54
Italy	Power	57	-5
Latvia	Residential	91	-5
Latvia	Services (P)	81	-4
Latvia	Services (NP)	77	-4
Latvia	Industrial	51	12
Latvia	Power	48	-21
Lithuania	Residential	84	-12
Lithuania	Services (P)	68	-20
Lithuania	Services (NP)	56	-30
Lithuania	Industrial	36	-21
Lithuania	Power	50	-17
Luxembourg	Residential	107	12
Luxembourg	Services (P)	95	11
Luxembourg	Services (NP)	82	3

Member State	Sector	UCM^{f}_{SLMSi} [€/MWh]	Difference from EU Mean [%]
Luxembourg	Industrial	34	-26
Luxembourg	Power	57	-6
Netherlands	Residential	62	-36
Netherlands	Services (P)	52	-39
Netherlands	Services (NP)	51	-36
Netherlands	Industrial	44	-3
Netherlands	Power	75	24
Poland	Residential	83	-13
Poland	Services (P)	74	-13
Poland	Services (NP)	66	-17
Poland	Industrial	38	-18
Poland	Power	54	-10
Portugal	Residential	105	9
Portugal	Services (P)	94	11
Portugal	Services (NP)	90	14
Portugal	Industrial	60	32
Portugal	Power	72	20
Romania	Residential	84	-12
Romania	Services (P)	74	-13
Romania	Services (NP)	70	-12
Romania	Industrial	33	-27

Member State	Sector	UCM^{f}_{SLMSi} [€/MWh]	Difference from EU Mean [%]
Romania	Power	56	-7
Slovakia	Residential	118	24
Slovakia	Services (P)	96	12
Slovakia	Services (NP)	87	10
Slovakia	Industrial	56	23
Slovakia	Power	63	5
Slovenia	Residential	87	-9
Slovenia	Services (P)	77	-9
Slovenia	Services (NP)	72	-10
Slovenia	Industrial	38	-17
Slovenia	Power	65	9
Spain	Residential	111	16
Spain	Services (P)	102	20
Spain	Services (NP)	94	18
Spain	Industrial	45	-1
Spain	Power	51	-15
Sweden	Residential	66	-31
Sweden	Services (P)	44	-48
Sweden	Services (NP)	41	-49
Sweden	Industrial	36	-20
Sweden	Power	80	32

Member State	Sector	UCM^{f}_{SLMSi} [€/MWh]	Difference from EU Mean [%]
United Kingdom	Residential	118	23
United Kingdom	Services (P)	107	26
United Kingdom	Services (NP)	101	27
United Kingdom	Industrial	60	32
United Kingdom	Power	52	-14

Appendix 19 Member State Level – UCM values (natural gas-as-fuel)

Table 99: Member State level UCM_{MS}^{f}

Member State	UCM_{MS}^{f}	
	Value [€/MWh]	Difference from EU Mean [%]
Austria	53	-21%
Belgium	90	34%
Bulgaria	47	-30%
Croatia	65	-3%
Czech Republic	49	-26%
Denmark	102	53%
Estonia	51	-23%
Finland	57	-15%
France	63	-5%
Germany	103	55%
Greece	63	-5%
Hungary	59	-11%
Ireland	71	6%
Italy	84	26%
Latvia	56	-17%
Lithuania	52	-22%
Luxembourg	69	3%

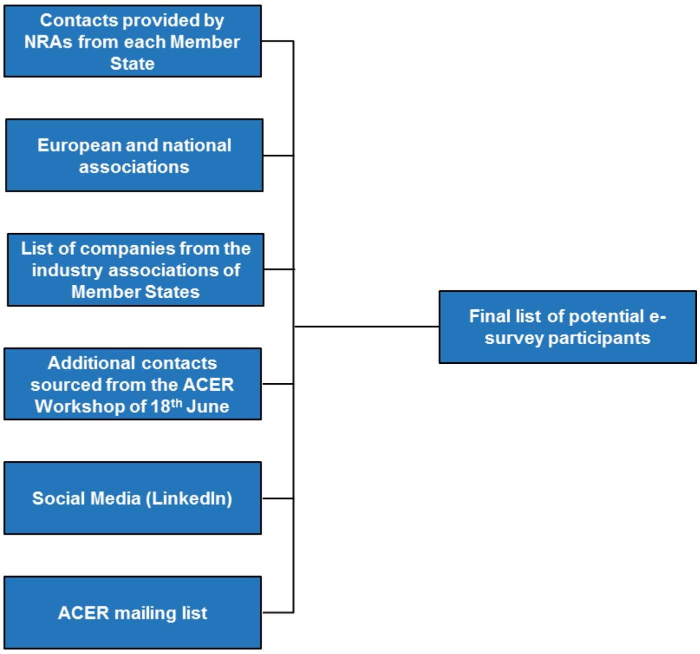
Member State	UCM_{MS}^{f}	
	Value [€/MWh]	Difference from EU Mean [%]
Netherlands	62	-8%
Poland	62	-7%
Portugal	72	8%
Romania	60	-11%
Slovakia	87	31%
Slovenia	53	-21%
Spain	66	-1%
Sweden	55	-18%
United Kingdom	84	26%

Appendix 20 Methodology related to the eSurveys and interviews

Preparation of a list of potential eSurvey recipients

The procedure summarised in Figure 50 has led to the creation of a list of 90 entries (email addresses), and 15 associations. The survey was distributed to all potential respondents and made available in ACER website[42]. Associations were also asked to distribute the questionnaires to their members. Interviews were also sought.

Figure 50: Methodology for building up the target audience of the eSurvey

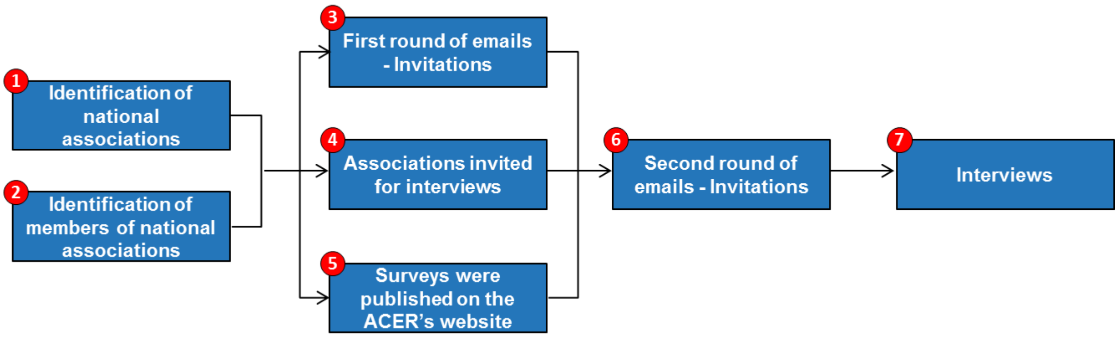


The survey targeted the EU-26 countries in order to increase participation.

The ToR further specified that emphasis should be placed upon the industrial sectors and that interviews with selected stakeholders should be carried out. Figure 51 details our specific methodology for contacting industrial participants

42 https://www.acer.europa.eu/Events/Workshop-on-the-estimation-of-the-cost-of-disruption-of-gas-supply-CoDG-and-the-value-of-lost-load-in-power-supply-systems-VoLL-in-Europe/default.aspx

Figure 51: Methodology of Selection of eSurvey participants of the Industrial and Power Sectors



In-depth interviews

In addition to the Questionnaires we conducted interviews by phone with stakeholders and associations active in the industrial and power sectors.

Interviews were carried over the telephone and realised in several steps.

Each interview was carried out according to the following general structure:

- The Consultant presented the general scope of the study.
- The interviewees introduced themselves and presented the profile of the company or association they represented and the countries of their activity.
- Interviewees were then invited to express their point of view. We note that most interviewees chose to provide a more high-level view upon the scope of the study rather than follow the strict format of the Questionnaires.
- Additional questions were asked during the interview in order to clarify the points that the interviewee has presented and better understand the reasoning and arguments for the opinions expressed.

Preparation of Questionnaires

For the purposes of our survey to gas users we developed the following Questionnaires

1) **Questionnaire addressed to the industrial and power sectors** with an aim to identify:

    a) Fuel switching possibilities

    b) Costs related to fuel switching

    c) Switching possibilities if gas is used gas as a feedstock

    d) Cost for switching if gas is used as feedstock

   e) The effect of gas disruption in the industrial and power sectors in terms of loss of production, damage to equipment etc.
   f) The severity of disruption as a function of day and time of week and season if any.

2) **Questionnaire addressed to the services sector** with aim to identify:
   a) Fuel switching possibilities
   b) Costs related to fuel switching
   c) Switching possibilities if gas is used gas as a feedstock
   d) Cost for switching if gas is used as feedstock
   e) The severity of disruption as a function of day and time of week and season if any.

3) **Questionnaire addressed to the residential sector** with aim to identify:
   a) Fuel switching possibilities
   b) Costs related to fuel switching
   c) Switching possibilities if gas is used gas as a feedstock
   d) Cost for switching if gas is used as feedstock
   e) The effect of gas disruption in the industrial and power sectors in terms of loss of production, damage to equipment etc.
   f) The cost of disruption and if there is dependence on seasonality, day of week and time of day

As discussed in Task A we have obtained initial estimates on a proxy of a gas disruption cost which we call Unit Cost Measure. This proxy was developed as a function of country, sector, particular gas use within the sector (e.g. feedstock, heating, cooking etc) and taking into account the alternative appliance/fuel employed to substitute the natural gas firing equipment in the case of a disruption.

In all Questionnaires we asked participants about their views on the proposed methodology and whether the proposed UCM value could be accepted as CoDG. In the case of a negative response, participants were asked to express their views on how much the proposed UCM value should be increased or decreased to their perception of a fair value.

Appendix 21 Additional data collected by the Residential Sector Questionnaire

Table 100: Residential Sector - Monthly dependency on natural gas – space heating. Colours in cells indicate the percentage of responses received for each cell. The colour scale is shown below.

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Months	Dependence on natural gas (%)					Total respondents
	0-20	20-40	40-60	60-80	80-100	
January	0%	9%	9%	22%	61%	23
February	0%	13%	13%	13%	61%	23
March	9%	9%	17%	43%	22%	23
April	17%	13%	35%	30%	4%	23
May	39%	39%	9%	9%	4%	23
June	57%	22%	13%	4%	4%	23
July	57%	22%	13%	4%	4%	23
August	61%	13%	17%	4%	4%	23
September	39%	17%	26%	13%	4%	23
October	17%	26%	13%	22%	22%	23
November	17%	4%	22%	13%	43%	23
December	0%	17%	13%	17%	52%	23

Table 101: Residential Sector - Monthly dependency on natural gas – water heating Colours in cells indicate the percentage of responses received for each cell. The colour scale is shown below.

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Months	Dependence on natural gas (%)					Total respondents
	0-20	20-40	40-60	60-80	80-100	
January	5%	10%	10%	15%	60%	20
February	5%	10%	15%	10%	60%	20
March	10%	10%	20%	40%	20%	20
April	20%	10%	35%	30%	5%	20
May	40%	35%	10%	10%	5%	20
June	55%	20%	15%	5%	5%	20

Months	Dependence on natural gas (%)					Total respondents
	0-20	20-40	40-60	60-80	80-100	
July	55%	20%	15%	5%	5%	20
August	55%	15%	20%	5%	5%	20
September	45%	10%	25%	15%	5%	20
October	20%	30%	10%	15%	25%	20
November	20%	5%	25%	10%	40%	20
December	5%	15%	15%	15%	50%	20

Table 102: Residential Sector - Monthly dependency on natural gas – cooking. Colours in cells indicate the percentage of responses received for each cell. The colour scale is shown below.

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Months	Dependence on natural gas (%)					Total respondents
	0-20	20-40	40-60	60-80	80-100	
January	17%	8%	0%	17%	58%	12
February	17%	8%	8%	8%	58%	12
March	25%	8%	8%	33%	25%	12
April	33%	0%	25%	33%	8%	12
May	42%	33%	0%	17%	8%	12
June	58%	17%	8%	8%	8%	12
July	58%	17%	8%	8%	8%	12
August	67%	8%	8%	8%	8%	12
September	50%	8%	17%	17%	8%	12
October	33%	17%	8%	33%	8%	12
November	33%	0%	25%	8%	33%	12
December	17%	17%	0%	25%	42%	12

Table 103: Residential Sector - Hourly dependency on natural gas – space heating

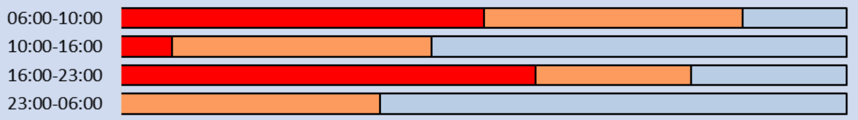
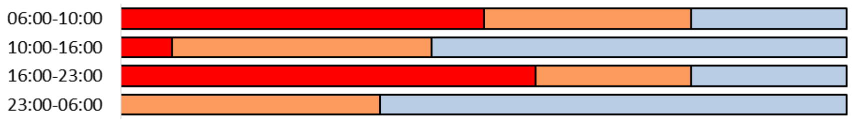
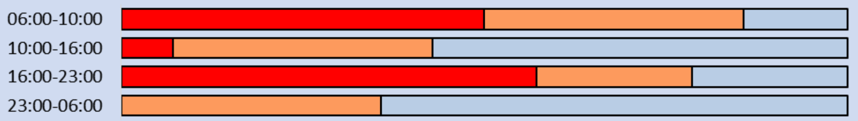
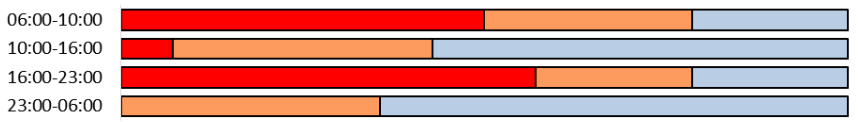
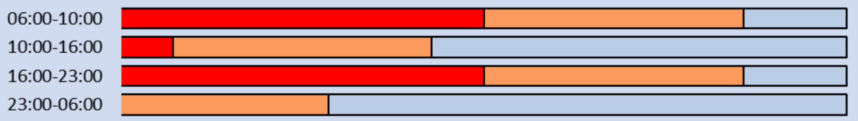
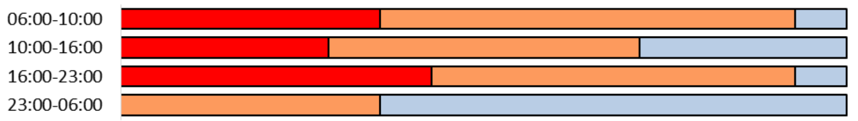
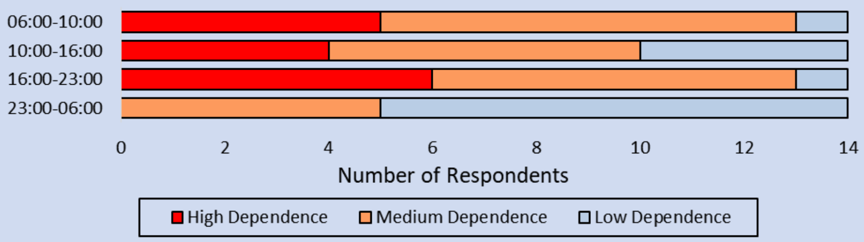
Weekday	Hourly dependence on natural gas consumption
Monday	
Tuesday	
Wednesday	
Thursday	
Friday	
Saturday	
Sunday	

Table 104: Residential Sector - Hourly dependency on natural gas – water heating

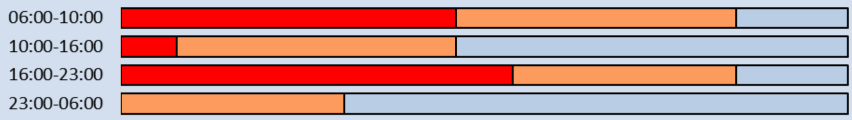
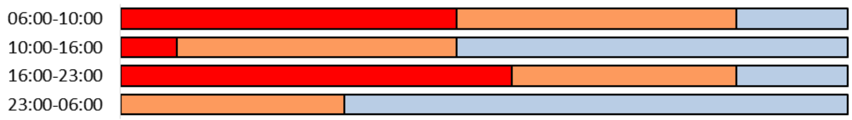
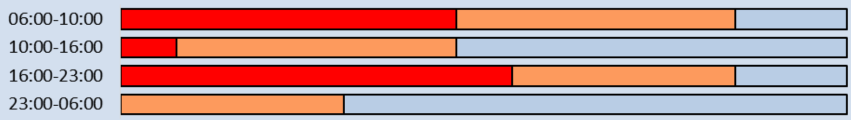
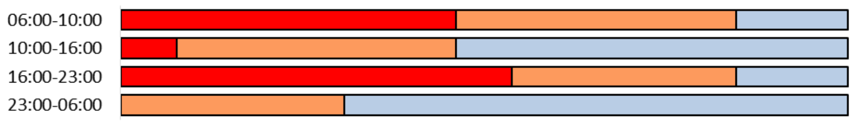
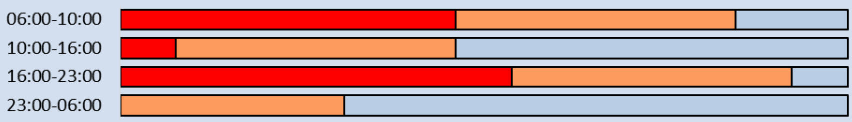
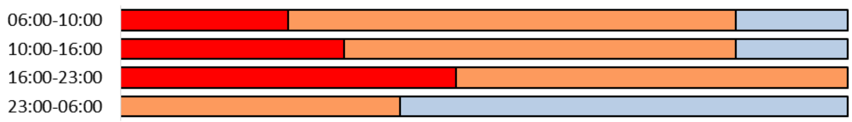
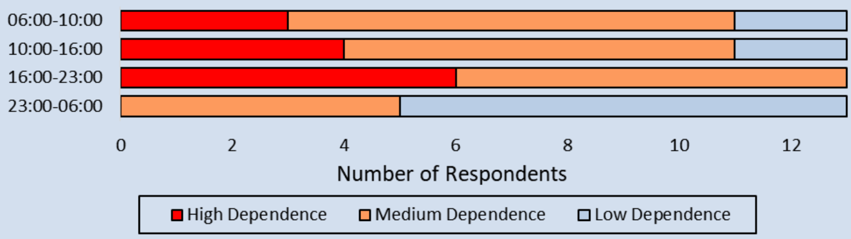
Weekday	Hourly dependence on natural gas consumption
Monday	
Tuesday	
Wednesday	
Thursday	
Friday	
Saturday	
Sunday	

Table 105: Residential Sector - Hourly dependency on natural gas - cooking

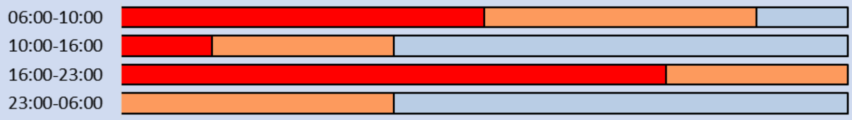
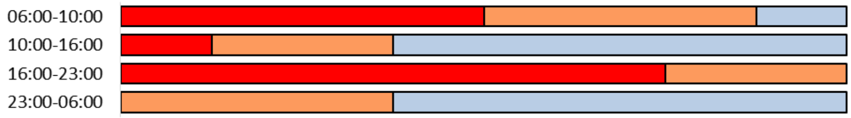
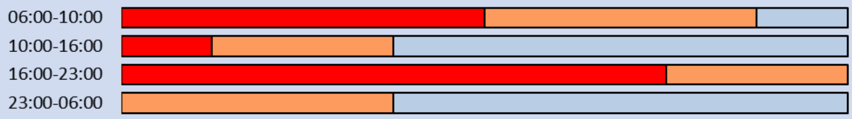
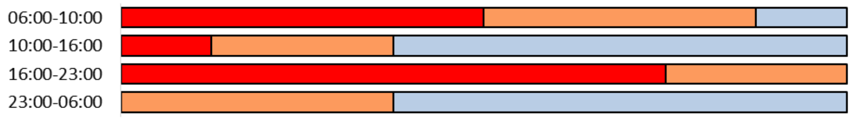
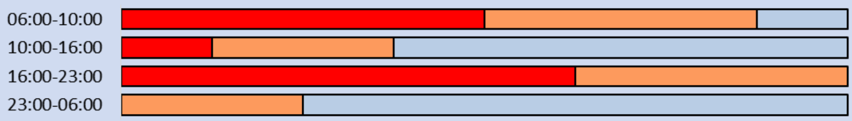
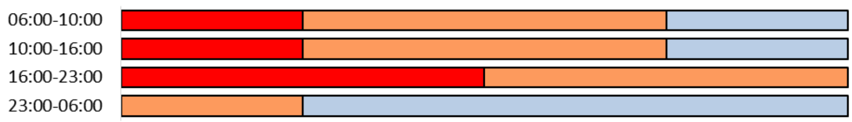
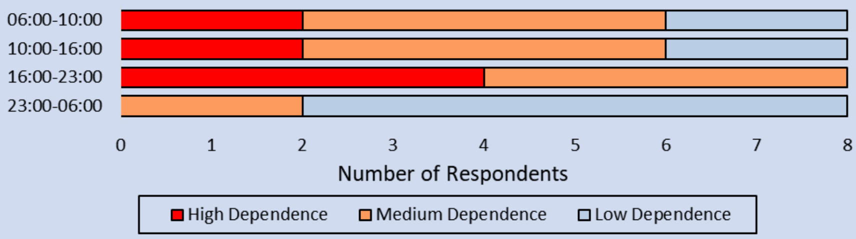
Weekday	Hourly dependence on natural gas consumption
Monday	
Tuesday	
Wednesday	
Thursday	
Friday	
Saturday	
Sunday	

