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Study on recommendable updates and improvements of the ENTSOG methodology for cost-benefit analysis of gas infrastructures

Final report

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LOGO

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Executive summary

Regulation (EU) No 347/2013 (the Regulation) sets out the guidelines for the identification, analysis and selection of socio-economic beneficiary energy infrastructure projects called Projects of Common Interest (PCI). To become a PCI and benefit from the Regulation and the Connecting Europe Facility, candidates to the PCI status must provide a cost-benefit analysis in compliance with methodologies developed by the European Networks of the Transmission System Operators for electricity (ENTSO-E) and for gas (ENTSOG). Those Energy System-Wide Cost-Benefit Analysis (ESW-CBA) methodologies are themselves framed by the Regulation, which specify the objectives to achieve and level of detail that the methodologies should incorporate.

The European Commission launched this study to review the first version of the ESW-CBA methodology for gas projects. The methodology was published by ENTSOG in 2015 and was used for the adoption of the Ten-Year Network Development Plan 2017 as well as the adoption of the first and second PCI Union lists. The study concludes that the methodology has significant potential for improvement at both regulatory and economic levels. The methodology is too simplistic in its modelling and monetisation assumptions and lacks sufficient level of transparency. This limits its ability to provide sound and unbiased outputs which is needed for the defined decision processes, such as PCI selection, CBCA decisions and evaluation of co-financing requests.

The study has identified a series of necessary improvements to cope with the methodological shortfalls. They were designed in collaboration with the key stakeholders and substantiated through a public survey. Special attention was given to the relevance of proposed improvements from an economic viewpoint and to their ability to serve decision-makers. An according update to the methodology will ensure more accurate, reliable and useful output that can be used more directly by decision-makers, while striking a practical balance between the methodology's accuracy and the cost of its implementation.

The final report entails fourteen recommendations. They are sorted by order of priority to guide ENTSOG towards the most efficient way of implementing them. They are also grouped into four key areas, corresponding to the key issues identified with the methodology:

- **The modelling assumptions and model transparency**: the market model needs to be adjusted to better reflect actual gas flows. ENTSOGs model is significantly weaker than other commercially available gas market models, and lacks important elements e.g. infrastructure tariffs' impact on flows or strategic behaviour. Increased transparency and guidance in applying the CBA results are also necessary.
- **Choice, measure and delivery of outputs**: outputs should be made more manageable for the users of the methodology to reduce the risk of bias and to produce a more robust and accurate analysis. In particular, stakeholders should be able to better perceive the uncertainty of the methodology's outputs to balance them in their own analysis.
- **Monetisation**: a partial and targeted monetisation will enable a sharper focus on the most important indicators, which will help reach more reliable decisions. Updating efforts should also focus on currently inaccurate monetisation assumptions, as is the case for the monetisation of disrupted demand and CO2 emissions.
- **Alignment with the needs and purposes of decision-makers**: the methodology should do more to meet decision-makers' expectations, beyond monetisation and modelling issues. New processes should be implemented to make the methodology fit-for-purpose. In particular, the identification of complementary and competing projects and the verification of PCI input data should be improved.

Executive summary (French)

Le règlement (UE) N° 347/2013 (le Règlement) définit les lignes directrices pour l'identification, l'analyse et la sélection de projets d'infrastructure énergétique transeuropéens appelés Projets d'Intérêt Commun (PIC). Pour devenir un PIC et bénéficier des dispositions du Règlement et du Connecting Europe Facility, les projets candidats doivent fournir une analyse coûts-avantages conforme aux méthodologies développées par les Réseaux Européens des Gestionnaires de Réseaux de Transport pour le Gaz (ENTSOG) et l'Electricité (ENTSO-E). Ces méthodologies d'analyse des coûts et avantages pour l'ensemble du système énergétique sont elles-mêmes encadrées par le Règlement, qui spécifie leurs objectifs et le niveau de détail à atteindre.

La Commission européenne a lancé cette étude pour examiner la première version de la méthodologie d'analyse coûts-avantages pour les projets gaziers. La méthodologie a été publiée par l'ENTSOG en 2015 et a été utilisée pour l'adoption du plan décennal de développement du réseau 2017 et des deux premières listes de PIC. L'étude a conclu que la méthodologie pouvait être améliorée significativement aux niveaux régulatoire et économique. La méthodologie est notamment trop simpliste dans ses hypothèses de modélisation et de monétisation et elle manque de transparence. Cela limite la capacité des décideurs à réaliser des choix pertinents et impartiaux lors des procédures pour la sélection des PIC, des décisions d'allocation des coûts, et des requêtes pour co-financement.

L'étude a permis d'identifier une série d'améliorations nécessaires adressant les insuffisances de la méthodologie. Ils ont été conçus en collaboration avec les principales parties prenantes et ont été corroborés par une enquête publique des acteurs du secteur. Une attention particulière a été accordée à la pertinence économique des améliorations proposées et à leur utilité pour les décideurs. La mise à jour de la méthodologie garantira alors aux décideurs des résultats plus précis, plus fiables et plus utiles, tout en établissant un meilleur arbitrage entre la précision et le coût de mise en œuvre des améliorations proposées.

Le rapport final comporte quatorze recommandations. Elles sont classées par ordre de priorité afin de mieux guider l'ENTSOG dans ses contraintes de mise en œuvre. Elles sont également groupées selon les quatre principaux problèmes identifiés:

- **Les hypothèses de modélisation et la transparence du modèle** : le modèle de marché doit être ajusté pour mieux refléter les flux gaziers. Le modèle de l'ENTSOG est bien plus fragile que d'autres modèles de marché gazier disponibles dans la littérature, y compris ceux traitant du comportement stratégique des acteurs. Une transparence accrue est également souhaitée.
- **Choix, mesure et interprétation des résultats de l'analyse** : les résultats devraient être plus faciles à gérer pour les utilisateurs de la méthodologie, permettant ainsi une analyse plus précise et objective. En particulier, les parties prenantes devraient pouvoir mieux capter l'incertitude inhérente aux résultats afin de l'intégrer dans leurs propres analyses.
- **Monétisation** : une monétisation partielle et ciblée permettra de se concentrer sur les indicateurs les plus pertinents et qui ont le plus d'impact sur les décisions finales. Il conviendra aussi de corriger les hypothèses imprécises de monétisation, s'agissant par exemple de l'interruption de la demande et des émissions de CO_2.
- **Alignement avec les besoins et les objectifs des décideurs** : la méthodologie devrait mieux répondre aux attentes des décideurs, au-delà des problèmes de monétisation et de modélisation. La méthodologie devrait ainsi être mieux adaptée pour répondre à leurs interrogations s'agissant de la complémentarité entre projets ou de la vérification des inputs à l'analyse coût-avantage.

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Glossary

ACER	Agency for the Cooperation of Energy Regulators
ACER GITF	ACER Gas Infrastructure Taskforce
CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CBCA	Cross-Border Cost Allocation
CEER	Council of European Energy Regulators
CEF	Connecting Europe Facility
CoDU	Cost of Disruption per Unit of energy
EC	European Commission
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
ESW-CBA	Energy System-Wide Cost-Benefit Analysis
ETS	Emissions Trade System
EU28