Table 106: Hourly dependency on natural gas use per country - Monday

Monday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	High	Medium
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Medium	Low	Low	Low
Italy	15	Medium	Low	Medium	Low

Table 107: Hourly dependency on natural gas use per country - Tuesday

Tuesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	High	Medium
Belgium	11	Low	Low	Medium	Low

Tuesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Low	Low	Low	Low
Italy	15	Medium	Low	Medium	Low

Table 108: Hourly dependency on natural gas use per country - Wednesday

Wednesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	High	Medium
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Medium	Low	Low	Low
Italy	15	Medium	Low	Medium	Low

Table 109: Hourly dependency on natural gas use per country - Thursday

Thursday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low

Thursday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	High	Medium
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Low	Low	Low	Low
Italy	15	Medium	Low	Medium	Low

Table 110: Hourly dependency on natural gas use per country - Friday

Friday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Medium	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	Medium	Low
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Medium	Low	Low	Low
Italy	15	Medium	Low	Medium	Low

Table 111: Hourly dependency on natural gas use per country - Saturday

Saturday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	High	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	High	Medium	Low
Austria	4	Medium	Low	Medium	Medium
Slovakia	5	High	High	High	Medium
Luxembourg	6	Medium	Medium	High	Low
Italy	7	Low	High	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	Medium	Medium	Medium	Low
Italy	10	High	Low	Medium	Low
Belgium	11	Medium	Medium	Medium	Low
Slovenia	12	Medium	Medium	Medium	Medium
Italy	13	Medium	Medium	High	Low
Spain	14	High	Low	Low	Low
Italy	15	Low	Medium	Medium	Low

Table 112: Hourly dependency on natural gas use per country - Sunday

Sunday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	High	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	High	Medium	Low
Austria	4	Medium	Low	Medium	Medium
Slovakia	5	High	High	High	Medium
Luxembourg	6	Medium	Medium	High	Low
Italy	7	Low	High	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	Medium	Medium	Medium	Low
Italy	10	High	Low	Medium	Low
Belgium	11	Medium	Medium	Medium	Low
Slovenia	12	Medium	Medium	Medium	Medium

Sunday					
Country	S/N	Period of Day			
		06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Italy	13	Medium	Medium	High	Low
Spain	14	High	Low	Low	Low
Italy	15	Low	Medium	Medium	Low

Table 113: Hourly dependency on natural gas use per country – space heating (Monday)

Monday					
Country	S/N	Period of Day			
		06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	High	Medium
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Medium	Low	Low	Low

Table 114: Hourly dependency on natural gas use per country – space heating (Tuesday)

Tuesday					
Country	S/N	Period of Day			
		06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low

Tuesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	High	Medium
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Low	Low	Low	Low

Table 115: Hourly dependency on natural gas use per country – space heating (Wednesday)

Wednesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	High	Medium
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Medium	Low	Low	Low

Table 116: Hourly dependency on natural gas use per country – space heating (Thursday)

Thursday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	High	Medium
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low
Spain	14	Low	Low	Low	Low

Table 117: Hourly dependency on natural gas use per country – space heating (Friday)

Friday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Medium	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Italy	10	High	Low	Medium	Low
Belgium	11	Low	Low	Medium	Low
Slovenia	12	Low	Low	Low	Medium
Italy	13	Medium	High	High	Low

Friday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Spain	14	Medium	Low	Low	Low

Table 118: Hourly dependency on natural gas use per country – space heating (Saturday)

Saturday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	High	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	High	Medium	Low
Austria	4	Medium	Low	Medium	Medium
Slovakia	5	High	High	High	Medium
Luxembourg	6	Medium	Medium	High	Low
Italy	7	Low	High	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	Medium	Medium	Medium	Low
Italy	10	High	Low	Medium	Low
Belgium	11	Medium	Medium	Medium	Low
Slovenia	12	Medium	Medium	Medium	Medium
Italy	13	Medium	Medium	High	Low
Spain	14	High	Low	Low	Low

Table 119: Hourly dependency on natural gas use per country – space heating (Sunday)

Sunday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	High	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	High	Medium	Low
Austria	4	Medium	Low	Medium	Medium
Slovakia	5	High	High	High	Medium
Luxembourg	6	Medium	Medium	High	Low
Italy	7	Low	High	High	Low

Sunday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Italy	8	Medium	Low	High	Medium
Austria	9	Medium	Medium	Medium	Low
Italy	10	High	Low	Medium	Low
Belgium	11	Medium	Medium	Medium	Low
Slovenia	12	Medium	Medium	Medium	Medium
Italy	13	Medium	Medium	High	Low
Spain	14	High	Low	Low	Low

Table 120: Hourly dependency on natural gas use per country – water heating (Monday)

Monday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Belgium	10	Low	Low	Medium	Low
Slovenia	11	Low	Low	Low	Medium
Italy	12	Medium	High	High	Low
Italy	13	Medium	Low	Medium	Low

Table 121: Hourly dependency on natural gas use per country – water heating (Tuesday)

Tuesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium

Tuesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Belgium	10	Low	Low	Medium	Low
Slovenia	11	Low	Low	Low	Medium
Italy	12	Medium	High	High	Low
Italy	13	Medium	Low	Medium	Low

Table 122: Hourly dependency on natural gas use per country – water heating (Wednesday)

Wednesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Belgium	10	Low	Low	Medium	Low
Slovenia	11	Low	Low	Low	Medium
Italy	12	Medium	High	High	Low
Italy	13	Medium	Low	Medium	Low

Table 123: Hourly dependency on natural gas use per country – water heating (Thursday)

Thursday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Low	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Belgium	10	Low	Low	Medium	Low
Slovenia	11	Low	Low	Low	Medium
Italy	12	Medium	High	High	Low
Italy	13	Medium	Low	Medium	Low

Table 124: Hourly dependency on natural gas use per country – water heating (Friday)

Friday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	Medium	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	Low	Medium	Low
Austria	4	Medium	Low	Medium	Low
Slovakia	5	High	Medium	High	Medium
Luxembourg	6	High	Medium	High	Low
Italy	7	High	Medium	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	High	Low	High	Low
Belgium	10	Low	Low	Medium	Low
Slovenia	11	Low	Low	Low	Medium
Italy	12	Medium	High	High	Low
Italy	13	Medium	Low	Medium	Low

Table 125: Hourly dependency on natural gas use per country – water heating (Saturday)

Saturday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	High	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	High	Medium	Low
Austria	4	Medium	Low	Medium	Medium
Slovakia	5	High	High	High	Medium
Luxembourg	6	Medium	Medium	High	Low
Italy	7	Low	High	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	Medium	Medium	Medium	Low
Belgium	10	Medium	Medium	Medium	Low
Slovenia	11	Medium	Medium	Medium	Medium
Italy	12	Medium	Medium	High	Low
Italy	13	Low	Medium	Medium	Low

Table 126: Hourly dependency on natural gas use per country – water heating (Sunday)

Sunday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Austria	1	High	High	High	Low
Spain	2	Medium	Medium	Medium	Medium
Austria	3	High	High	Medium	Low
Austria	4	Medium	Low	Medium	Medium
Slovakia	5	High	High	High	Medium
Luxembourg	6	Medium	Medium	High	Low
Italy	7	Low	High	High	Low
Italy	8	Medium	Low	High	Medium
Austria	9	Medium	Medium	Medium	Low
Belgium	10	Medium	Medium	Medium	Low
Slovenia	11	Medium	Medium	Medium	Medium
Italy	12	Medium	Medium	High	Low
Italy	13	Low	Medium	Medium	Low

Table 127: Hourly dependency on natural gas use per country – cooking (Monday)

Monday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovakia	1	High	Medium	High	Medium
Italy	2	High	Medium	High	Low
Italy	3	Medium	Low	High	Medium
Austria	4	High	Low	High	Low
Italy	5	High	Low	High	Medium
Belgium	6	Low	Low	Medium	Low
Italy	7	Medium	High	High	Low
Italy	8	Medium	Low	Medium	Low

Table 128: Hourly dependency on natural gas use per country – cooking (Tuesday)

Tuesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovakia	1	High	Medium	High	Medium
Italy	2	High	Medium	High	Low
Italy	3	Medium	Low	High	Medium
Austria	4	High	Low	High	Low
Italy	5	High	Low	High	Medium
Belgium	6	Low	Low	Medium	Low
Italy	7	Medium	High	High	Low
Italy	8	Medium	Low	Medium	Low

Table 129: Hourly dependency on natural gas use per country – cooking (Wednesday)

Wednesday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovakia	1	High	Medium	High	Medium
Italy	2	High	Medium	High	Low
Italy	3	Medium	Low	High	Medium
Austria	4	High	Low	High	Low
Italy	5	High	Low	High	Medium
Belgium	6	Low	Low	Medium	Low
Italy	7	Medium	High	High	Low
Italy	8	Medium	Low	Medium	Low

Table 130: Hourly dependency on natural gas use per country – cooking (Thursday)

Thursday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovakia	1	High	Medium	High	Medium
Italy	2	High	Medium	High	Low
Italy	3	Medium	Low	High	Medium
Austria	4	High	Low	High	Low
Italy	5	High	Low	High	Medium
Belgium	6	Low	Low	Medium	Low
Italy	7	Medium	High	High	Low
Italy	8	Medium	Low	Medium	Low

Table 131: Hourly dependency on natural gas use per country – cooking (Friday)

Friday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovakia	1	High	Medium	High	Medium
Italy	2	High	Medium	High	Low
Italy	3	Medium	Low	High	Medium
Austria	4	High	Low	High	Low
Italy	5	High	Low	Medium	Low

Friday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Belgium	6	Low	Low	Medium	Low
Italy	7	Medium	High	High	Low
Italy	8	Medium	Low	Medium	Low

Table 132: Hourly dependency on natural gas use per country – cooking (Saturday)

Saturday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovakia	1	High	High	High	Medium
Italy	2	Low	High	High	Low
Italy	3	Medium	Low	High	Medium
Austria	4	Medium	Medium	Medium	Low
Italy	5	High	Low	Medium	Low
Belgium	6	Medium	Medium	Medium	Low
Italy	7	Medium	Medium	High	Low
Italy	8	Low	Medium	Medium	Low

Table 133: Hourly dependency on natural gas use per country – cooking (Sunday)

Sunday					
		Period of Day			
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00	23:00-06:00
Slovakia	1	High	High	High	Medium
Italy	2	Low	High	High	Low
Italy	3	Medium	Low	High	Medium
Austria	4	Medium	Medium	Medium	Low
Italy	5	High	Low	Medium	Low
Belgium	6	Medium	Medium	Medium	Low
Italy	7	Medium	Medium	High	Low
Italy	8	Low	Medium	Medium	Low

Table 134: Residential Sector – Agreement with the approach

Use of Natural Gas	realistic values	
	Yes	no
Space heating	10	13
Water Heating	8	12
Cooking	3	9

Table 135: Residential Sector – Comments on the tables above

No	Country	Comments
No.1	Italy	No costs linked to lack of gas are clearly evident (but just a bit of reduced comfort) when gas is used only for water heating and cooking.
No.2	Belgium	Higher value at peak moments

Table 136: Residential Sector – Change of the values if an early warning of 4 hours in advance of disruption has been provided

No	Country	Comments
No.1	Italy	Should be set close to zero (possible to shift gas use in time)
No.2	Belgium	depends on the duration of the expected disruption
No.3	Slovenia	decrease it

Appendix 22 Additional data collected by the Industrial Sector Questionnaire

Table 137 Industrial Sector – Per annum utilization of natural gas firing equipment at sector level

Question	Number of responses		Total respondents
	Yes	no	
Is natural gas used as a fuel in your facility throughout the year? (e.g. 365 days per year excluding maintenance periods)	17	14	31

Table 138: Industrial Sector – Per annum utilization of natural gas firing equipment by sub-sector

Sector	Is natural gas as a fuel continuously (e.g. 24 hours per day, 350 days a year with 15 days reserved for planned and unplanned maintenance)?	
	Yes	No
Iron & steel industry	3	7
Paper, Pulp and Print	6	1
Chemical and Petrochemical industry	2	3
Non-ferrous metal industry	4	0
Textile and Leather	1	2
Ammonia, acids and mineral Fertilizers production	0	0
Coated abrasives	0	1
Machinery	0	0
Non-metallic Minerals (Glass, pottery & building mat. Industry)	1	0
Construction	1	0
Mining and Quarrying	0	1

Table 139: Industrial Sector – Per annum utilization of natural gas firing equipment by country

Country	Is natural gas as a fuel continuously (e.g. 24 hours per day, 350 days a year with 15 days reserved for planned and unplanned maintenance)?	
	Yes	No
Italy	11	11
UK	5	1
Germany	1	0
France	2	0
Spain	2	0
Poland	0	0
Belgium	0	0
Greece	1	0
Portugal	1	0
Czech Republic	2	1
Lithuania	0	0
Finland	0	0
Hungary	1	1
Austria	0	1
Bulgaria	0	1
Denmark	0	1
Ireland	1	0

Table 140: Industrial Sector - Requirements in natural gas-as-fuel as a percentage of overall fuel consumption

Sub-Sectors	[%] of overall fuel consumption of the industrial facility									
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
Iron & steel industry	1	1	0	2	0	0	0	0	1	5
Chemical and Petrochemical industry	0	0	0	0	0	1	0	0	1	3
Non-ferrous metal industry	0	0	0	0	0	0	0	1	1	1
Non-metallic Minerals (Glass, pottery & building mat. Industry)	0	0	0	0	0	0	0	0	1	0
Machinery	0	0	0	0	0	0	0	0	0	0
Mining and Quarrying	0	0	0	0	0	0	0	0	0	1
Paper, Pulp and Print	1	0	0	0	0	0	0	0	2	4
Construction	0	0	0	1	0	0	0	0	0	0
Textile and Leather	0	0	0	0	0	1	0	0	0	2
Ammonia, acids and mineral Fertilizers production	0	0	0	0	0	0	0	0	0	0
coated abrasives	0	0	0	0	0	0	0	0	0	1

Table 141: Industrial Sector – Fuel switching capabilities by sub-sector

Sector	Do your facilities have fuel switching capabilities?		Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?	
	Yes	No	Yes	No
Iron & steel industry	1	9	0	1
Paper, Pulp and Print	1	6	0	1
Chemical and Petrochemical industry	0	5	0	0
Non-ferrous metal industry	2	2	1	1
Textile and Leather	0	3	0	0
Ammonia, acids and mineral Fertilizers production	0	0	0	0
Coated abrasives	0	1	0	0
Machinery	0	0	0	0
Non-metallic Minerals (Glass, pottery & building mat. Industry)	0	1	0	0
Construction	1	0	1	0
Mining and Quarrying	0	1	0	0

Table 142: Industrial Sector: – Fuel switching capabilities and the continuity of the flow of natural gas (per country)

Country	Do your facilities have fuel switching capabilities?		Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?	
	Yes	No	Yes	No
Italy	0	22	0	0
UK	2	4	1	1
Germany	0	1	0	0

Country	Do your facilities have fuel switching capabilities?		Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?	
	Yes	No	Yes	No
France	0	2	0	0
Spain	0	2	0	0
Poland	0	0	0	0
Belgium	0	0	0	0
Greece	1	0	0	1
Portugal	0	1	0	0
Czech Republic	1	2	1	0
Lithuania	0	0	0	0
Finland	0	0	0	0
Hungary	0	2	0	0
Austria	0	1	0	0
Bulgaria	0	1	0	0
Denmark	0	1	0	0
Ireland	0	1	0	0

Figure 52: Industrial Sector: The level of alternative fuel maintained in storage (as a multiple of peak day consumption)

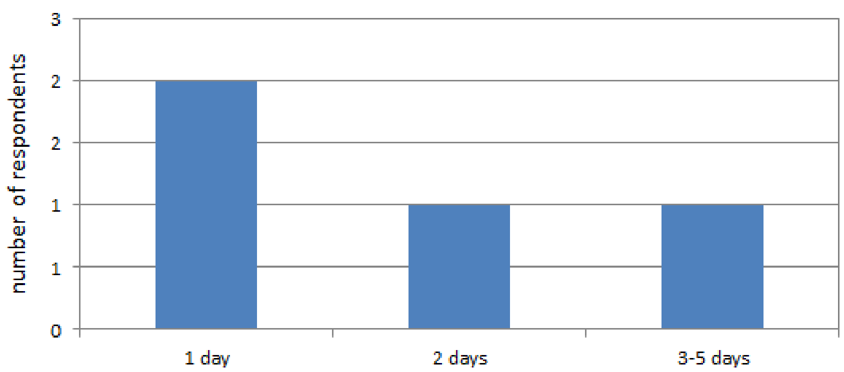


Figure 53: Industrial Sector: The type of alternative fuel that maybe used in case of a disruption

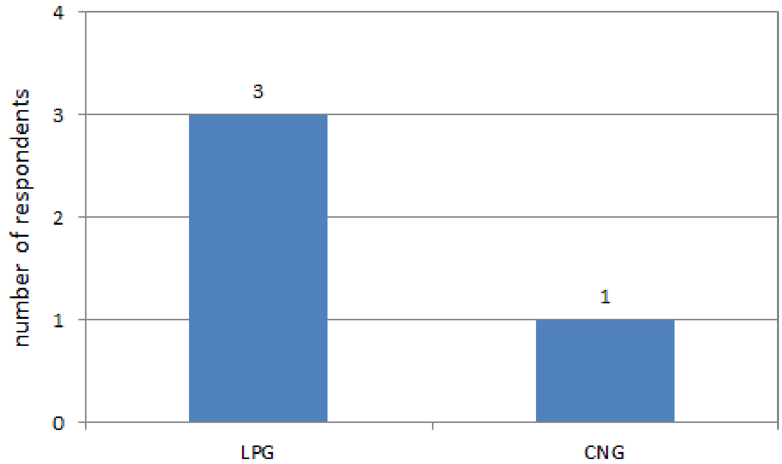


Table 143: Industrial Sector - Operating cost per annum for maintaining fuel switching facilities

Questions	Proportion of the operating cost per annum				Total Respondents
	1-5%	5-10%	10-15%	>15%	
	Number of responses				
Proportion of the operating cost per annum for maintaining fuel switching facilities (not including the cost of the alternative fuel e.g. alternative fuel replacement fired during a planned maintenance procedure)	3	1	0	0	4
Proportion of the operating cost for replacing alternative fuel fired during a planned maintenance (not due to fuel switching because of a disruption)	2	2	0	0	4

Table 144: Industrial Sector - Voluntary gas demand reduction schedule per country

Country	To address gas disruptions, some EU members have in place a voluntary gas demand reduction schedule. Is such a demand measure in place in your country?		Do you participate in such a demand side measure?		Are you compensated if you are disrupted?	
	Yes	No	Yes	No	Yes	No
Italy	9	20	6	3	5	1
UK	4	2	-	4	-	-
Germany	1	1	-	1	-	-
France	1	2	-	1	-	-
Spain	1	2	-	1	-	-
Poland	-	1	-	-	-	-
Romania	-	1	-	-	-	-
Greece	2	-	-	2	-	-
Portugal	1	-	-	1	-	-
Czech Republic	1	2	-	1	-	-
Hungary	2	1	1	1	1	-
Austria	1	1	-	1	-	-
Bulgaria	1	-	-	1	-	-
Denmark	1	-	-	1	-	-
Ireland	1	-	-	1	-	-

Table 145: Industrial Sector - Terms and conditions

No	Comments
No.1	Normally in the January-January period of each year there is the possibility of adhering to a reduction in consumption of the gas communicated the day before against a gas prize for this availability.
No.2	please refer to Italian procedure under the supervision of ARERA.

Table 146: Industrial Sector - Monthly dependence on natural gas - Iron & Steel industry

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	7%	7%	0%	7%	79%	14
February	7%	7%	0%	0%	86%	14
March	7%	7%	0%	0%	86%	14
April	7%	7%	0%	7%	79%	14
May	7%	7%	0%	7%	79%	14
June	7%	7%	0%	7%	79%	14
July	7%	7%	0%	7%	79%	14
August	21%	14%	0%	7%	57%	14
September	7%	7%	0%	7%	79%	14
October	7%	7%	0%	7%	79%	14
November	7%	7%	0%	0%	86%	14
December	7%	7%	0%	14%	71%	14

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 147: Industrial Sector - Monthly dependence on natural gas – Paper, Pulp and Print

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	13%	0%	0%	0%	88%	8
February	13%	0%	0%	0%	88%	8
March	13%	0%	0%	0%	88%	8
April	13%	0%	0%	0%	88%	8
May	13%	0%	0%	0%	88%	8

June	13%	0%	0%	0%	88%	8
July	13%	0%	0%	0%	88%	8
August	13%	0%	0%	25%	63%	8
September	13%	0%	0%	0%	88%	8
October	13%	0%	0%	0%	88%	8
November	13%	0%	0%	0%	88%	8
December	13%	0%	0%	0%	88%	8

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 148: Industrial Sector - Monthly dependence on natural gas – Chemical and Petrochemical industry

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	0%	0%	0%	0%	100%	5
February	0%	0%	0%	0%	100%	5
March	0%	0%	0%	0%	100%	5
April	0%	20%	0%	0%	80%	5
May	0%	20%	0%	0%	80%	5
June	0%	20%	0%	0%	80%	5
July	0%	20%	0%	0%	80%	5
August	0%	20%	0%	0%	80%	5
September	0%	20%	0%	0%	80%	5
October	0%	20%	0%	0%	80%	5
November	0%	0%	0%	0%	100%	5
December	0%	0%	0%	0%	100%	5

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 149: Industrial Sector - Monthly dependence on natural gas – Non-ferrous metal industry

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	20%	20%	0%	0%	60%	5
February	20%	20%	0%	0%	60%	5

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
March	40%	0%	0%	0%	60%	5
April	40%	0%	0%	0%	60%	5
May	40%	0%	0%	0%	60%	5
June	20%	20%	0%	0%	60%	5
July	20%	20%	0%	0%	60%	5
August	20%	20%	0%	0%	60%	5
September	40%	0%	0%	0%	60%	5
October	40%	0%	0%	0%	60%	5
November	20%	20%	0%	0%	60%	5
December	20%	20%	0%	0%	60%	5

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 150: Industrial Sector - Monthly dependence on natural gas – Textile and Leather

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	0%	0%	0%	0%	100%	4
February	0%	0%	0%	0%	100%	4
March	0%	0%	0%	0%	100%	4
April	0%	0%	0%	0%	100%	4
May	0%	0%	0%	0%	100%	4
June	0%	0%	0%	0%	100%	4
July	0%	0%	0%	0%	100%	4
August	50%	0%	50%	0%	0%	4
September	0%	0%	0%	0%	100%	4
October	0%	0%	0%	0%	100%	4
November	0%	0%	0%	0%	100%	4
December	0%	0%	0%	0%	100%	4

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 151: Industrial Sector - Monthly dependence on natural gas – Coated abrasives

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	0%	0%	0%	0%	100%	1
February	0%	0%	0%	0%	100%	1
March	0%	0%	0%	0%	100%	1
April	0%	0%	0%	0%	100%	1
May	0%	0%	0%	0%	100%	1
June	0%	0%	0%	0%	100%	1
July	0%	0%	0%	0%	100%	1
August	0%	100%	0%	0%	0%	1
September	0%	0%	0%	0%	100%	1
October	0%	0%	0%	0%	100%	1
November	0%	0%	0%	0%	100%	1
December	0%	0%	0%	0%	100%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 152: Industrial Sector - Monthly dependence on natural gas – Machinery

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	0%	0%	0%	100%	0%	1
February	0%	0%	0%	100%	0%	1
March	0%	0%	0%	100%	0%	1
April	0%	0%	0%	100%	0%	1
May	0%	0%	0%	100%	0%	1
June	0%	0%	0%	100%	0%	1
July	0%	0%	0%	100%	0%	1
August	0%	0%	0%	100%	0%	1
September	0%	0%	0%	100%	0%	1
October	0%	0%	0%	100%	0%	1
November	0%	0%	0%	100%	0%	1
December	0%	0%	0%	100%	0%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 153: Industrial Sector - Monthly dependence on natural gas – Non-metallic Minerals (Glass, pottery & building mat. Industry)

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	0%	0%	0%	0%	100%	1
February	0%	0%	0%	0%	100%	1
March	0%	0%	0%	0%	100%	1
April	0%	0%	0%	0%	100%	1
May	0%	0%	0%	0%	100%	1
June	0%	0%	0%	0%	100%	1
July	0%	0%	0%	0%	100%	1
August	0%	0%	0%	0%	100%	1
September	0%	0%	0%	0%	100%	1
October	0%	0%	0%	0%	100%	1
November	0%	0%	0%	0%	100%	1
December	0%	0%	0%	0%	100%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 154: Industrial Sector - Monthly dependence on natural gas – Construction

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	100%	0%	0%	0%	0%	1
February	0%	100%	0%	0%	0%	1
March	100%	0%	0%	0%	0%	1
April	100%	0%	0%	0%	0%	1
May	100%	0%	0%	0%	0%	1
June	100%	0%	0%	0%	0%	1
July	100%	0%	0%	0%	0%	1
August	100%	0%	0%	0%	0%	1
September	100%	0%	0%	0%	0%	1
October	100%	0%	0%	0%	0%	1
November	100%	0%	0%	0%	0%	1
December	100%	0%	0%	0%	0%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 155: Industrial Sector - Monthly dependence on natural gas – Mining and Quarrying

Months	Dependence on natural gas (%)					Total Respondents
	0-20	20-40	40-60	60-80	80-100	
January	0%	0%	0%	0%	100%	1
February	0%	0%	0%	0%	100%	1
March	0%	0%	0%	0%	100%	1
April	0%	100%	0%	0%	0%	1
May	0%	100%	0%	0%	0%	1
June	0%	100%	0%	0%	0%	1
July	0%	100%	0%	0%	0%	1
August	0%	100%	0%	0%	0%	1
September	0%	100%	0%	0%	0%	1
October	0%	100%	0%	0%	0%	1
November	0%	0%	0%	0%	100%	1
December	0%	0%	0%	0%	100%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 156: Industrial Sector - Intensity of natural gas use by country (Monday)

Monday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy/Czech Republic	1	Medium	High	High
Austria/Bulgaria/Denmark	2	High	High	High
Italy/Germany	3	High	High	High
Italy	4	Low	Low	High
Italy	5	Medium	Medium	Low
Italy	6	High	High	High
Italy	7	Medium	High	Medium
Italy	8	High	High	High
Italy	9	Low	Low	Low
Italy	10	Medium	Medium	Medium
Italy	11	High	High	High
Italy	12	High	High	High
Italy	13	High	High	High
Italy	14	High	High	Medium
UK	15	Low	Low	Low
UK	16	High	High	High

Table 157: Industrial Sector - Intensity of natural gas use by country (Tuesday)

Tuesday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy/Czech Republic	1	High	High	High
Austria/Bulgaria/Denmark	2	High	High	High
Italy/Germany	3	High	High	High
Italy	4	Low	Low	High
Italy	5	Medium	Medium	Low
Italy	6	High	High	High
Italy	7	Medium	High	Medium
Italy	8	High	High	High

Tuesday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy	9	Low	Low	Low
Italy	10	High	High	Medium
Italy	11	High	High	High
Italy	12	High	High	High
Italy	13	High	High	High
Italy	14	High	High	Medium
UK	15	Low	Low	Low
UK	16	High	High	High

Table 158: Industrial Sector - Intensity of natural gas use by country (Wednesday)

Wednesday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy/Czech Republic	1	High	High	High
Austria/Bulgaria/Denmark	2	High	High	High
Italy/Germany	3	High	High	High
Italy	4	Low	Low	High
Italy	5	Medium	Medium	Low
Italy	6	High	High	High
Italy	7	Medium	High	Medium
Italy	8	High	High	High
Italy	9	Low	Low	Low
Italy	10	High	High	Medium
Italy	11	High	High	High
Italy	12	High	High	High
Italy	13	High	High	High
Italy	14	High	High	Medium
UK	15	Low	Low	Low
UK	16	High	High	High

Table 159: Industrial Sector - Intensity of natural gas use by country (Thursday)

Thursday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy/Czech Republic	1	High	High	High
Austria/Bulgaria/Denmark	2	High	High	High
Italy/Germany	3	High	High	High
Italy	4	Low	Low	High
Italy	5	Medium	Medium	Low
Italy	6	High	High	High
Italy	7	Medium	High	Medium
Italy	8	High	High	High
Italy	9	Low	Low	Low
Italy	10	High	High	Medium
Italy	11	High	High	High
Italy	12	High	High	High
Italy	13	High	High	High
Italy	14	High	High	Medium
UK	15	Low	Low	Low
UK	16	High	High	High

Table 160: Industrial Sector - Intensity of natural gas use by country (Friday)

Friday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy/Czech Republic	1	High	High	Medium
Austria/Bulgaria/Denmark	2	High	High	High
Italy/Germany	3	High	High	High
Italy	4	Low	Low	High
Italy	5	Medium	Medium	Low
Italy	6	High	High	High
Italy	7	Medium	High	Medium
Italy	8	High	High	High

Friday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy	9	Low	Low	Low
Italy	10	High	High	Medium
Italy	11	High	High	High
Italy	12	High	High	High
Italy	13	High	High	High
Italy	14	High	High	Medium
UK	15	Low	Low	Low
UK	16	High	High	High

Table 161: Industrial Sector - Intensity of natural gas use by country (Saturday)

Saturday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy/Czech Republic	1	Low	Low	Low
Austria/Bulgaria/Denmark	2	Low	Low	Low
Italy/Germany	3	High	High	High
Italy	4	Low	Low	Low
Italy	5	Low	Low	Low
Italy	6	High	High	High
Italy	7	Low	Low	Low
Italy	8	Low	Low	Low
Italy	9	Low	Low	Low
Italy	10	Low	Low	Low
Italy	11	High	High	High
Italy	12	High	High	High
Italy	13	Medium	Medium	Medium
Italy	14	High	Low	Low
UK	15	Low	Low	Low
UK	16	High	High	High

Table 162: Industrial Sector - Intensity of natural gas use by country (Sunday)

Sunday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Italy/Czech Republic	1	Low	Low	Low
Austria/Bulgaria/Denmark	2	Low	Low	Low
Italy/Germany	3	High	High	High
Italy	4	Low	Low	Low
Italy	5	Low	Low	Low
Italy	6	High	High	High
Italy	7	Low	Low	Low
Italy	8	Low	Low	Low
Italy	9	Low	Low	Low
Italy	10	Low	Low	Low
Italy	11	High	High	High
Italy	12	High	High	High
Italy	13	Medium	Medium	Medium
Italy	14	Low	Low	Low
UK	15	Low	Low	Low
UK	16	High	High	High

Table 163: Power Sector - Intensity of natural gas use by country (Monday)

Monday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Finland	1	High	Medium	Medium
Austria/Bulgaria/Denmark	2	High	High	High
Lithuania	3	Low	Low	Low
Italy	4	High	High	High
Italy	5	High	High	High
Finland	6	High	High	Medium
Lithuania	7	High	High	High
Belgium/Poland	8	Medium	Low	Medium
Belgium	9	High	High	High

Monday				
Country	S/N	Period of Day		
		06:00-10:00	10:00-16:00	16:00-23:00
Spain/Portugal	10	Low	Medium	Medium

Table 164: Power Sector - Intensity of natural gas use by country (Tuesday)

Tuesday				
Country	S/N	Period of Day		
		06:00-10:00	10:00-16:00	16:00-23:00
Finland	1	High	Medium	Medium
Austria/Bulgaria/Denmark	2	High	High	High
Lithuania	3	Low	Low	Low
Italy	4	High	High	High
Italy	5	High	High	High
Finland	6	High	High	Medium
Lithuania	7	High	High	High
Belgium/Poland	8	Medium	Low	Medium
Belgium	9	High	High	High
Spain/Portugal	10	Low	Medium	Medium

Table 165: Power Sector - Intensity of natural gas use by country (Wednesday)

Wednesday				
Country	S/N	Period of Day		
		06:00-10:00	10:00-16:00	16:00-23:00
Finland	1	High	Medium	Medium
Austria/Bulgaria/Denmark	2	High	High	High
Lithuania	3	Low	Low	Low
Italy	4	High	High	High
Italy	5	High	High	High
Finland	6	High	High	Medium
Lithuania	7	High	High	High
Belgium/Poland	8	Medium	Low	Medium
Belgium	9	High	High	High

Wednesday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Spain/Portugal	10	Low	Medium	Medium

Table 166: Power Sector - Intensity of natural gas use by country (Thursday)

Thursday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Finland	1	High	Medium	Medium
Austria/Bulgaria/Denmark	2	High	High	High
Lithuania	3	Low	Low	Low
Italy	4	High	High	High
Italy	5	High	High	High
Finland	6	High	High	Medium
Lithuania	7	High	High	High
Belgium/Poland	8	Medium	Low	Medium
Belgium	9	High	High	High
Spain/Portugal	10	Low	Medium	Medium

Table 167: Power Sector - Intensity of natural gas use by country (Friday)

Friday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Finland	1	High	Medium	Medium
Austria/Bulgaria/Denmark	2	High	High	High
Lithuania	3	Low	Low	Low
Italy	4	High	High	High
Italy	5	High	High	High
Finland	6	High	High	Medium
Lithuania	7	High	High	High
Belgium/Poland	8	Medium	Low	Medium
Belgium	9	High	High	High

Friday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Spain/Portugal	10	Low	Medium	Medium

Table 168: Power Sector - Intensity of natural gas use by country (Saturday)

Saturday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Finland	1	Low	Low	Low
Austria/Bulgaria/Denmark	2	Low	Low	Low
Lithuania	3	Low	Low	Low
Italy	4	High	High	High
Italy	5	High	High	High
Finland	6	Medium	Low	Low
Lithuania	7	High	High	High
Belgium/Poland	8	Medium	Low	Medium
Belgium	9	Medium	Medium	Medium
Spain/Portugal	10	Low	Medium	Medium

Table 169: Power Sector - Intensity of natural gas use by country (Sunday)

Sunday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Finland	1	Low	Low	Low
Austria/Bulgaria/Denmark	2	Low	Low	Low
Lithuania	3	Low	Low	Low
Italy	4	High	High	High
Italy	5	High	High	High
Finland	6	Medium	Low	Low
Lithuania	7	High	High	High
Belgium/Poland	8	Medium	Low	Medium
Belgium	9	Medium	Medium	Medium

Sunday				
		Period of Day		
Country	S/N	06:00-10:00	10:00-16:00	16:00-23:00
Spain/Portugal	10	Low	Medium	Medium

Table 170: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Iron & Steel industry

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	50%	0%	14%	0%	21%	14%	14
	4-8h	50%	7%	7%	21%	0%	14%	14
	8-16h	71%	7%	14%	0%	0%	7%	14
	16-24h	71%	14%	7%	0%	0%	7%	14
	24-48h	86%	0%	7%	0%	0%	7%	14
	48-96h	86%	0%	7%	0%	7%	0%	14
70	2-4h	29%	0%	21%	0%	14%	36%	14
	4-8h	29%	7%	14%	14%	7%	29%	14
	8-16h	50%	7%	14%	7%	7%	14%	14
	16-24h	50%	7%	14%	7%	7%	14%	14
	24-48h	57%	7%	14%	0%	7%	14%	14
	48-96h	57%	7%	14%	0%	14%	7%	14
30	2-4h	14%	7%	21%	7%	21%	29%	14
	4-8h	14%	14%	14%	21%	14%	21%	14
	8-16h	21%	7%	43%	14%	0%	14%	14
	16-24h	36%	7%	29%	14%	0%	14%	14
	24-48h	50%	14%	14%	7%	0%	14%	14
	48-96h	50%	14%	14%	7%	7%	7%	14

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 171: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Chemical and Petrochemical industry

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	50%	17%	33%	0%	0%	0%	6
	4-8h	50%	33%	0%	17%	0%	0%	6
	8-16h	67%	0%	17%	17%	0%	0%	6

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
	16-24h	67%	0%	17%	17%	0%	0%	6
	24-48h	67%	0%	0%	17%	0%	17%	6
	48-96h	67%	0%	0%	0%	17%	17%	6
70	2-4h	33%	0%	33%	33%	0%	0%	6
	4-8h	33%	0%	50%	17%	0%	0%	6
	8-16h	33%	0%	50%	17%	0%	0%	6
	16-24h	33%	17%	33%	17%	0%	0%	6
	24-48h	33%	17%	33%	17%	0%	0%	6
	48-96h	33%	17%	33%	17%	0%	0%	6
30	2-4h	17%	17%	0%	0%	50%	17%	6
	4-8h	17%	17%	0%	0%	67%	0%	6
	8-16h	17%	17%	0%	0%	67%	0%	6
	16-24h	17%	17%	0%	0%	67%	0%	6
	24-48h	17%	17%	0%	0%	67%	0%	6
	48-96h	17%	17%	0%	0%	67%	0%	6

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 172: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Non-ferrous metal industry

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	60%	20%	0%	0%	20%	0%	5
	4-8h	80%	0%	0%	20%	0%	0%	5
	8-16h	80%	20%	0%	0%	0%	0%	5
	16-24h	80%	20%	0%	0%	0%	0%	5
	24-48h	100%	0%	0%	0%	0%	0%	5
	48-96h	100%	0%	0%	0%	0%	0%	5
70	2-4h	60%	0%	0%	0%	40%	0%	5
	4-8h	60%	0%	0%	20%	20%	0%	5
	8-16h	60%	20%	0%	0%	20%	0%	5
	16-24h	60%	20%	0%	0%	20%	0%	5
	24-48h	80%	0%	0%	0%	20%	0%	5
	48-96h	80%	0%	0%	0%	20%	0%	5
30	2-4h	60%	20%	0%	0%	0%	20%	5
	4-8h	80%	0%	0%	0%	20%	0%	5
	8-16h	80%	0%	20%	0%	0%	0%	5
	16-24h	80%	0%	20%	0%	0%	0%	5

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
	24-48h	80%	20%	0%	0%	0%	0%	5
	48-96h	80%	20%	0%	0%	0%	0%	5

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 173: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Textile and Leather

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	50%	50%	0%	0%	0%	0%	4
	4-8h	50%	25%	0%	25%	0%	0%	4
	8-16h	50%	25%	0%	0%	25%	0%	4
	16-24h	75%	0%	0%	0%	0%	25%	4
	24-48h	75%	0%	0%	0%	0%	25%	4
	48-96h	75%	0%	0%	0%	0%	25%	4
70	2-4h	25%	25%	25%	0%	0%	25%	4
	4-8h	50%	0%	25%	0%	25%	0%	4
	8-16h	50%	0%	25%	25%	0%	0%	4
	16-24h	50%	0%	25%	25%	0%	0%	4
	24-48h	50%	0%	25%	25%	0%	0%	4
	48-96h	50%	25%	25%	0%	0%	0%	4
30	2-4h	0%	25%	0%	50%	25%	0%	4
	4-8h	25%	0%	25%	50%	0%	0%	4
	8-16h	25%	25%	0%	50%	0%	0%	4
	16-24h	50%	0%	25%	25%	0%	0%	4
	24-48h	50%	0%	25%	25%	0%	0%	4
	48-96h	50%	0%	25%	25%	0%	0%	4

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 174: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Ammonia, acids and mineral Fertilizers production

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	100%	0%	0%	0%	0%	0%	1

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
	4-8h	100%	0%	0%	0%	0%	0%	1
	8-16h	100%	0%	0%	0%	0%	0%	1
	16-24h	100%	0%	0%	0%	0%	0%	1
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	100%	0%	0%	0%	0%	0%	1
70	2-4h	100%	0%	0%	0%	0%	0%	1
	4-8h	100%	0%	0%	0%	0%	0%	1
	8-16h	100%	0%	0%	0%	0%	0%	1
	16-24h	100%	0%	0%	0%	0%	0%	1
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	100%	0%	0%	0%	0%	0%	1
30	2-4h	0%	0%	0%	0%	100%	0%	1
	4-8h	0%	0%	0%	0%	100%	0%	1
	8-16h	0%	0%	0%	0%	100%	0%	1
	16-24h	0%	0%	0%	0%	100%	0%	1
	24-48h	0%	0%	0%	0%	100%	0%	1
	48-96h	0%	0%	0%	0%	100%	0%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 175: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Coated abrasives

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	100%	0%	0%	0%	0%	0%	1
	4-8h	100%	0%	0%	0%	0%	0%	1
	8-16h	100%	0%	0%	0%	0%	0%	1
	16-24h	100%	0%	0%	0%	0%	0%	1
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	100%	0%	0%	0%	0%	0%	1
70	2-4h	0%	0%	100%	0%	0%	0%	1
	4-8h	0%	0%	100%	0%	0%	0%	1
	8-16h	0%	0%	100%	0%	0%	0%	1
	16-24h	0%	0%	100%	0%	0%	0%	1
	24-48h	0%	0%	100%	0%	0%	0%	1
	48-96h	0%	0%	100%	0%	0%	0%	1
30	2-4h	0%	0%	0%	0%	100%	0%	1

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
	4-8h	0%	0%	0%	0%	100%	0%	1
	8-16h	0%	0%	0%	0%	100%	0%	1
	16-24h	0%	0%	0%	0%	100%	0%	1
	24-48h	0%	0%	0%	0%	100%	0%	1
	48-96h	0%	0%	0%	0%	100%	0%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 176: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Machinery

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	0%	100%	0%	0%	0%	0%	1
	4-8h	0%	100%	0%	0%	0%	0%	1
	8-16h	0%	100%	0%	0%	0%	0%	1
	16-24h	0%	100%	0%	0%	0%	0%	1
	24-48h	0%	100%	0%	0%	0%	0%	1
	48-96h	0%	100%	0%	0%	0%	0%	1
70	2-4h	0%	100%	0%	0%	0%	0%	1
	4-8h	0%	0%	100%	0%	0%	0%	1
	8-16h	0%	0%	0%	100%	0%	0%	1
	16-24h	0%	0%	0%	100%	0%	0%	1
	24-48h	0%	0%	0%	100%	0%	0%	1
	48-96h	0%	0%	0%	100%	0%	0%	1
30	2-4h	0%	100%	0%	0%	0%	0%	1
	4-8h	0%	0%	100%	0%	0%	0%	1
	8-16h	0%	0%	0%	0%	100%	0%	1
	16-24h	0%	0%	0%	0%	100%	0%	1
	24-48h	0%	0%	0%	0%	100%	0%	1
	48-96h	0%	0%	0%	0%	100%	0%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 177: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Construction

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	0%	0%	0%	100%	0%	0%	1
	4-8h	0%	0%	100%	0%	0%	0%	1
	8-16h	0%	0%	0%	100%	0%	0%	1
	16-24h	0%	0%	0%	0%	100%	0%	1
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	0%	100%	0%	0%	0%	0%	1
70	2-4h	0%	100%	0%	0%	0%	0%	1
	4-8h	0%	0%	100%	0%	0%	0%	1
	8-16h	0%	100%	0%	0%	0%	0%	1
	16-24h	0%	0%	0%	100%	0%	0%	1
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	100%	0%	0%	0%	0%	0%	1
30	2-4h	100%	0%	0%	0%	0%	0%	1
	4-8h	0%	100%	0%	0%	0%	0%	1
	8-16h	0%	100%	0%	0%	0%	0%	1
	16-24h	0%	100%	0%	0%	0%	0%	1
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	100%	0%	0%	0%	0%	0%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 178: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Non-metallic Minerals

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	100%	0%	0%	0%	0%	0%	1
	4-8h	100%	0%	0%	0%	0%	0%	1
	8-16h	100%	0%	0%	0%	0%	0%	1
	16-24h	100%	0%	0%	0%	0%	0%	1
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	100%	0%	0%	0%	0%	0%	1
70	2-4h	100%	0%	0%	0%	0%	0%	1
	4-8h	100%	0%	0%	0%	0%	0%	1
	8-16h	100%	0%	0%	0%	0%	0%	1
	16-24h	100%	0%	0%	0%	0%	0%	1

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	100%	0%	0%	0%	0%	0%	1
30	2-4h	100%	0%	0%	0%	0%	0%	1
	4-8h	100%	0%	0%	0%	0%	0%	1
	8-16h	100%	0%	0%	0%	0%	0%	1
	16-24h	100%	0%	0%	0%	0%	0%	1
	24-48h	100%	0%	0%	0%	0%	0%	1
	48-96h	100%	0%	0%	0%	0%	0%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 179: Industrial Sector - % of output activity continued as a function of level of curtailment and disruption duration - Mining and quarrying

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
100	2-4h	0%	0%	100%	0%	0%	0%	1
	4-8h	0%	0%	0%	100%	0%	0%	1
	8-16h	0%	0%	0%	100%	0%	0%	1
	16-24h	0%	0%	0%	100%	0%	0%	1
	24-48h	0%	0%	0%	100%	0%	0%	1
	48-96h	0%	0%	0%	0%	100%	0%	1
70	2-4h	0%	0%	100%	0%	0%	0%	1
	4-8h	0%	0%	100%	0%	0%	0%	1
	8-16h	0%	0%	100%	0%	0%	0%	1
	16-24h	0%	0%	100%	0%	0%	0%	1
	24-48h	0%	0%	100%	0%	0%	0%	1
	48-96h	0%	0%	100%	0%	0%	0%	1
30	2-4h	0%	100%	0%	0%	0%	0%	1
	4-8h	0%	100%	0%	0%	0%	0%	1
	8-16h	0%	100%	0%	0%	0%	0%	1

Loss of gas supply [%]	Duration of disruption [h]	Level of production maintained [%]						Total Responses
		0-10%	10-20%	20-40%	40-60%	60-80%	80-100%	
	16-24h	0%	100%	0%	0%	0%	0%	1
	24-48h	0%	100%	0%	0%	0%	0%	1
	48-96h	0%	100%	0%	0%	0%	0%	1

<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100

Table 180 Industrial Sector - Voluntary gas demand reduction schedule

Questions	Number of responses		Total respondents
	Yes	No	
To address gas disruptions, some EU members have in place a voluntary gas demand reduction schedule. Is such a demand measure in place in your country?	18	22	40
Do you participate in such a demand side measure?	7	11	18
Are you compensated if you are disrupted?	6	1	7

Table 181: Industrial Sector - Compensation level (EUR/MWh).

Country	Sector	Compensation level
Italy	Iron & steel industry	28
Italy	Chemical and Petrochemical industry	100

Table 182: Industrial Sector - Comments on the tables above

No	Country	Comments
No.1	United Kingdom	It is not possible to use electricity as an alternative to temporarily heat a gas fired kiln, either the technology does not exist, or substantial modification would be required. While oil fired options could be possible it would be expensive to install, maintain and implement such a system for back-up firing.
No.2	Italy	too cheap value
No.3	Italy	price of diesel fuel too low
No.4	Italy	for small boiler/heater lie ours the investment vs the generated power is going to be much greater than that.

Appendix 23 Additional data collected by the Power Sector Questionnaire

Figure 54: Power Sector – Per annum average utilization of natural gas firing equipment (percentages correspond to production at full load)

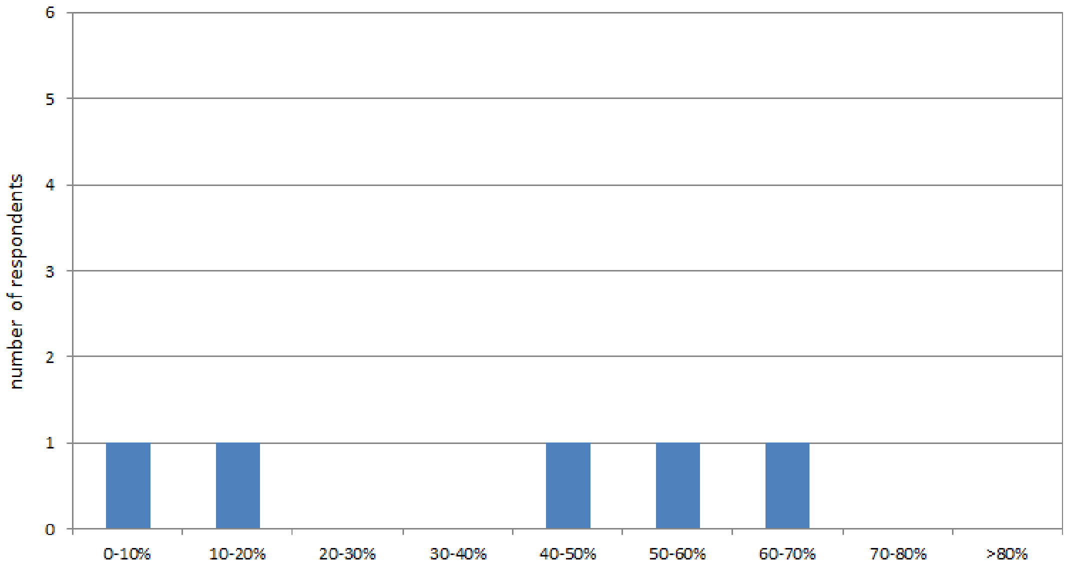


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Table 183: Power Sector – Fuel switching capabilities and the continuity of the flow of natural gas (per sector)

Questions	Number of responses		Total respondents
	Yes	no	
Do your facilities have fuel switching capabilities?	7	10	17
Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?	1	6	7
Is natural gas as a fuel continuously (e.g. 24 hours per day, 350 days a year with 15 days reserved for planned and unplanned maintenance)?	12	5	17

Table 184: Power Sector – Fuel switching capabilities and the continuity of the flow of natural gas (per country)

Country	Do your facilities have fuel switching capabilities?		Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?		Is natural gas as a fuel continuously (e.g. 24 hours per day, 350 days a year with 15 days reserved for planned and unplanned maintenance)?	
	Yes	No	Yes	No	Yes	No
Italy	0	8	0	0	8	0
UK	1	1	1	0	2	0
Germany	0	0	0	0	0	0
France	0	2	0	0	2	0
Spain	1	2	0	1	2	1
Poland	1	0	0	1	1	0
Belgium	2	0	0	2	2	0
Greece	0	0	0	0	0	0
Portugal	1	1	0	1	1	1
Czech Republic	0	0	0	0	0	0
Lithuania	1	1	0	1	0	2
Finland	2	0	0	2	1	1
Hungary	0	1	0	0	1	0
Austria	0	1	0	0	0	1
Bulgaria	0	1	0	0	0	1
Denmark	0	1	0	0	0	1
Ireland	0	1	0	0	1	0

Figure 55: Power Sector: The level of alternative fuel that you maintain in storage (as a multiple of peak day consumption

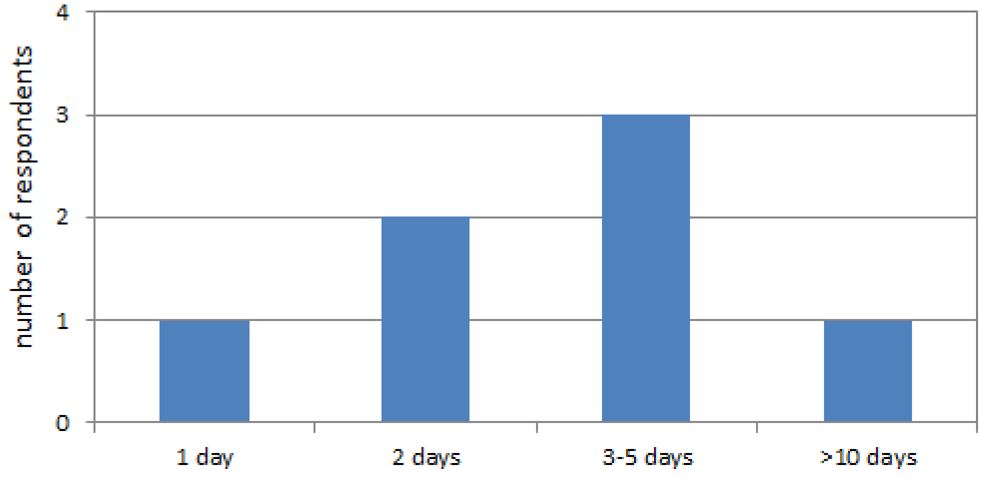

Figure 56: Power Sector: The type of alternative fuel that they may use in case of a disruption

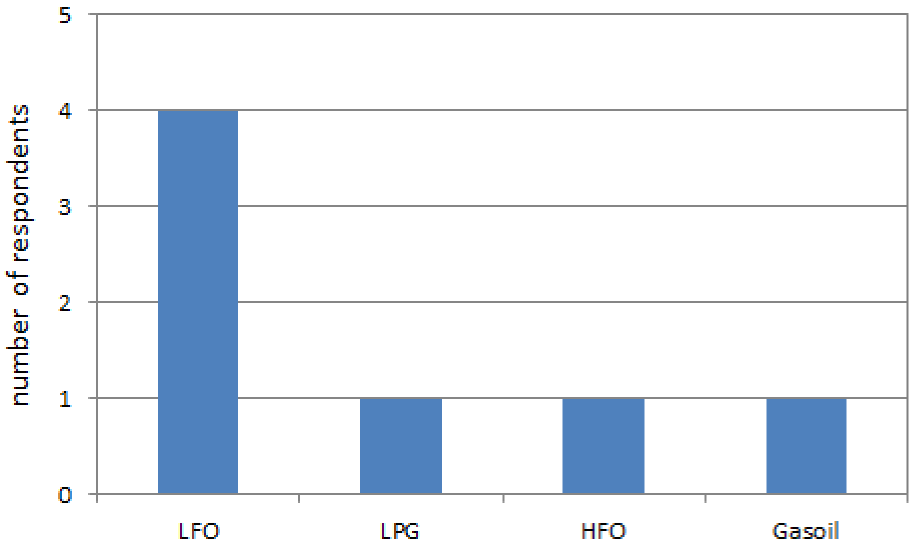

Table 185: Power Sector - Operating cost

Questions	Number of Responses				Total Respondents
	1-5%	5-10%	10-15%	>15%	
Proportion of the operating cost per annum for maintaining fuel switching facilities (not including the cost of the alternative fuel e.g. alternative fuel replacement fired during a planned maintenance procedure)	5	2	0	0	7
Proportion of the operating cost for replacing alternative fuel fired during a planned maintenance (not due to fuel switching because of a disruption)	4	0	1	2	7

Table 186: Power Sector: Scheme in place for the compensation of dual fired power plants (results by country)

Yes		No	
Country	Number of Answers	Country	Number of Answers
Italy	1	Italy	7
UK	1	Spain	3
		France	2
		Belgium	2
		Portugal	2
		Finland	2
		Lithuania	2
		UK	1
		Poland	1
		Hungary	1
		Austria	1
		Bulgaria	1
		Denmark	1
		Ireland	1

Appendix 24 InfoSheets

Interviewee 1	Countries of activity: EU-26

General Comments

This interviewee stressed the importance of using a market price as a proxy for the estimation of gas disruption and argued that consequential value approaches have distinguishable drawbacks in their implementation in practical cases. Administrative price caps should be avoided

The solidarity cost of gas disruption is not equal to the CoDG in the context of a CBA methodology and a TYNDP. The former addresses a comparatively short-term impact of a disruption while the latter aims to quantify the benefits of a new infrastructure which will be delivering gas over several decades.

DETAILS

POTENTIAL PROXIES TO A CoDG

Comments below are made with a view of a comparatively short-term gas disruption e.g. in the case where solidarity gas would need to be offered from one Member State to another.

- At a high level, the Cost of Gas Disruption should be set by market value, that is the price of gas in a functioning wholesale gas market.
- In case that the market has stopped functioning, the average market price of gas, prior to the disruption can be an appropriate value indicator.
- If the market price of gas, prior to the disruption is not available, the last available known market can be used (e.g. the average price of gas 30 days prior to the disruption)
- If there is no functioning gas market, neighbouring market prices can be used as proxies.
- In case of isolated gas markets, illiquid markets or countries without functional hubs were Over-the-Counter (OTC) contracts are concerned, the price of the long-term contracts cannot be considered as representative to the price of gas in a crisis. According to the interviewees view it would be still better even in such a case to take the value of gas at the nearest gas market (or any relevant approximation using the neighbouring market price).

Comments below are made with a view of quantifying the monetary impact of a disruption as in the case of the CBA methodology.

- The interviewee considers that the current value of ENTSOG (as used in the CBA methodology and the 2017 TYNDP) maybe be an overestimate of the actual monetary impact of a disruption for the purposes of new infrastructure.
- Using sector-based approaches (e.g. the Gross Value Added of the sector divided by the sectoral gas consumption) may not provide a solution to the problem as it is known that in some sectors the computed ratio is large due to a large nominator (GVA) and a comparatively small denominator (limited gas consumption),

CONCERNS

Interviewee 1	Countries of activity: EU-26
• An over inflated solidarity price will actually act as a countermeasure to the application of the solidarity mechanism. The solidarity receiving MS will never accept an over-inflated gas price and solidarity will be never realised. • The introduction of administrative caps while markets are still functioning should be avoided. • Consequential value approaches (such as the GVA approach or the GDP approach used by ENTSOG have distinguishable drawbacks in their implementation in practical cases. It is not a simple task to estimate the level of consequential damage experienced by a certain sector/industry in the case of a gas disruption. Consequences such as loss of production and loss of reputation can lead to a massive high price, in contrast to solidarity mechanism.	
Other issues	

Interviewee 2	Countries of activity: EU-28
General Comments	

Four topics were discussed by this interviewee

- The role of gas as a commodity
- The role of gas infrastructure
- The security of gas supply
- The value of lost load (with reference to gas)

The role of gas as a commodity

Interdependency between gas and electricity is expected to grow so consistency in market design of between both sectors is needed. The evolution of the gas market design (including tariffs for accessing gas infrastructure) is a topic that needs serious consideration by policy makers. The interaction of both commodities needs to be taken into account (gas-to-power and in the future power-to-gas).

In the short-term gas will play a bridge role in power generation over the coming years and topics like intermittency, power variability and flexibility are becoming more and more important. Access to flexible and competitive gas is absolutely key to the integration of renewables in the electricity sector with green gas becoming a key component of the decarbonisation process.

The role of gas infrastructure

Power-to-gas will probably be the best way to store gas in the future. Electricity and gas storages will play a complementary role to each other in the future (with storage of electricity a short-term flexibility measure and gas storage more in the mid-long term, not only for gas-to-power but also power-to-gas). Gas storages and gas infrastructure is necessary for gas to play its role as a flexibility provider.

The paragraph above provided the long-term view. In the short term, the utilisation of existing gas storages and pipelines should be optimised. Where bottlenecks exist these need to be addressed. In the eastern part of Europe some investment may be needed. To identify such needs, if any the proposed infrastructure should be subject to clear Cost Benefit Analysis. Where there is a need for new infrastructure for reasons related to security of supply or market integration, this need should be assessed through a CBA. Access should be in an affordable price and this is a key element of an efficient decarbonisation process.

The security of gas supply

In many EU MS, gas fired generation can be on many occasions, in terms of merit order the marginal plant to maintain demand. Because electricity and gas are inevitably interrelated, it is important to guarantee security of gas supply to gas fired power generators so that they are in turn able to provide security of electricity supply.

The new Regulation on Security of Gas supply recognises the importance of power plants vis-à-vis a gas disruption leading to a subsequent electricity disruption. Thus, gas fired plants may be considered as critical by national electricity TSOs and this status is taken into account in the gas load

Interviewee 2	Countries of activity: EU-28

shedding process. In this way, uninterrupted electricity supply can be provided as critical plants essentially enjoy the status of protected customers and will be amongst the last to be interrupted.

The need for coordination between the electricity TSO and the gas TSO is very important in the case of a gas crisis, such a coordination includes the need for coordination amongst electricity and gas TSOs of neighbouring countries. An example of such a case where the coordination of TSOs involved could have been beneficial in a crisis situation is the 2012 disruption of pipeline gas in the Balkans. At that time in Greece there was a tense situation regarding electricity production whereas in Bulgaria there was a tense situation regarding gas supplies. Efficient coordination between the electricity TSO from one side and the gas TSO from the other side could have well contributed towards addressing the crisis. Crises like the example above should be addressed in a cross-commodity manner. The new SoS regulation has provisions for a good progress in this topic.

The value of lost load

Any regulatory framework attempting to set the value of lost load for a customer should be based on pragmatism and simplicity and it should take into account that this is a quite complex theoretical concept. Thus, a detailed calculation/estimate may not be possible but only an order of magnitude estimation. Detailed values will essentially and inevitably give rise to controversial debates.

Sophisticated approaches may lead to failure due to the subjective nature of the VoLL (or CoDG). The cost of disruption may be different from customer A to customer B. Differences are expected between customer categories and Member States, the latter for example due to different geographical locations. The VoLL can only be reported as an order of magnitude. It is very hard to specify a detailed value because the degree of uncertainty is substantial.

Certain rules need to be met regarding the estimation of the cost of disruption.

- The VoLL (or CoDG) value should not interfere with the market functioning and distort market signals. There is a risk that an administratively set cost of disruption can play the role of a price cap in the commodity market (wholesale market) in both gas and electricity.
- The VoLL (or CoDG) should not prevent (or be a barrier) to the emergence of scarcity prices that reveal a tense situation in the supply and demand balance. In general, it is noted that particularly in gas, even if there is no particular crisis but merely a tense situation the balance between supply and demand is quite fragile. In such a case, the gas price in the commodity market will increase. In case however that the value of lost load is set at quite a low value, then this affects the marginal price in the gas market and it does not allow for the scarcity value to be revealed. Essentially such a disruption price acts as a price cap and can be detrimental to the functioning of the wholesale market.

In general, the VoLL can play a role in defining a market price cap. To make sure that this is not the case sufficiently high values should be pursued. For electricity the VoLL price should be more than 3000 $€/MWh$. This value is high enough to allow for the emergence of a scarcity value. Such a value can indeed be relevant.

For gas things are more complex are there is in general no define opinion formed. Taking into account the fact that a generally accepted VoLL for electricity maybe of the order of 3000 $€/MWh$, a CoDG should be formulated accordingly. In an effort to specify this correlation between electricity and gas we may say that if a CoDG is defined at a level of 10 times lower the electricity VoLL then

Interviewee 2	Countries of activity: EU-28
this would not work well. It is acknowledged however that the cost of CoDG may depend on the day of the week or the duration of the disruption. Thus, the value of the lost load maybe quite volatile.	

DETAILS

POTENTIAL PROXIES FOR A GAS DISRUPTION COST

The value of lost load can be set at an order of magnitude, but it will be very hard to have a fixed price. It cannot certainly be set at an order of precision of 1 €. The value will differ depending on the crisis scenario in an ex-ante mode. In an ex-post mode, for a stakeholder that has already faced an interruption in the gas supply, it may be possible to evaluate the cost of gas disruption. But ex-ante this is a very difficult task.

On the CoDG value used for the CBA methodology

The value of 600 $€/MWh$ currently used by ENTSOG is not irrelevant. However, it is important to note the difference that exists between a protected customer and a non-protected customer. The value of lost load between the two consumer categories needs to be different.

For the case of the protected customer, when a crisis occurs gas needs to flow at that customer essentially at all circumstances. This means that for this category of consumers the value of lost load is very high (as the customers of such a category should not be left without gas). Then, for protected consumers the value of lost load can be even higher than the 600 $€/MWh$ estimated by ENTSOG.

For the non-protected customer, the social welfare at a national level is not so critical and such customers may be interrupted. Thus, the CoDG can be lower than the value of the protected customers. This (a differentiation between protected and non-protected customers) may need to be taken into account in the evaluation of a new investment for the sake of the CBA.

On the solidarity price

Forced interruption of non-protected customers in the MS providing the solidarity (SP-MS) would have to be compensated at the value of the lost load as set by the policy maker for the particular category of customers.

The cost of gas for the country receiving the solidarity (SR-MS) should depend on two things (1) the market value of the cost of gas at the SP-MS and (2) a premium for the solidarity service delivered. This scenario assumes that the SP-MS although resorting into load shedding to assist the SR-MS it is not in a crisis situation and then the cost of gas should be at its market value (assuming however that some scarcity pricing has been observed in the market). Items (1) and (2) above should equal the value of the compensation to be paid to the forcibly disrupted consumer, with the premium essentially closing the gap between the value of lost load and the gas market price.

When the crisis begins you would see the gas prices in both MS increasing to indicate the scarcity. As a second step you would demand side measures may be employed. Such DSM measures will be employed while the market is still functioning, and gas prices increase due to scarcity. Here it is assumed that the value of lost load has a very high value (well above the scarcity price). As a third step, forced interruption will occur to supply the solidarity protected customers of the SR-MS. At that point the market of the SR-MS would not be functioning. This means that the market would not be able to attract gas any more. According to the interviewee, the market of the SP-MS would

Interviewee 2	Countries of activity: EU-28
still be functioning but due to a political decision the solidarity mechanism would be initiated. The only non-functioning market would be the market of the solidarity receiving MS. **CONCERNS** The design of any mechanism for the estimation of the cost of gas disruption should avoid market distortion and market manipulation. The design should ensure that market participants do not wait for the gas market value to reach the lost load value but instead are active participants to a DS mechanism. Efficient employment of market-based DSM tools is central to avoid market manipulation and the provision of solidarity at very high prices.	
Other issues	

Interviewee 3	**Countries of activity: West Europe, Balkans**

General Comments

If a regulatory framework is set-up to value the cost of supply disruption for consumers, pragmatism and simplicity should prevail. The Cost of Disruption or the Value of Lost Load are complex theoretical concepts. Any fine-tuned quantification exercise can be subject to controversial debates.

A sophisticated approach to provide accurate estimates could fail to deliver the appropriate signals, especially due to the expected discrepancies between consumers, as well as between Member States. The growing interdependency between gas and electricity sectors in Europe could make the exercise even more complex, see e.g. the case of gas-fired power plants.

The contributor puts forward the following basic principles that should be met as “golden rules”:

- Disruption cost estimates should not interfere in free price formation and markets signals: the theoretical concept should not be abused to hinder emergence of scarcity values in case of tense situation on the supply-demand balance. In other words, estimates should not prevent spikes in commodity prices in case of adequacy issues.
- As VoLL estimates could play a role in defining technical market price caps, they have to be fixed at sufficiently high values, both for natural gas (> 500 €/MWhg) and electricity (> 3000 €/MWhe).
- Most consumers cannot properly define the exact costs they could have to bear in case of supply disruption. They would depend on numerous factors (duration of disruption, context of the crisis, industrial process or economic activity involved, etc) and would vary for each consumer. Therefore, disruption cost estimates can only be reported in terms of orders of magnitude.
- Disruption costs for protected consumers (vis-à-vis risk of disruption) should be in line with the underlying rational for protecting these consumers. This inherently implies that disruption cost estimates for protected customers should be higher than the VoLL estimates of non-protected customers (i.e. CoDG estimates for distribution consumers should be significantly higher than CoDG estimates applied to (non-protected) consumers connected to the transmission network). Under such a consideration if a gas-fired power plant is considered critical for the power system (e.g. as per paragraph 7 of Article 11 and paragraph 1 of Article 13 of Regulation (EU) 2017/1938), the relevant CoDG estimates should probably be closer to values applicable to gas protected customers than to the one related to non-protected customers.

DETAILS

POTENTIAL PROXIES FOR A CoDG

Estimates should necessarily be significantly above the opportunity costs of voluntary demand-side management measures.

CONCERNS

Interviewee 3	Countries of activity: West Europe, Balkans
The design of any mechanism needs to avoid unintended consequences and potential distortions and/or market manipulation in areas such as credit risk and efficient market functioning.	
Other issues	
Demand-side management (DSM) measures, based on volunteered interruption or reduction of demand, should be effectively triggered as a market-based voluntary solution prior to considering any forced interruption.	

Interviewee 4	EU-28
General Comments	
The interviewee stressed the importance of solidarity provisions in the content of the amended regulation of the security of gas supply, although they may not have any effect on gas supply financial contracts. The value of natural gas should be limited to the value of the product and not the consequences of using the product. Consequential damage is calculated through the calculation of GVA. The last market value before the breakdown would be recommended as a more representative value, if there is a liquid market in neighbouring countries.	
DETAILS	

POTENTIAL PROXIES FOR A CoDG

The cost of gas disruption (CoDG) should be set by the market value of gas, i.e. the price of gas in a functioning wholesale market.

- In the event that a disruption of gas supply causes the market to stop functioning and requires Solidarity arrangements to be implemented, the average market price of gas of the 30 days prior to the disruption could be used as a proxy (this price is used in the UK).
- In regions where there is no functioning gas market, the price of gas at a nearby functioning gas hub (NBP / TTF) could be used as a proxy, considering (1) the objective that all regions will together function as a single market and (2) that the technology for dual fuel installations will be the same for all regions.

The benefit of using a market price in the context of the Solidarity arrangements is that the incentives remain in place for voluntary demand reductions prior to the emergency which can reduce the likelihood of involuntary supply interruptions and the associated economic costs.

CONCERNS

The approach to determine a CoDG on the basis of the consequences that a disruption could have on the user of gas is not acceptable. This is similar to a consequential damage approach.

ENTSOG has used this approach to quantify a CoDG in the context of the Cost-Benefit Analysis as a uniform level of 600 €/MWh, corresponding to the total EU28 GDP divided by the total gas consumption. This value is inflated as it includes the GDP contribution of activities that do not use gas or for which gas is not essential.

This approach is used in a more sophisticated manner by distinguishing between different categories of gas consumers and different Member States. For the U.K. a similar study was undertaken by London Economics on request of Ofgem. This study showed a wide range of outcomes from 0 to 2,398 p/therm (approx. 0 – 1,000 €/MWh). Still this study is based on the added value of the different sectors divided by their gas consumption.

Dual fuel facilities can be installed when the uninterrupted supply of energy is critical to a consumer. Under this approach dual fuel facilities would reduce the CoDG to zero, or to the difference in fuel

Interviewee 4	EU-28
efficiencies. For consumers that do not have dual fuel facilities installed the CoDG could be very high. This serves to illustrate the weakness of this approach. Using the consequential damage approach in the context of the Solidarity arrangements could seriously undermine the concept of solidarity, as Member States requesting Solidarity would have to pay a very high price. Also, this approach could introduce a perverse incentive to hold back on voluntary demand reductions in anticipation of an emergency. This could increase the risk of involuntary supply interruptions and increase the associated economic costs.	
Other issues	
The interviewee has provided by email an overview of the UK approach which is considered as relevant for the determination of a cost of gas disruption. Elements as provided by the interviewee are noted below for the sake of completeness. We note that the comments provided stem from Ofgem's Gas Security of Supply Significant Code Review[43]. *Approach to pricing involuntary interruptions to DM consumers* DM (daily metered) consumers are industrial and commercial (I&C) consumers that have relatively large levels of consumption. One study commissioned by Ofgem highlighted that interruption costs vary significantly between sectors. Another study looked at differences in the dispensability of parts of certain large consumers' loads. This revealed that even within sectors and within the overall loads of individual consumers, there is scope for even greater variation in the costs of reducing demand. Because of their size and daily-read capability DM consumers have the ability to directly reflect these individual interruption costs in the wholesale market when providing demand side response (DSR). DM interruptions to be priced in a market-based manner. This can be done by consumers negotiating for interruptible contracts or ad-hoc interruption agreements with their shippers/ suppliers. The more efficient use of DSR in and of itself can also reduce the likelihood, severity and duration of a gas disruption event as well as the economic costs associated with one. Despite the avenues open to DM consumers to provide DSR voluntarily, a price for DM consumers that are *involuntarily i*nterrupted is also introduced. This is in recognition of the fact that even involuntary interruptions still constitute balancing actions. Importantly though, the price chosen for involuntary DM interruptions – the average System Average Price (SAP) of the 30 days prior to the GDE ("30-day SAP") is chosen. This is price is not intended to reflect the interruption costs of any particular DM consumer. It is expected that any DM interruptions priced in at this level will not constitute the marginal balancing action. As such, they will not have much of a direct effect on the efficiency of price signals. Instead DM consumers are much more likely to have an impact on the efficiency of price	

43 https://www.ofgem.gov.uk/sites/default/files/docs/2014/09/gas_scr_final_decision.pdf

Interviewee 4	EU-28
signals through providing *voluntary* DSR. The choice of 30-day SAP is intended to ensure the incentives remain in place for this. *Approach to pricing involuntary interruptions to NDM consumers* Unlike DM consumers, NDM (Non-Daily Metered) consumers are generally not able to participate directly in the wholesale market at present. This is because their meters are not read on a daily basis and so interruption cannot easily be measured or verified. As a result, Ofgem proposals directly price NDM consumer interruptions into the cash-out arrangements by introducing a proxy estimate for NDM VoLL. This is based on a typical domestic consumer and set at £14/therm. Again, this was underpinned by the London Economics study commissioned that sought to calculate the value that consumers place on uninterrupted gas supplies. We have also taken on board some stakeholder feedback in our calculation of NDM VoLL in order to ensure it better reflects the value that consumers place on their supplies during winter. The detailed rationale underpinning this is set out in past documents, notably the July 2013 updated proposed final decision letter. Importantly, we have taken the view that it is not desirable for NDM VoLL to reflect the full marginal cost of network isolation. In part this is to limit liabilities on shippers in a GDE. Moreover, the duration of NDM interruptions is not within the control of shippers. Following network isolation, consumers must be visited individually by engineers to be safely reconnected to the system. This is the responsibility of distribution networks. Even if shippers recovered sufficient gas supplies quickly, safely reconnecting consumers could still take weeks. As such we have limited the pricing-in of NDM VoLL to days when any new network isolation is initiated. On these days, NDM VoLL would be incorporated into cash-out to ensure that prices reflect the value domestic consumers place on secure supplies. This means that the price signal will incentivise shippers to deliver security of supply up to the value NDM consumers place on it. Modelling showed that our reforms have the potential to ensure that the right price signals are sent to attract gas to GB. Our cash-out reforms treat involuntary interruptions to NDM consumers as balancing actions and price them into cash-out at £14/therm on the first day that they are subject to network isolation.	

Interviewee 5	EU-28

General Comments

The interviewee pointed out that a similar study has been made, in terms of the Value of Lost Load and in various sectors in Germany.

DETAILS

POTENTIAL PROXIES FOR A CoDG

Comments below are made, due to another study made by the interviewee.

- National statistics have been used, as far as specific branches are concerned like chemical industry, in order the Gross Value Added to be calculated.
- If the Gross Value Added is divided by gas consumption, a value for the whole branch is set.
- The Value of Lost Load differs from individual to individual.
- The Value of Lost Load has to be seen as a minimum.
- If the gas consumption has to be stopped, there may be further costs, contracts which cannot be fulfilled and penalty payments.
- In this way, denatures in the estimation are arising.
- The Value of Lost Load is 100 €/MWh.
- Concerning the energy intensive area, the Value of Lost Load goes up to 1000 €/MWh, while in area which is not gas intensive the Value of Lost Load is higher, as the whole production is breaking down.
- For example, in the car industry the Value of Lost Load is about 20,000 €/MWh or so.

CONCERNS

The following concerns arise from the aforementioned study made by the interviewee.

- Over the last decade, customers have just received gas and they don't have any problems so far.
- In this way, they don't think about denatures and disruptions.
- That could be critical, because most of them don't know and the first thing that they normally say is that they can't switch off.
- They don't want to think about the case they don't receive any gas.

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Other issues

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Interviewee 6	UK
General Comments	
The comments below were provided in writing (email) and are thus not a product of a direct interview. They are in the form of questions which we consider as highly relevant in the general framework of security of supply and are thus reported herein. <u>Defining and measuring gas security of supply</u> How should security of gas supply be defined and measured? What is the relevance/significance to the industrial and commercial sector of the current EU Gas Security Standard for protected consumers? What metrics, in addition to the standard N-1 test, would be useful in evaluating the UK's security of supply status? What is an acceptable level and frequency of unmet gas demand that might occur in future? Which market sectors would this impact on most and what would the impact of such unmet demand in the power sector be on electricity consumers? Would it be feasible to introduce a minimum gas security standard for all or sections of industry and the power sector? What would be the implications in terms of the need to underpin short-term supply flexibility e.g. a higher ratio of LNG stocks or gas storage to total demand? How would the aims for greater gas security fit with the Government's wider economic policy objectives such as those relating to industrial strategy and the impact of Brexit on energy policy? <u>Defining and measuring sources of flexible gas supply</u> What are the different forms of gas flexibility? Would there be merit in distinguishing between them, highlighting the role of different types of infrastructure asset in meeting each type of flexibility (e.g. pipeline, LNG, DSR and gas storage)? How flexible have gas supplies been in the recent past and what is the likely future reliability and responsiveness (i.e. elasticity of supply) of available sources of short-term gas supply e.g. pipeline, LNG, DSR, and gas storage? What are the current and likely future UK, European and international political, geopolitical and economic factors impacting on the sources of flexible gas supply? What is the likely relative market impact on flexibility of specific factors including variation of interconnector supplies competing EU demand at times of system stress, declining coal and nuclear generation, a reduction in LNG availability due to rising Asian demand, the unreliability of meaningful demand-side reduction and the lack of any new investment in UK gas storage capacity? <u>Defining and measuring gas and electricity price volatility</u> How have wholesale gas and electricity prices reacted to the incidence of unmet gas demand? Has energy price volatility risen, fallen or remained stable? Has the likelihood and severity of gas supply disruptions and related price volatility increased in recent years and if so why?	

Interviewee 6	UK
In the future, does BEIS believe that the frequency of short-term gas supply disruptions and the associated impact on energy prices will increase, decrease or remain stable and why?	

Defining the likelihood and relative impact of risks to security of supply

What is likely to be the significance and impact on shorter term supply and price security of expected/possible UK and international market developments?

What is the likely individual and collective market impact of the following? e.g. - closure of Rough and possible closure of other gas storage facilities, rising import dependency, closure of all coal fired electricity generation, closure of nuclear generation and increase in intermittent generation.

Evaluating the market, economic and welfare impact on all consumers

What is the estimated impact of the closure of Rough on both average and peak wholesale/retail gas and electricity prices?

What is the impact on industry (i.e. in terms of lost revenue, competitiveness and profitability) and domestic consumers of either short term supply disruptions and/or increased energy price volatility?

What is the VOLL (value of lost load) that industrial consumers of gas would be willing to pay to avoid disruptions to supplies? How accessible is forward purchasing on the gas market to all industrial and commercial customers?

What impact does the threat of more frequent and more significant gas supply disruptions and greater energy price volatility have on have on the attractiveness of the UK as an investment destination (UK and foreign direct investment) in UK gas consuming industries?

What would the original Redpoint modelling (2013) show in terms of the welfare impact of increased levels of gas storage under updated assumptions based on declining UK production, reduced short-term flexibility of supply and a lower level of UK gas storage?

Identifying and evaluating policy options to underpin flexibility of gas supplies

What evidence is there in the UK, EU and internationally that gas storage has or could help facilitate a reduction in the frequency and mitigate the impact of short-term gas shortages on energy costs?

What evidence is there in the UK, EU and internationally that in recent years seasonal gas price variations do not reflect the higher price that all consumers would be willing to pay to avoid supply disruptions and increased energy price volatility?

What would be the relative costs and benefits to the UK economy of different regulatory options to maintain existing gas storage capacity and increase the level of capacity in line with storage to demand ratios elsewhere in the EU?

How do we avoid existing assets being undermined by new assets, without creating a net system benefit?

What would be the relative costs and benefits associated with particular measures such as supply obligations, revenue support (e.g. the French capacity auction model) and investment incentives to underpin investment in both existing and new gas storage capacity?

Interviewee 6	UK
DETAILS	
nap	
Other issues	

This part of the infosheet includes a copy of the document entitled «QUESTIONS IN SUPPORT OF AN URGENT INQUIRY INTO GAS SECURITY (GAS SECURITY LOBBY GROUP MEETING WITH BEIS – 27 MARCH 2018» provided to the Consultant by the same interviewee. Again, the topics raised are most relevant in the understanding of the overall impact of gas supply disruptions to the overall energy cost.

Is the Government's strategic assessment of the UK gas market sufficiently comprehensive?

The Government's report (BEIS -CEPA – October 2017) concludes that "our system is robust" but, as recent evidence has demonstrated, this analysis is too narrow because:

it focuses only on potential import capacity and not deliverability,

it ignores the inter-dependency between gas and electricity security of supply and overall energy price volatility,

it ignores the elasticity of market response to actual or expected imbalances in supply arising from one or more source, particularly in the short-term,

it makes unrealistic assumptions regarding the logistical responsiveness of compensating imports via LNG shipments or pipeline supplies,

it understates the overall economic impact of potential supply disruptions, and

it fails to model the expected increase in both the frequency and economic impact of future supply disruptions under different gas storage scenarios.

Why is the UK more vulnerable to short-term gas market disruptions?

On the demand side there is the potential for significant variations in gas demand for heating linked to weather changes and a growing potential for large daily variations in demand linked to the demise of coal generation and the growth in intermittent power generation (see below).

During the recent crisis, coal-fired generation saved the gas system from interruption by reducing demand for gas generation Over 11GW of coal generation was called upon to keep the lights on and under current policies all this capacity will be gone by 2025.

On the supply side, the UK is becoming more dependent on imports (expected to rise from ~60% now to 80% by 2030) and there is the potential for delays in LNG shipments and bottlenecks in pipeline supplies (see below). Without adequate UK based gas storage, these factors will increase the frequency of gas market disruption and energy price spikes to the detriment of all consumers.

Is there acknowledgment from Government that there might be a problem?

Interviewee 6	UK
Yes, in its report, BEIS highlights that "LNG imports might be limited by the speed with which the market responds" and "where there is regional stress, pipeline imports may also be restricted" and that "gas storage has the capability to provide a source of flexible capacity in the intervening period". However, despite recent events, BEIS and Ofgem appear to believe that the market is working and that price spikes are essential to attract imports and that the "low level" of gas storage is an issue for the market to resolve and not the Government. This underestimates the cost to the economy and all consumers who are exposed to unnecessarily higher prices to facilitate the operation of the market – a cost that, it is acknowledged, is mitigated by the availability of gas storage. <u>Were the recent gas alert and energy price spikes a one-off incident?</u> At one point (01/03/2018) during the recent gas crisis, the SAP of gas peaked at over 372p/therm while the price of electricity soared to almost £1,000/MWh, but this price volatility was not a one-off incident. In recent months, there have been other incidents, which were not solely weather-related (e.g. Forties and Austrian gas explosion). Historically, the availability of Rough has helped moderate the impact price impact of short-term supply disruptions and the sluggish response of compensating LNG shipments. Indeed, the recent crisis would have been materially worse had: the bad weather lasted a few days longer, there been little wind power on the system due to low wind, and coal fired-generation was no longer on the system. Under these circumstances, National Grid would have had no option but to curtail gas supplies to industry and power generators who are (unlike residential consumers) not protected under the current EU security standard. <u>What's the likely impact of supply interruptions on future consumer energy costs?</u> Available evidence indicates that in the foreseeable future there is likely to be an increase in both the frequency and economic impact of price spikes, resulting from the combined effect of (a) increasing gas import dependency rising to 80% by 2030, (b) continued importance of gas in heating (70%), (c) the growth in demand for gas for system balancing and peak load power generation (currently 60%) triggered by the demise of coal and expansion in intermittent renewable generation, and (d) the current low level of gas storage relative to demand, ~2% following the closure of Rough, compared with ~25% across the EU. Of all the supply options available, only gas storage offers market response at short notice. Without more gas storage (see below) energy price spikes are likely to increase to unacceptable levels. Storage assets take years to build and the Government needs to take action now to determine whether or not some form of regulatory framework is appropriate to rectify the problem. <u>How reliable are LNG shipments and pipeline supplies in the short term?</u> As we have seen recently "security of LNG supply cannot be taken for granted" (IEA -October 2017). The IEA cites the case of LNG delays to Southern Europe in the Winter of 2016, which resulted in prices escalating to the highest in the world. National Grid's own analysis shows that in the recent gas crisis it took two weeks for an LNG shipment to arrive. (see attached LNG delivery charts).	

Interviewee 6	UK
Furthermore, evidence shows that it usually takes 10-15 days for a shipment to unload (not a few days as CEPA assume) and once downloaded there is no guarantee that the ship will not re-load and go elsewhere in response to higher prices in another market. LNG is a valuable source of import flexibility, but it is important to recognize that the UK's LNG stocks are shared with the rest of the world. In the short-term, the reliability of pipeline supplies is also suspect as happened recently when cold weather (i.e. competing demand) across Europe impacted negatively on the availability of supplies from the Continent. This constraint is especially pronounced in those countries which have Public Service Obligations (PSOs) in place, e.g. France, and servicing the needs of the national market are a priority. Some 60% of all EU gas storage is located in those countries which have PSOs. <u>Who pays the cost of disruptions to the supply of gas?</u> Suppliers and shippers can transfer their risk to customers by buying gas in the forward markets and then adjusting the price they charge to customers. They therefore face no, or little forward price exposure to expected tight supply conditions. They are exposed to a certain degree to high cash out prices if there is a physical security of supply issue, but the incentives to balance do not adequately reflect the true cost of flexibility in the market. Therefore, it is both industrial and residential consumers who suffer most from the detrimental impact from both long-term supply fears and short-term supply shocks. <u>Why are major energy users particularly vulnerable?</u> Major industrial energy users are especially at risk because the impact of gas and electricity price spikes on output and revenues, but also because their gas supplies are not (unlike residential consumers) protected under the EU gas security standard. Furthermore, contrary to what BEIS/Ofgem appear to believe, many of the major energy users are SME's and have limited balance sheet capacity to forward purchase a material proportion of their gas consumption. This problem is compounded where batch processes are used, because orders (and thus gas consumption) cannot be predicted months or years ahead. In addition, when day ahead prices rise, so do forward prices. The inability of certain companies to obtain credit cover is also a potential problem for those seeking hedge their energy price exposure. <u>Does the BEIS/CEPA analysis understate the "opportunity cost" and economic impact of gas supply disruptions?</u> Yes. The CEPA report assumes that that 'provided consumers are willing to pay the cost (of avoided Value of Lost Load- VoLL)' by buying gas supplies at emergency prices, then in the medium to long term gas supplies will be forthcoming to compensate for what CEPA see as shortfalls due to mainly geo-political causes. This analysis appears to assume that businesses and industries have disruptible gas supply contracts and have the choice to not pay the cost of avoided VoLL. The majority has to pay whatever price the gas market requires in a gas emergency. Although the price of emergency	

Interviewee 6	UK

gas supplies may be distributed differently around different classes of gas consumers, it must inevitably impact negatively on GDP.

CEPA does not acknowledge the inextricable link between gas and electricity security of supply in terms of both physical and price security, which undermines the value of the report. Because of the important role that gas plays in meeting regular and peak electricity demand (see below), a full-on gas supply failure is likely to prompt an electricity supply failure. In this context, gas and electricity VoLL's are inter-dependent. The best substitute for electricity VoLL is the 'fine' payable under the capacity market for a failure to generate when requested at 4-hour notice. The Capacity Market 'fine' of £4000/MWh would imply a gas VoLL of 4000p/therm, not the 100p/therm used in the CEPA study.

A second major impact assessment omission in the CEPA report is that the combination of 'N - 1' system resilience analysis, and long-term geo-political risks, does not reflect real world events or possibilities. The prospect of 2/3 gas infrastructure failures (either in UK or abroad) occurring simultaneously across short periods of a few days to a few weeks is a real possibility. Under such circumstances, it will not matter how much money is offered to the international gas market, physical supplies will not be capable of being delivered fast enough as, unlike electricity, gas cannot be transmitted instantaneously. (see above)

<u>What is the negative impact of gas market disruptions on gas generation and energy suppliers?</u>

Gas currently provides >40% of power generation and 70% of all heating. Furthermore, its role in supporting electricity system balancing is set to rise sharply as coal-fired generation closes and the amount of intermittent renewable generation increases. This means that gas demand will fluctuate dramatically, heavily dependent on the weather and time of day. National Grid Gas has forecast that by 2020/21, the variation in gas demand due to wind alone could be around 90 million cubic metres per day (mcm/d) – (National Grid UK Future Energy Scenarios – July 2013 Section 4.3.6). This is exceptionally high compared with UK average daily demand of around 200 mcm/d.

Without a minimum level of reliable and flexible gas storage capacity, the ability to meet this variable demand is at risk, which will impact negatively on the availability and cost of power at times of peak demand. The frequency and impact of these price spikes is set to increase, adding another layer of operational and investment uncertainty for gas generators at a time of low Capacity Market clearing prices and unpredictable market revenues.

The inability of major industrial users to fully hedge unpredictable spikes in gas prices is also a problem for smaller energy suppliers whose ability to offer low and competitive prices for both gas and electricity to consumers is severely limited by sudden spikes in the wholesale price of gas.

The net result is that smaller suppliers (e.g. Brighter World Energy) close or suppliers are forced to pass on sharp increases in fuel prices to consumers. Larger integrated suppliers are better able to manage these wholesale price risks. Any measure (e.g. additional gas storage) designed to mitigate the impact of wholesale gas price volatility would per se help to underpin competition in the retail energy market.

<u>What is the current situation on UK gas storage capacity?</u>

The UK's comparatively low level of gas storage does not look set to increase, and further existing capacity is at risk of near-term closure. A number of proposed and fully consented storage projects have been cancelled (such as Baird, Deborah and Caythorpe), put on hold, or are struggling to attain

Interviewee 6	UK
a final investment decision (FID). Given the economic challenges for gas storage in the UK, no FIDs have been taken for over 10 years. To compound the problem, Centrica Storage has been given approval to close its major Rough Storage Facility and SSE has announced reductions in the level of capacity at its Hornsea facility. <u>What are the barriers to new gas storage investment?</u> Gas storage is a long-term, capital intensive investment and recent seasonal price differentials have brought into question the viability of existing capacity and have been insufficient to support the level of investment required to replace Rough. In effect what has happened is that LNG shipments have to some extent eroded the seasonal price differential that gas storage operators have traditionally relied upon. <u>Is this an example of market failure?</u> Consequently, the challenge of encouraging new investment in gas storage to help mitigate the social and economic cost of higher energy costs is not an issue that the current market can resolve. If a minimal level of UK gas storage is to be retained as a component of system resilience and insurance against international market volatility, then some form of regulatory framework (e.g. storage obligations or investment incentives) will be required to support new and existing capacity, as is common on the Continent. Historically, seasonal gas price differentials have not reflected the “welfare” value that consumers would place on having additional storage to help mitigate short term price volatility. As the Daily Telegraph wrote during the recent gas crisis “No one likes paying for insurance but in the case of gas storage it could be worthwhile”. Or in the words of the Times “If the Government can expect consumers to shell out billions of pounds to finance Hinkley Point C, then it should be able to find a way to bankroll a few gas storage projects”. What the minimum of level of UK storage should be, how, if required, new investment might be supported by some form of regulation and what the insurance premium might be require urgent investigation. (see below) <u>So far, what has been the political approach to gas security?</u> To date, the Government has adopted a laissez-faire approach to the issues of gas security, concluding that no market intervention is required and that short- term price volatility demonstrates that the market is working. Back in 2011, the ECC Select Committee took a different view saying that the Government should “seek to double the UK’s current gas storage (then 5bcm) by 2020 to avoid exposure to gas supply interruptions”. In 2012, an MoD paper assessing the energy resilience in the UK concluded “The UK depends heavily on gas and needs additional storage in order to offer some resilience in the face of unexpected events”. The Government subsequently commissioned economic analysis in 2013 which showed a net welfare gain to consumers in six out of seven cases, yet no action was taken. <u>Why do the Government need to re-assess and what should they consider?</u> Since 2013, for reasons outlined above, the likely future frequency and economic impact of short-term gas supply disruptions has increased significantly. Following the media coverage of the last two weeks, there is now a growing recognition across industry and among expert commentators of the need for a fresh inquiry into gas security.	

Interviewee 6	UK
The key objectives of such an inquiry should be: To re-assess UK physical security of supply based on updated market assumptions, with particular reference to the future frequency and economic impact of short-term disruptions in actual or expected market imbalances and the cost implications of gas storage in mitigating the impact of such disruptions; To analyse the impact on both gas and electricity price volatility of short-term market disruptions and the economic and welfare impact of increased energy price volatility on industry, gas generators, energy suppliers and domestic consumers; To explore the problems currently faced by existing storage operators and developers (unsustainable level of business rates, new threats via the gas charging review, low spreads) and what kind of solutions would be available to ensure a level playing field with other EU storage operators and flexibility providers. <u>Is there growing support for a fresh inquiry into gas security?</u> Yes. Recent comments from across industry and amongst expert opinion formers and the media indicate that there is a growing call for an urgent inquiry along the lines that we recommended to Ministers and BEIS last November and we have repeated above. A great deal has changed since the last official inquiry in 2013, namely (a) the closure of Rough increases the likelihood and frequency of short-term market disruptions, (b) the average impact of energy price spikes is likely to place an unfair burden on both industry and consumers, and (c) setting a minimum level of UK gas storage would underpin a level of price protection for consumers and generate a significant net welfare gain for the economy as a whole. These arguments need to be tested via formal analysis and consultation with the objective of defining whether specific policy recommendations are required.	

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Appendix 26 NRA Survey

Table 187: Main findings of the NRA survey

Question	Responses		Total Respondents
	YES	NO	
Is the NRA the competent authority for Security of Gas Supply according to Regulation 2017/1938?	3 (EE, IR, SI)	13 (AT, BE, CZ, FI, FR, DE, HU, IT, LT, LU, PT, SP, UK(GB)[44])	16
Is there a methodology for calculating the cost of gas disruption (CoDG) in your country?	1 (UK(GB))	15 (AT, BE, CZ, EE, FI, FR, DE, HU, IR, IT, LT, LU, PT, SI, SP)	16
To address gas disruptions, some EU Member States have in place a voluntary gas demand reduction schedule. Is such a demand side measure in place in your country?	7 (AT, FI, FR, HU, IR, LU, UK(GB))	9 (BE, CZ, EE, DE, IT, LT, PT, SI, SP)	16
Do gas consumers participating in a demand side scheduling receive compensation?	3 (AT, LU, UK(GB))	4 (FI, FR, HU, IR)	7
Do power plants in your country have fuel switching obligations in case of gas disruption (e.g. switch to diesel oil)?	7 (AT, FI, FR, DE, HU, IR, IT)	9 (BE, CZ, EE, LT, LU, PT, SI, SP, UK(GB))	16
Is there a scheme in place for the compensation of power plants for maintaining dual fuel facilities and operating on alternative fuel?	1 (IR)	6 (AT, FI, FR, DE, HU, IT)	7
Do suppliers of protected customers (or other gas consumers) in your country have storage obligations?	6 (CZ, EE, HU, LT, PT, SP)	10 (AT, BE, FI, FR, DE, IR, IT, LU, SI, UK(GB))	16

[44] UK(GB) shown herein refers to the responses provided by the Regulator of Great Britain Ofgem.

Question	Responses		Total Respondents
	YES	NO	
Is there an obligation for strategic storage in place in your country?	4 (HU, IT, PT, SP)	12 (AT, BE, CZ, EE, FI, FR, DE, IR, LT, LU, SI, UK(GB))	16
Are these suppliers compensated for the cost maintaining gas in storage for security of supply?	2 (EE, LT)	5 (CZ, HU, IT, PT, SP)	7
Is there a security of supply levy imposed on gas customers to fund security of supply actions (e.g. emergency actions in the case of disruption) in your country?	3 (FI, FR, HU)	13 (AT, BE, CZ, EE, DE, IR, IT, LT, LU, PT, SI, SP, UK(GB))	16

Table 188: Additional information provided by NRAs

Question	Country	Response
Do you consider different CoDG values for different consumption sectors or one single value at country level?	UK	• Different CoDG values for different sectors • £14/therm (approx. 549 [€/MWh] for non-daily metered customers (residential, etc). • No value of lost load is specified for other types of customers
Which industrial categories have signed voluntary load reduction agreements?	AT	• Load-metered consumers with a contracted capacity of more than 10 MW are allowed to take part in the 'flexible merit order list' for providing balancing energy
	FR	• All industrial categories
	HU	• All industrial categories
	LU	• Voluntary basis

Question	Country	Response
Please provide information on the terms of load reduction agreements (voluntary gas demand reduction schedule) and on the methodology for the calculation of the compensation amount if any.	AT	• Gas Market Model Ordinance section 20 (6): Balance responsible parties shall conclude agreements about the participation in and handling of the merit order list pursuant to para. 31 with all those load-metered consumers in their balance group that have a contracted capacity of more than 10,000 kWh/h and intend to participate in the merit order mechanism.
	FR	• At this stage, there is only one existing mechanism: consumers volunteer in their responses to a DSO questionnaire, to reduce their consumption in case of supply crisis. There is no financial compensation and no penalty if the consumer does not reduce effectively its consumption. The methods for an interruptibility mechanism under contract, and in particular the type or volume where clients could benefit from it, are not known at this stage. All consumers suitable for load-shedding do not pay the dedicated storage tariff fee included in the Gas Transmission Tariff (297,1 €/MWh/d/y).
	LU	• Customers indicate in their contractual arrangements if they want their load to be reduced in case there is a problem, before the national shedding plan enters into application in case of bigger problems
	UK	• National Grid DSR mechanism allows industrial and commercial users to signal their willingness to make additional DSR energy quantities available following a Gas Deficit Warning. DSR offers are posted on the OCM Locational market and include a price45.

[45] More information can be found here: https://www.nationalgrid.com/uk/gas/balancing/demand-side-response-dsr And here: https://www.gasgovernance.co.uk/sites/default/files/ggf/Gas DSR Methodology FINAL - July 2016.pdf

Question	Country	Response
	FI	• Basically, it is not voluntary load reduction agreement, but market based. In emergency situations retail customers are protected customers.
Are these suppliers compensated for the cost maintaining gas in storage for security of supply? Please provide information on the compensation methodology?	EE	• Full recover really made costs
	LT	• According to the Cabinet of Ministers of Latvia Regulation Nr.312 "Procedures for the Supply of Energy Users and Sale of Heating Fuel During Declared Energy Crisis and in Case of Endangerment to the State" in force from May 6, 2011, obligation of the TSO is to keep reserves of natural gas for the protected customers. It is compensated by including those costs in the transmission system's justified costs (tariffs).
Additional comments	PT	• In Portugal it's not mandatory, but if CC Power Plants want, they may have switching fuel facilities. In this case they don't need to have natural gas storage reserves which are obligatory for all other cases.

Appendix 27 Questionnaire to the Residential Sector

Questionnaire addressed to Residential Sector using natural gas.

Thank you for agreeing to participate. It will only take a few minutes to complete. All of your answers are private and confidential.

Page 1

Welcome to this survey looking into the Cost of Gas Disruption (CoDG) in the Residential sector in Europe.

The survey is addressed to individuals using natural gas in their homes for space heating and/or water heating and/or cooking and/or any other household use.

The survey is carried out by KANTOR MANAGEMENT CONSULTANTS (KMC), Greece and Economic Consulting Associates (ECA), UK in the context of the project entitled "STUDY ON THE ESTIMATION OF THE COST OF DISRUPTION OF GAS SUPPLY IN EUROPE", commissioned by the Agency for the Cooperation of Energy Regulators (ACER).

Achieving and maintaining an adequate level of security of natural gas supply (SoS) is one of the goals the EU energy policy. An increased level of SoS can be achieved through the development of new gas infrastructure. New infrastructure can provide additional capacity and/or link Member States to new sources and markets. However, efficient gas infrastructure development entails that costs should not exceed benefits, including the benefit from an increased value of SoS. A uniform disruption cost has been quantified by the European Network of Transmission System Operators for Gas (ENTSOG) and is applied to estimate the benefits of new proposed infrastructure.

However, applying a uniform value across all customer categories and Member States may not represent adequately the actual Cost of Gas Disruption (CoDG).

In the context of this survey we seek to understand if indeed there is a potential dependence of the CoDG by country and categories of consumers and if further patterns defined by the duration of the disruption, and the way in which a prior notice (e.g. 24 hours ahead of the disruption) may impact the cost of disruption.

Your contribution is greatly valued towards the development of cost-effective new gas infrastructure and the efficient management of gas supply disruptions.

Please address any questions you may have concerning this questionnaire to Ms Katerina Leividioti (kgl@kantor-group.eu) and Mr Kostas Lymperis (kcl@kantor-group.eu).

We would be grateful for your responses by 30 June.

Page 2

*** 1. Name**

*** 2. Email**

Additional options (question 2)
› Validation:

*** 3. Please specify where do you use natural gas.**

- ☐ space heating
- ☐ water heating
- ☐ cooking
- ☐ Other, please specify

Page 3

*** 4. In the case of a gas disruption, which of the uses above you consider to be the most critical and should be made available (or replaced by use of alternative equipment) as soon as possible. Please rank your response with 1 being the most critical.**

	1-most critical	2-average	3-non critical
$$$Quest3-1$$$	○	○	○
$$$Quest3-2$$$	○	○	○
$$$Quest3-3$$$	○	○	○
$$$Quest3-4$$$	○	○	○

Additional options (question 4)
› Extraction based on: *3. Please specify where do you use natural gas.*

Page 4

*** 5. At which EU Member State is your home located?**

- Germany
- France
- United Kingdom
- Italy
- Spain
- Poland
- Romania
- Netherlands
- Belgium
- Greece
- Portugal
- Czech Republic
- Hungary
- Sweden
- Austria
- Bulgaria
- Denmark
- Finland
- Slovakia
- Ireland
- Croatia
- Lithuania
- Slovenia
- Latvia
- Estonia
- Cyprus
- Luxembourg
- Malta

*** 6. What is your dependence on natural gas during the year?**

Month	Dependence on natural gas (%)				
	0-20%	20-40%	40-60%	60-80%	80-100%
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					

*** 7. In the months you are most dependent on natural gas, is your gas demand independent of time in the day?**

- yes
- no

- Go to **page 5** if
  7. In the months you are most dependent on natural gas, is your gas demand independent of time in the day?...
  is *no*
- **Else go to page 6**

Page 5

*** 8. When do you use natural gas mostly (day and time of week)?**

From 06:00 to 10:00

	Low	Medium	High
Monday			

Tuesday			
Wednesday	○	○	○
Thursday	○	○	○
Friday	○	○	○
Saturday	○	○	○
Sunday	○	○	○

* 9. From 10:00 to 16:00

	Low	Medium	High
Monday	○	○	○
Tuesday	○	○	○
Wednesday	○	○	○
Thursday	○	○	○
Friday	○	○	○
Saturday	○	○	○
Sunday	○	○	○

* 10. From 16:00 to 23:00

	Low	Medium	High
Monday	○	○	○
Tuesday	○	○	○
Wednesday	○	○	○
Thursday	○	○	○
Friday	○	○	○
Saturday	○	○	○
Sunday	○	○	○

* 11. From 23:00 to 6:00

	Low	Medium	High
Monday	○	○	○
Tuesday	○	○	○
Wednesday	○	○	○
Thursday	○	○	○
Friday	○	○	○
Saturday	○	○	○
Sunday	○	○	○

12. **Do you already have alternative appliances which you may use in case of gas disruption? Please let us know on the type of appliances by clicking on the checkboxes below.**

	electric kitchen	LPG cooking appliance	microwave	other (please specify)
Cooking	☐	☐	☐	

* **13. water heating**

	electric water heater	solar water heater
.	☐	☐

* **14. space heating**

	Air conditioning	Heat pumps	Burner using alternative fuel	other electrical appliances (please specify)
.	☐	☐	☐	

- Go to **page 7** if
  14.1 space heating. .
  is *Burner using alternative fuel*
- **Else go to page 8**

Page 7

* **15. Please specify the fuel used in burner from the list below.**

	LPG	Light Fuel Oil	wood/biomass/pellets	Other, please specify
.	☐	☐	☐	

Page 8

* **16. Did you reach a decision to purchase an alternative source of space heating/water heating/cooking after a gas supply interruption?**

○ yes ○ no

- Go to **page 9** if
  16. Did you reach a decision to purchase an alternative source of space heating/water heating/cooking after a gas supply interruption?...
  is *yes*
- **Else go to page 10**

Page 9

17. **Can you please describe the conditions that led you to this decision (duration of disruption, time of year etc.)?**

Page 10

We are in the process of trying to evaluate the cost of gas disruption for residential gas consumers in EU member states.

For your country we have calculated the value shown below. This value can be interpreted as a cost you incur due to the disruption (e.g. the cost of an alternative equipment taking into account the lifetime of the equipment). On top of this cost one of course would need to add the fuel price difference (e.g. price of LPG - price of natural gas per unit of energy consumed).

Value corresponds to the time that gas is most needed (for example night in winter for space heating).

Countries	UCM (€/MWh)
Austria	163
Belgium	195
Bulgaria	188
Croatia	178
Czech Republic	164
Denmark	178
Estonia	183
Finland	220
France	166
Germany	155
Greece	177
Hungary	189
Ireland	189
Italy	183
Latvia	181
Lithuania	179
Luxembourg	173
Netherlands	189
Poland	188
Portugal	189
Romania	176
Slovakia	195
Slovenia	175
Spain	162
Sweden	235
United Kingdom	175

Page 12

*** 18. Do you agree with this value?**

- yes
- no

19. Please justify your response.

*** 20. Do you think we should adjust the value above by:**

- Decreasing it
- Increasing it

*** 21. Decreasing it by:**

- ≤20%
- 20-50%
- 50-100%
- 100-200%
- 200-500%
- >500%

*** 22. Increasing it by:**

- ≤20%
- 20-50%
- 50-100%
- 100-200%
- 200-500%
- >500%

23. How should this value be changed if an early warning of 4 hours in advance of the disruption has been provided?

Appendix 28 Questionnaire to the Services Sector

Questionnaire addressed to Services Sectors using natural gas.

Thank you for agreeing to participate. It will only take a few minutes to complete. All of your answers are private and confidential.

Page 1

Welcome to this survey looking into the Cost of Gas Disruption (CoDG) in the Services sectors in Europe.

The survey is addressed to small, medium (SMEs) and larger enterprises active in the commercial sector, to social service providers (healthcare, social care), primary and secondary education and universities, public administration and security and emergency services using natural gas for their everyday activities.

The survey is carried out by KANTOR MANAGEMENT CONSULTANTS (KMC), Greece and Economic Consulting Associates (ECA), UK in the context of the project entitled "STUDY ON THE ESTIMATION OF THE COST OF DISRUPTION OF GAS SUPPLY IN EUROPE", commissioned by the Agency for the Cooperation of Energy Regulators (ACER).

Achieving and maintaining an adequate level of security of natural gas supply (SoS) is one of the goals the EU energy policy. An increased level of SoS can be achieved through the development of new gas infrastructure. New infrastructure can provide additional capacity and/or link Member States to new sources and markets. However, efficient gas infrastructure development entails that costs should not exceed benefits, including the benefit from an increased value of SoS. A uniform disruption cost has been quantified by the European Network of Transmission System Operators for Gas (ENTSOG) and is applied to estimate the benefits of new proposed infrastructure.

However, applying a uniform value across all customer categories and Member States may not represent adequately the actual Cost of Gas Disruption (CoDG).

In the context of this survey we seek to understand if indeed there is a potential dependence of the CoDG by country and categories of consumers and if further patterns defined by the duration of the disruption, and the way in which a prior notice (e.g. 24 hours ahead of the disruption) may impact the cost of disruption.

Your contribution is greatly valued towards the development of cost-effective new gas infrastructure and the efficient management of gas supply disruptions.

Please address any questions you may have concerning this questionnaire to Ms Katerina Leividioti (kgl@kantor-group.eu) and Mr Kostas Lymperis (kcl@kantor-group.eu).

We would be grateful for your responses by 30 June.

Page 2

Part 1 General Information

*** 1. Name**

Additional options (question 1)
- Validation: string length

*** 2. Department**

Additional options (question 2)
- Validation: string length

*** 3. Company**

Additional options (question 3)
- Validation: string length

*** 4. Address**

Additional options (question 4)

› Validation: string length

* 5. Email

Additional options (question 5)
› Validation: email address

* 6. Please specify your activity.

	Small/Medium Enterprise	Large Commercial Enterprise	Healthcare/ social care	primary and secondary education	university	Public administration	security and emergency services
activity	○	○	○	○	○	○	○

* 7. Please specify where do you use natural gas.

- space heating
- water heating
- steam production
- space cooling
- cooking
- Other, please specify

- Go to **page 3** if
  7. Please specify where do you use natural gas.
  is *steam production*
- **Else go to page 4**

Page 3

* 8. How steam is produced?

- in a CHP plant
- by boilers

Page 4

* 9. At which EU Member States is/are your activity/activities located?

- Germany
- United Kingdom
- Spain
- Romania
- Belgium
- Portugal
- Hungary
- Austria
- Denmark
- Slovakia
- Croatia
- Slovenia
- Estonia
- Luxembourg
- France
- Italy
- Poland
- Netherlands
- Greece
- Czech Republic
- Sweden
- Bulgaria
- Finland
- Ireland
- Lithuania
- Latvia
- Cyprus
- Malta

* 10. Is there a gas demand scheme in you country that you participate in?

- yes
- no

- Go to **page 5** if
  10. Is there a gas demand scheme in you country that you participate in?
  is *yes*
- **Else go to page 7**

Page 5

11. **Please provide information on this scheme.**

* **12. Have you signed a gas supply agreement that includes a provision for you to be voluntarily interrupted and be compensated for such an interruption?**

yes

no

- Go to **page 6** if
  12. Have you signed a gas supply agreement that includes a provision for you to be voluntarily interrupted and be compensated for such an interruption?...
  is *yes*
- **Else go to page 7**

Page 6

13. **Please provide more information.**

Page 7

Part 2 Understanding the granularity of disruptions

In this section we seek to understand if your natural gas consumption varies with seasons (winter vs summer) and weekdays vs weekends and if there is a variation by time of day.

* **14. On a scale of 1 to 5, with 5 corresponding to a 100% disruption in gas supply and 0 to no disruption, how would you evaluate the severity of gas supply curtailments. By this question we seek to establish if your dependence on natural gas is linear or if there is a curtailment level above which natural gas related services are completely halted as in the case of a full disruption.**

	1	2	3	4	5
Level of curtailment: ≤20% of maximum daily demand (MDD) for a certain year Severity					
Level of curtailment: >20% but ≤40% of MDD Severity					
Level of curtailment: >40% but ≤60% of MDD Severity					
Level of curtailment: >60% but ≤80% of MDD Severity					
Level of curtailment: >80% of MDD Severity					

* **15. What is your dependence on natural gas during the year?**

Month	Dependence on natural gas (%) 0-20%	20-40%	40-60%	60-80%	80-100%
January					
February					
March					
April					

May	◯	◯	◯	◯	◯
June	◯	◯	◯	◯	◯
July	◯	◯	◯	◯	◯
August	◯	◯	◯	◯	◯
September	◯	◯	◯	◯	◯
October	◯	◯	◯	◯	◯
November	◯	◯	◯	◯	◯
December	◯	◯	◯	◯	◯

*** 16. In the months you are most dependent on natural gas, is your gas demand independent of time in the day?**

◯ yes ◯ no

- Go to **page 8** if
  16. In the months you are most dependent on natural gas, is your gas demand independent of time in the day?...
  is *no*
- **Else go to page 9**

Page 8

*** 17. When do you use natural gas mostly (day and time of week)?**

From 06:00 to 10:00

	Low	Medium	High
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

*** 18. From 10:00 to 16:00**

	Low	Medium	High
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

*** 19. From 16:00 to 23:00**

	Low	Medium	High
Monday	◯	◯	◯
Tuesday	◯	◯	◯

	Low	Medium	High
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

* **20. From 23:00 to 06:00**

	Low	Medium	High
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

Page 9

Part 3 Switching capabilities

In this section we seek to understand better what type of alternative options you are employing in the case of a gas supply disruption. Please respond to the questions in this section if you maintain boilers, CHP units or other appliances that have fuel switching capabilities.

* **21. Which of your appliances have fuel switching capabilities?**

- Boilers
- CHP units
- Cooking appliances
- Other, please specify
- None of the above

* **22. What is the type of alternative fuel you may use in case of a gas disruption?**

- LFO
- LPG
- CNG
- electricity
- Other, please specify
- no alternative

- Go to **page 10** if
  21. Which of your appliances have fuel switching capabilities?
  is not *None of the above*
  and
  22. What is the type of alternative fuel you may use in case of a gas disruption?
  is not *electricity*
- **Else go to page 14**

Page 10

* **23. To help us understand the quantity of the fuel that you keep in storage please indicate approximately for how long your appliance can run at full load on alternative fuel that you already have in storage.**

- 1 day
- 2 days
- 3-5 days
- 5-10 days

>10 days

* 24. Do you know the proportion of the operating cost per annum for maintaining fuel switching facilities?

yes

no

- Go to **page 11** if
  24. Do you know the proportion of the operating cost per annum for maintaining fuel switching facilities?...
  is *yes*
- **Else go to page 12**

Page 11

* 25. Please let us know the proportion of the operating cost per annum for maintaining fuel switching facilities? In your response do not include the cost of the alternative fuel (e.g. alternative fuel replacement fired during a planned maintenance procedure in your response).

1-5%

5-10%

10-15%

>15%

Page 12

* 26. What is the proportion of the operating cost for replacing alternative fuel fired during a planned maintenance (not due to fuel switching because of a disruption)?

1-5%

5-10%

10-15%

>15%

* 27Did you reach a decision to install dual fuel capabilities after a gas supply interruption?

yes

no

- Go to **page 13** if
  27. Did you reach a decision to install dual fuel capabilities after a gas supply interruption?
  is *yes*
- **Else go to page 14**

Page 13

* 28. Please state the year of installation of the alternative equipment.

Additional options (question 28)

› Validation: integer

Page 14

* 29. We are developing a methodology for the calculation of the Cost of Gas Disruption (CoDG). We have introduced a parameter which we named Unit Cost Measurement (UCM) and upon conditions (e.g. the granularity assessed in Part 2 of this questionnaire) can be considered as equal to the CoDG. The UCM is the sum of capital (UCM_{CAPEX}) and operating costs (UCM_{OPEX}). The capital cost relates to the additional cost of installing dual fuel equipment (e.g. an air conditioning appliance in addition to a natural gas boiler or a dual fired natural gas/LPG stove for cooking). We calculate a UCM_{CAPEX} as:

UCM_{CAPEX} [€/MWh] = CAPEX [€/MWh] / (utilization [%] × 8760 [h] × lifetime)

The value corresponding to the operational costs UCM_{OPEX} equals to the product of 1 MWh of alternative fuel multiplied by the difference between the average price of alternative fuel during the past 12 months and the average price of gas in the Member State.
Do you agree with this approach?

yes

no

30. Can you suggest improvements and if so in which direction?

From the methodology outlined previously we have estimated UCM (EUR/MWh), shown in the table below per type of activity.

Countries	UCM (€/MWh)								
	Healthcare	Education	Emergency	Security	Essential Social Care	Public Administration	Commercial	Retail Store	Private Office
Austria	77	96	78	78	77	90	78	111	108
Belgium	139	142	142	142	139	163	141	196	195
Bulgaria	51	83	53	53	51	55	52	57	54
Croatia	74	98	76	76	74	84	75	95	92
Czech Republic	54	80	55	55	54	64	55	77	75
Denmark	134	139	136	136	134	154	135	183	183
Estonia	68	93	69	69	68	78	70	89	87
Finland	114	131	116	116	114	125	116	133	134
France	67	90	70	70	67	78	68	92	92
Germany	145	143	147	147	146	169	145	207	206
Greece	98	115	100	100	98	111	99	129	126
Hungary	79	103	80	80	79	85	80	89	87
Ireland	107	121	109	109	84	126	108	153	149
Italy	105	120	108	108	105	119	106	138	137
Latvia	79	101	81	81	79	91	80	105	103
Lithuania	54	83	57	57	54	60	54	66	64
Luxembourg	92	109	94	94	92	106	93	127	124
Netherlands	53	82	55	55	53	62	54	70	69
Poland	70	97	72	72	70	80	71	89	85
Portugal	93	111	95	95	93	108	94	127	125
Romania	81	103	83	83	81	89	82	97	96
Slovakia	72	98	74	74	72	82	73	90	88
Slovenia	70	94	71	71	70	79	71	91	88
Spain	96	110	98	98	96	113	97	138	136
Sweden	40	75	44	44	40	56	42	65	64
United Kingdom	91	108	93	93	91	106	92	127	125

*** 31. Are the values above representative of the cost of gas disruption for your activity?**

- yes
- no

32. Please justify your response.

*** 33. Do you think we should adjust the values above by:**

- Decreasing them
- Increasing them

*** 34. Decreasing them by:**

- ≤ 20%
- 20-50%
- 50-100%
- 100-200%

*** 35. Increasing them by:**

- ≤ 20%
- 20-50%
- 50-100%
- 100-200%

36. How should these values be changed if an early warning has been provided?

Appendix 29 Questionnaire to the Industrial Sector

Questionnaire addressed to Industrial and Power Sectors using natural gas in the production process or as a fuel.

Thank you for agreeing to participate. All of your answers are private and confidential.

Page 1

Welcome to this survey looking into the Cost of Gas Disruption (CoDG) in Industrial and gas fired power sectors in Europe.

The survey is carried out by KANTOR MANAGEMENT CONSULTANTS (KMC), Greece and Economic Consulting Associates (ECA), UK in the context of the project entitled "STUDY ON THE ESTIMATION OF THE COST OF DISRUPTION OF GAS SUPPLY IN EUROPE", commissioned by the Agency for the Cooperation of Energy Regulators (ACER).

Achieving and maintaining an adequate level of security of natural gas supply (SoS) is one of the goals the EU energy policy. An increased level of SoS can be achieved through the development of new transmission, storage and/or LNG infrastructure. New infrastructure can provide additional capacity and/or link Member States to new sources and markets. However, efficient gas infrastructure development entails that costs should not exceed benefits, including the benefit from an increased value of SoS. ENTSOG has quantified the monetary impact of a disruption in the context of the Cost-Benefit Analysis methodology (CBA) and in the Ten-Year Network Development plan (TYNDP) of 2017 by considering a uniform Value of Lost Load (VoLL). The VoLL is fixed at EUR 600/MWh for the complete time horizon of any new proposed project and corresponds to a division of the total EU28 GDP by the gross inland gas consumption in EU28.

In the context of the ongoing revision of the CBA methodology it is useful to see if this value can be further refined so as to define a Cost of Disruption of gas supply (CoDG) by country and categories of consumers and if further patterns defined by the level of involuntary curtailment (1-100%) for industrial consumers, the duration of the involuntary curtailment/disruption, and the way in which a prior notice (e.g. 24 hours ahead of the disruption) may impact the cost of disruption.

Estimations of the value of SoS are also necessary when gas supplies to non-protected customers (generally industrial gas consumers) located in one or more Member States have to be curtailed in order to reallocate gas to protected customers (generally residential gas consumers) located in a neighbouring Member State in the context of the solidarity mechanism introduced by the new Security of Supply (SoS) Regulation (EU 2017/1938).

To derive a commonly accepted methodology for estimating the cost of gas disruption in the context of a revised CBA methodology and to guide Member States towards a commonly accepted procedure for determining the cost of solidarity gas, it is important for the Agency to understand the implications faced by the industrial and power sectors in the case of an involuntary disruption in their gas supply.

Your contribution is greatly valued towards the development of cost-effective new gas infrastructure and the efficient management of gas supply disruptions.

Please address any questions you may have concerning this questionnaire to Ms Katerina Leividioti (kgl@kantor-group.eu) and Mr Kostas Lymperis (kcl@kantor-group.eu).

We really need the input of the European industrial and power sector and thus we decided to extend the deadline for this questionnaire to the 30th June.

All responses to this questionnaire are treated as confidential and the names of the participants will not be disclosed.

Page 2

Part 1 General Information

*** 1. Name**

*** 2. Department**

*** 3. Company**

*** 4. Address**

*** 5. E-mail**

Additional options (question 5)

› Validation:

Page 3

* 6. At which EU Member State(s) are the power production and/or industrial facilities of your company located (multiple responses possible)?

- Germany
- France
- United Kingdom
- Italy
- Spain
- Poland
- Romania
- Netherlands
- Belgium
- Greece
- Portugal
- Czech Republic
- Hungary
- Sweden
- Austria
- Bulgaria
- Denmark
- Finland
- Slovakia
- Ireland
- Croatia
- Lithuania
- Slovenia
- Latvia
- Estonia
- Cyprus
- Luxembourg
- Malta

Page 4

* 7. Please specify the sector(s) of your activity (multiple responses possible).

- Iron & steel industry
- Chemical and Petrochemical industry
- Non-ferrous metal industry
- Non-metallic Minerals (Glass, pottery & building mat. Industry)
- Transport Equipment
- Machinery
- Mining and Quarrying
- Food and Tobacco
- Paper, Pulp and Print
- Wood and Wood Products
- Construction
- Textile and Leather
- Other, please specify

* 8. Do you use natural gas as a feedstock, as a fuel or both (multiple responses possible)?

- Natural gas used as a feedstock
- Natural gas used as a fuel

Go to **page 5** if

8. * Do you use natural gas as a feedstock, as a fuel or both (multiple responses possible)?

is *Natural gas used as a fuel*

- **Else go to page 6**

Page 5

* 9.Please help us understand the type of equipment where you burn natural gas.

- boiler
- CHP unit
- Other, please specify

* 10. What is the power range (MW) of your natural gas firing equipment (aggregated over all equipment)?

- <0.5
- 0.5-1
- 1-5
- 5-10
- 10-50
- 50-100
- 100-250
- 250-500
- >500

* 11. What are the requirements in natural gas as a fuel for your processes as a percentage of your overall fuel consumption?

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
requirements in natural gas as a fuel										

12. How old should your fuel firing equipment be before you replace it?

Additional options (question 15)
- Validation: decimal number

Page 6

Part 2 Understanding the granularity of disruptions

In this section we seek to understand if your natural gas consumption varies with seasons (winter vs summer) and weekdays vs weekends and if there is a variation by time of day. We would like to know if an early warning on a potential future disruption alleviates its implications (cost and/or technical), how "early" should this warning be provided, and by approximately how much do the disruption implications increase with the duration of disruption. We would also like to know if curtailments in gas supply can be sustained and if so at what level.

Page 7

* 13.Approximately what percentage of the output of your activity (as a% of activity without a disruption) can be continued in the event of 100% loss of gas supply depending on the disruption duration (h)?

Duration of disruption [h] Level of production maintained following a 100% gas disruption [%]

	0-10%	10-20%	20-40%	40-60%	60-80%	80-100%
2-4h						
4-8h						
8-16h						
16-24h						
24-48h						
48-96h						

14. Please tell us what actions and measures you will be undertaking to maintain your activity at the levels you indicated in the above table (if larger than 0).

* 15. Will your response be different if you received an early warning?

yes no

- Go to **page 8** if
  15. Will your response be different if you received an early warning?
  is *yes*
- **Else go to page 9**

Page 8

* 16.How early would you need to receive a warning to be able to continue your activity at levels over 60% for a disruption of up to 8 hours? Will your response change for a disruption of over 24 hours? Please fill in the Table below.

Duration of disruption [h] **Early warning ahead of the disruption [h]**

	2h	4h	8h	24h	>24h
8h					
24h					

Page 9

17. Does a natural gas disruption, without an early warning, have technical implications to your activity (e.g. abrupt shutdown causing faults in machinery and/or intermediate products)? Please explain.

* 18.Approximately what percentage of the output of your activity can be continued in the event of a 70% curtailment of hourly gas deliveries under normal operation depending on the disruption duration (h)? Please fill in the Table below.

Duration of disruption [h] **Level of production maintained following a 70% gas disruption [%]**

	0-10%	10-20%	20-40%	40-60%	60-80%	80-100%
2-4h						
4-8h						
8-16h						
16-24h						
24-48h						
48-96h						

* 19.Approximately what percentage of the output of your activity can be continued in the event of a 30% curtailment of hourly gas deliveries under normal operation depending on the disruption duration (h)? Please fill in the Table below.

Duration of disruption [h] **Level of production maintained following a 30% gas disruption [%]**

	0-10%	10-20%	20-40%	40-60%	60-80%	80-100%
2-4h						
4-8h						
8-16h						
16-24h						
24-48h						
48-96h						

*** 20.Please tell us about the months when you are most dependent on natural gas (for the production process - not for the heating offices or other service related uses).**

Months	Dependence on natural gas (%)				
	0-20%	20-40%	40-60%	60-80%	80-100%
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					

*** 21. In the months you are most dependent on natural gas, is your gas demand independent of time in day?**

yes

n

- Go to **page 10** if
  21. In the months you are most dependent on natural gas, is your gas demand independent of time in day?...
  is *no*
- **Else go to page 11**

Page 10

*** 22. When do you use natural gas mostly (day and time of week)?**

From 06:00 to 10:00

	Low	Medium	High
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

*** 23. From 10:00 to to 16:00**

	Low	Medium	High
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

*** 24. From 16:00 to to 23:00**

	Low	Medium	High
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

*** 25. From 23:00 to to 06:00**

	Low	Medium	High
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

Page 11

*** 26.To address gas disruptions, some EU Members have in place a voluntary gas demand reduction schedule. Is such a demand side measure in place in your country?**

◯ yes ◯ no

- Go to **page 12** if
  26. o address gas disruptions, some EU Members have in place a voluntary gas demand reduction schedule. Is such a demand side measure in place in your country?...
  is *yes*
- **Else go to page 15**

Page 12

* 27. Do you participate in such a demand side measure?

yes

no

- Go to **page 13** if
  27. Do you participate in such a demand side measure?
  is *yes*
- **Else go to page 15**

Page 13

28. Please describe the terms and conditions.

* 29. Are you compensated if you are disrupted?

yes

no

- Go to **page 14** if
  29. Are you compensated if you are disrupted?
  is *yes*
- **Else go to page 15**

Page 14

30. Please describe the methodology for estimating the compensation level.

31. Please provide the compensation level (EUR/MWh).

Page 15

Part 3 Natural gas as a fuel

In this section we seek to understand if your facilities have fuel switching capabilities and if so what is the operating cost for maintaining such facilities. A main scope of this study is the development of a methodology for the estimation of the Cost of Gas Disruption. Here we ask for our views on the methodology we are developing so that we can further refine and improve it.

Page 16

* 32.Do your facilities have fuel switching capabilities?

yes

no

- Go to **page 17** if
  32. *Do your facilities have fuel switching capabilities?*
  is *yes*
- **Else go to page 19**

Page 17

* 33. What is the level of alternative fuel that you maintain in storage (as a multiple of peak day consumption)?

1 day

2 days

3-5 days

5-10 days

>10 days

* 34.What is the type of alternative fuel that you may use in case of a disruption?

- LFO
- LPG
- CNG
- Other, please specify

* 35.What is the proportion of the operating cost per annum for maintaining fuel switching facilities? In your response please do not include the cost of the alternative fuel (e.g. alternative fuel replacement fired during a planned maintenance procedure).

- 1-5%
- 5-10%
- 10-15%
- >15%

36. Please justify your response in the above question.

* 37.What is the proportion of the operating cost for replacing alternative fuel fired during a planned maintenance (not due to fuel switching because of a disruption)?

- 1-5%
- 5-10%
- 10-15%
- >15%

* 38. Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?

- yes
- no

- Go to **page 18** if
  38. Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?
  is *yes*
- **Else go to page 19**

Page 18

* 39.Please state the year of installation of the alternative fuel facility .

Additional options (question 42)

› Validation: integer

Page 19

* 40. Is natural gas used as a fuel continuously (e.g. 24 hours per day, 350 days a year with 15 days reserved for planned and unplanned maintenance)?

- yes
- no

- Go to **page 20** if
  40. Is natural gas used as a fuel continuously (e.g. 24 hours per day, 350 days a year with 15 days reserved for planned and unplanned maintenance)?...
  is *no*
- **Else go to page 21**

Page 20

*** 41. What is the per annum average utilization of your natural gas firing equipment (percentages correspond to production at full load)?**

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	>80%
annual average utilization									

Page 21

We are developing a methodology for the calculation of the Cost of Gas Disruption (CoDG). We have introduced a parameter which we named Unit Cost Measurement (UCM) and upon conditions (e.g. the granularity assessed in Part 1 of this questionnaire) can be considered as equal to the CoDG. The UCM is the sum of capital (UCM_{CAPEX}) and operating costs (UCM_{OPEX}). The capital cost relates to the cost of installing dual fuel equipment (e.g. dual fuel burner, alternative fuel storage tanks, other auxiliary equipment and controls). We calculate a UCM_{CAPEX} as:

UCM_{CAPEX}[€/MWh] = CAPEX [€/MW]∕(utilisation[%]×H×lifetime)

The value corresponding to the operational costs UCM_{OPEX} equals to the product of 1 MWh of alternative fuel multiplied by the difference between the average price of alternative fuel during the past 12 months and the average price of gas in the Member State. The latter (gas price) can be the price of long-term gas supply contracts (in countries without a liquid market and a trading hub) or the price of the yearly gas future contract (in countries with access to hubs).

*** 42. Do you agree with this approach?**

- yes
- no

43. Can you suggest improvements and if so in which direction?

From the methodology outlined previously we have estimated a UCM (EUR/MWh) for industrial facilities.

Natural Gas as Fuel				
Countries	Continuous UCM (€/MWh)		Intermittent UCM (€/MWh)	
	oil fired boiler	electric boiler	oil fired boiler	electric boiler
Austria	7	66	8	73
Belgium	8	94	9	99
Bulgaria	15	57	15	59
Croatia	22	86	23	90
Czech Republic	9	45	10	45
Denmark	43	57	45	65
Estonia	3	84	4	88
Finland	31	26	32	32
France	18	73	19	80
Germany	16	127	17	133
Greece	14	83	15	87
Hungary	12	66	13	69
Ireland	14	96	15	102
Italy	13	125	14	129
Latvia	4	95	5	100
Lithuania	6	63	7	67
Luxembourg	13	51	14	57
Netherlands	51	33	33	60
Poland	10	64	11	68
Portugal	28	90	29	93
Romania	11	78	12	80
Slovakia	19	90	20	94
Slovenia	21	52	22	56
Spain	7	81	8	85
Sweden	36	31	38	39
United Kingdom	8	108	9	115

44.Do you think that these values are realistic?

- yes
- no

45. Please justify your response.

46. Do you think we should adjust the UCM by:

- Decreasing it
- Increasing it

47. Decreasing it by:

- ≤20%
- 20-50%
- 50-100%
- 100-200%
- 200-500%
- >500%

48. Increasing it by:

- ≤20%
- 20-50%
- 50-100%
- 100-200%
- 200-500%
- >500%

Page 23

Part 4 Natural gas as a feedstock

In this section we seek to understand if it is possible to modify the production chain order and if it is possible to substitute natural gas by another substance. Once more we will be asking here for your views on the methodology we are developing for the estimation of the CoDG so that we can further refine and improve it.

Page 24

49. Is it possible to limit the production loss by changing the production chain order?

- yes
- no

50. Please justify your response by listing related actions (e.g. keeping intermediary products requiring gas as a feedstock in storage, producing other intermediary products).

* 51. Is it possible to substitute natural gas by another substance in your production chain? Please indicate the material used for substitution.

- hydrogen
- LPG
- Other, please specify
- Substitution is not possible

* 52. Is your facility able to apply feedstock substitution?

- yes
- no

Page 25

Show page if
49. Is it possible to limit the production loss by changing the production chain order?
is *yes*
and
52. Is your facility able to apply feedstock substitution?
is *yes*

* 53.What portion of the peak day gas demand can be met by substitution or changes in the production chain during a 24-hour gas disruption?

Output of activity continued [as a% of activity without a disruption]

	0-10%	10-20%	20-40%	40-60%	60-80%	80-100%
With prior notice						
Without prior notice						

Page 26

Show page if
52. *Is your facility able to apply feedstock substitution?*
is *yes*

* 54. What is the level of alternative feedstock that you maintain?

	1 day	2 days	3-5 days	5-10 days	>10 days
Peak day consumption					

* 55 What is the proportion of the operating cost per annum for maintaining alternative feedstock (Do not include the cost of the feedstock in your response)?

	1-5%	5-10%	10-15%	>15%
proportion of annual operating cost				

56. Please justify your response in the above questions.

Page 27

* 57.To estimate the Cost of Gas Disruption in the industrial sectors for gas used as a feedstock, we define a Unit Cost Measurement (UCM) as equal to the ratio of the Gross Value Added to the fuel consumption by industrial sector (both as reported by Eurostat).
Do you agree with this approach?

- yes
- no

58. Can you suggest any improvements and if so in which direction?

Page 28

From the methodology outlined previously we have estimated a UCM for industrial sectors for gas used as a feedstock.

These values have been calculated using Eurostat 2017 reported values for 2016.

Natural Gas as Feedstock	
Countries	**UCM (€/MWh)**
Austria	613
Belgium	419
Bulgaria	307
Croatia	533
Czech Republic	546
Denmark	1326
Estonia	624
Finland	266
France	698
Germany	1023
Greece	498
Hungary	448
Ireland	3002
Italy	861
Latvia	336
Lithuania	623
Luxembourg	445
Netherlands	461
Poland	556
Portugal	551
Romania	527
Slovakia	372
Slovenia	626
Spain	751
Sweden	563
United Kingdom	990

59. **Do you think that the UCM as shown can form a base for the CoDG?**

- yes
- no

60. **Please justify your response.**

61. **Do you think we should adjust the UCM by:**

- Decreasing it
- Increasing it

62. **Decreasing it by:**

- ≤20%
- 20-50%
- 50-100%
- 100-200%
- 200-500%
- >500%

63. **Increasing it by:**

- ≤20%
- 20-50%
- 50-100%
- 100-200%
- 200-500%
- >500%

Appendix 30 Questionnaire to the Power Sector

Questionnaire addressed to Industrial and Power Sectors using natural gas in the production process or as a fuel.

Thank you for agreeing to participate. All of your answers are private and confidential.

Page 1

Welcome to this survey looking into the Cost of Gas Disruption (CoDG) in Industrial and gas fired power sectors in Europe.

The survey is carried out by KANTOR MANAGEMENT CONSULTANTS (KMC), Greece and Economic Consulting Associates (ECA), UK in the context of the project entitled "STUDY ON THE ESTIMATION OF THE COST OF DISRUPTION OF GAS SUPPLY IN EUROPE", commissioned by the Agency for the Cooperation of Energy Regulators (ACER).

Achieving and maintaining an adequate level of security of natural gas supply (SoS) is one of the goals the EU energy policy. An increased level of SoS can be achieved through the development of new transmission, storage and/or LNG infrastructure. New infrastructure can provide additional capacity and/or link Member States to new sources and markets. However, efficient gas infrastructure development entails that costs should not exceed benefits, including the benefit from an increased value of SoS. ENTSOG has quantified the monetary impact of a disruption in the context of the Cost-Benefit Analysis methodology (CBA) and in the Ten-Year Network Development plan (TYNDP) of 2017 by considering a uniform Value of Lost Load (VoLL). The VoLL is fixed at EUR 600/MWh for the complete time horizon of any new proposed project and corresponds to a division of the total EU28 GDP by the gross inland gas consumption in EU28.

In the context of the ongoing revision of the CBA methodology it is useful to see if this value can be further refined so as to define a Cost of Disruption of gas supply (CoDG) by country and categories of consumers and if further patterns defined by the level of involuntary curtailment (1-100%) for industrial consumers, the duration of the involuntary curtailment/disruption, and the way in which a prior notice (e.g. 24 hours ahead of the disruption) may impact the cost of disruption.

Estimations of the value of SoS are also necessary when gas supplies to non-protected customers (generally industrial gas consumers) located in one or more Member States have to be curtailed in order to reallocate gas to protected customers (generally residential gas consumers) located in a neighbouring Member State in the context of the solidarity mechanism introduced by the new Security of Supply (SoS) Regulation (EU 2017/1938).

To derive a commonly accepted methodology for estimating the cost of gas disruption in the context of a revised CBA methodology and to guide Member States towards a commonly accepted procedure for determining the cost of solidarity gas, it is important for the Agency to understand the implications faced by the industrial and power sectors in the case of an involuntary disruption in their gas supply.

Your contribution is greatly valued towards the development of cost-effective new gas infrastructure and the efficient management of gas supply disruptions.

Please address any questions you may have concerning this questionnaire to Ms Katerina Leividioti (kgl@kantor-group.eu) and Mr Kostas Lymperis (kcl@kantor-group.eu).

We really need the input of the European industrial and power sector and thus we decided to extend the deadline for this questionnaire to the 30th June.

All responses to this questionnaire are treated as confidential and the names of the participants will not be disclosed.

Page 2

Part 1 General Information

*** 1. Name**

*** 2. Department**

*** 3. Company**

*** 4. Address**

*** 5. E-mail**

Additional options (question 5)

› Validation:

Page 3

* 6. **Please let us know if you produce electricity to cover own needs or if you are also active in the power market (multiple responses possible).**

- electricity production solely for own needs
- active in the power market

Page 4

* 7. **At which EU Member State(s) are the power production and/or industrial facilities of your company located (multiple responses possible)?**

- Germany
- France
- United Kingdom
- Italy
- Spain
- Poland
- Romania
- Netherlands
- Belgium
- Greece
- Portugal
- Czech Republic
- Hungary
- Sweden
- Austria
- Bulgaria
- Denmark
- Finland
- Slovakia
- Ireland
- Croatia
- Lithuania
- Slovenia
- Latvia
- Estonia
- Cyprus
- Luxembourg
- Malta

* 8. **Please provide further information on gas usage as a fuel in the power sector (multiple responses possible).**

- Natural gas fired in Combined Cycle Gas Turbines
- Natural gas fired in open cycle gas turbines
- Natural gas fired in CHPs
- Other, please specify

Page 5

Part 2 Understanding the granularity of disruptions

In this section we seek to understand if your natural gas consumption varies with seasons (winter vs summer) and weekdays vs weekends and if there is a variation by time of day. We would like to know if an early warning on a potential future disruption alleviates its implications (cost and/or technical), how "early" should this warning be provided, and by approximately how much do the disruption implications increase with the duration of disruption. We would also like to know if curtailments in gas supply can be sustained and if so at what level.

Page 6

* 9. **Approximately what percentage of the output of your activity (as a% of activity without a disruption) can be continued in the event of a 100% loss of gas supply depending on the disruption duration (h)?**

Duration of disruption [h] **Level of production maintained following a 100% gas disruption [%]**

	0-10%	10-20%	20-40%	40-60%	60-80%	80-100%
2-4h						
4-8h						
8-16h						
16-24h						
24-48h						
48-96h						

10. Please tell us what actions and measures you will be undertaking to maintain your activity at the levels you indicated in the above table (if larger than 0).

* 11. Will your response be different if you received an early warning?

yes no

- Go to **page 7** if
  11. Will your response be different if you received an early warning?
  is *yes*
- **Else go to page 8**

Page 7

* 12.How early would you need to receive a warning to be able to continue your activity at levels over 60% for a disruption of up to 8 hours? Will your response change for a disruption of over 24 hours? Please fill in the Table below.

Duration of disruption [h] **Early warning ahead of the disruption [h]**

	2h	4h	8h	24h	>24h
8h					
24h					

Page 8

13. Does a natural gas disruption, without an early warning, have technical implications to your activity (e.g. abrupt shutdown causing faults in machinery and/or intermediate products)? Please explain.

* 14.Approximately what percentage of the output of your activity can be continued in the event of a 70% curtailment of hourly gas deliveries under normal operation depending on the disruption duration (h)? Please fill in the Table below.

Duration of disruption [h] **Level of production maintained following a 70% gas disruption [%]**

	0-10%	10-20%	20-40%	40-60%	60-80%	80-100%
2-4h						
4-8h						
8-16h						
16-24h						
24-48h						
48-96h						

* 15.Approximately what percentage of the output of your activity can be continued in the event of a 30% curtailment of hourly gas deliveries under normal operation depending on the disruption duration (h)? Please fill in the Table below.

Duration of disruption [h] **Level of production maintained following a 30% gas disruption [%]**

	0-10%	10-20%	20-40%	40-60%	60-80%	80-100%
2-4h						
4-8h						
8-16h						
16-24h						
24-48h						
48-96h						

* 16.Please tell us about the months when you are most dependent on natural gas (for the production process - not for the heating offices or other service related uses).

Months	Dependence on natural gas (%)				
	0-20%	20-40%	40-60%	60-80%	80-100%
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					

* 17.In the months you are most dependent on natural gas, is your gas demand independent of time in day?

yes no

- Go to **page 9** if
  17. In the months you are most dependent on natural gas, is your gas demand independent of time in day?...
  is *no*
- **Else go to page 10**

Page 9

* 18.When do you use natural gas mostly (day and time of week)?

From 06:00 to 10:00

	Low	Medium	High
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

*** 19. From 10:00 to to 16:00**

	Low	Medium	High
Monday	○	○	○
Tuesday	○	○	○
Wednesday	○	○	○
Thursday	○	○	○
Friday	○	○	○
Saturday	○	○	○
Sunday	○	○	○

*** 20. From 16:00 to to 23:00**

	Low	Medium	High
Monday	○	○	○
Tuesday	○	○	○
Wednesday	○	○	○
Thursday	○	○	○
Friday	○	○	○
Saturday	○	○	○
Sunday	○	○	○

*** 21.From 23:00 to to 06:00**

	Low	Medium	High
Monday	○	○	○
Tuesday	○	○	○
Wednesday	○	○	○
Thursday	○	○	○
Friday	○	○	○
Saturday	○	○	○
Sunday	○	○	○

Page 10

Part 3 Natural gas as a fuel

In this section we seek to understand if your facilities have fuel switching capabilities and if so what is the operating cost for maintaining such facilities. A main scope of this study is the development of a methodology for the estimation of the Cost of Gas Disruption. Here we ask for our views on the methodology we are developing so that we can further refine and improve it.

Page 11

*** 22. Do your facilities have fuel switching capabilities?**

- yes
- no

- Go to **page 12** if
  22. Do your facilities have fuel switching capabilities?
  is *yes*
- **Else go to page 14**

Page 12

*** 23. What is the level of alternative fuel that you maintain in storage (as a multiple of peak day consumption)?**

- 1 day
- 2 days
- 3-5 days
- 5-10 days
- >10 days

*** 24. What is the type of alternative fuel that you may use in case of a disruption?**

- LFO
- LPG
- CNG
- Other, please specify

*** 25.What is the proportion of the operating cost per annum for maintaining fuel switching facilities? In your response please do not include the cost of the alternative fuel (e.g. alternative fuel replacement fired during a planned maintenance procedure).**

- 1-5%
- 5-10%
- 10-15%
- >15%

26. Please justify your response in the above question.

*** 27.What is the proportion of the operating cost for replacing alternative fuel fired during a planned maintenance (not due to fuel switching because of a disruption)?**

- 1-5%
- 5-10%
- 10-15%
- >15%

*** 28.Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?**

- yes
- no

- Go to **page 13** if
  28. Did you reach a decision of installing dual fuel capabilities after a gas supply interruption?
  is *yes*
- **Else go to page 14**

Page 13

* 29.Please state the year of installation of the alternative fuel facility .

Page 14

* 30.Is natural gas used as a fuel continuously (e.g. 24 hours per day, 350 days a year with 15 days reserved for planned and unplanned maintenance)?

○ yes ○ no

- Go to **page 15** if
  30. Is natural gas used as a fuel continuously (e.g. 24 hours per day, 350 days a year with 15 days reserved for planned and unplanned maintenance)?...
  is *no*
- **Else go to page 16**

Page 15

* 31. What is the per annum average utilization of your natural gas firing equipment (percentages correspond to production at full load)?

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	>80%
annual average utilization	○	○	○	○	○	○	○	○	○

Page 16

* 32.Is there a scheme in place for the compensation of power plants for maintaining dual fuel facilities and operation on alternative fuel?

○ yes ○ no

- Go to **page 17** if
  32. Is there a scheme in place for the compensation of power plants for maintaining dual fuel facilities and operation on alternative fuel?
  is *yes*
- **Else go to page 18**

Page 17

33. Please provide information on the methodology for estimating the level of compensation.

34 Please provide the compensation level [EUR/MWh]

Page 18

We are developing a methodology for the calculation of the Cost of Gas Disruption (CoDG). We have introduced a parameter which we named Unit Cost Measurement (UCM) and upon conditions (e.g. the granularity assessed in Part 1 of this questionnaire) can be considered as equal to the CoDG. The UCM is the sum of capital (UCM_{CAPEX}) and operating costs (UCM_{OPEX}). The capital cost relates to the cost of installing dual fuel equipment (e.g. dual fuel burner, alternative fuel storage tanks, other auxiliary equipment and controls). We calculate a UCM_{CAPEX} as:

UCM_{CAPEX}[€/MWh] = CAPEX [€/MW]∕(utilisation[%]×H×lifetime)

The value corresponding to the operational costs UCM_{OPEX} equals to the product of 1 MWh of alternative fuel multiplied by the difference between the average price of alternative fuel during the past 12 months and the average price of gas in the Member State. The latter (gas price) can be the price of long-term gas supply contracts (in countries without a liquid market and a trading hub) or the price of the yearly gas future contract (in countries with access to hubs).

*** 35. Do you agree with this approach?**

- yes
- no

36. Can you suggest improvements and if so in which direction?

Page 19

*** 37.From the methodology outlined above we have estimated a UCM equal to 89 eur/MWh.**

Do you think that this value is realistic?

- yes
- no

38. Please justify your response.

*** 39. Do you think we should adjust the UCM by:**

- Decreasing it
- Increasing it

*** 40. Decreasing it by:**

- ≤20%
- 20-50%
- 50-100%
- 100-200%
- 200-500%
- >500%

*** 41. Increasing it by:**

- ≤20%
- 20-50%
- 50-100%
- 100-200%
- 200-500%
- >500%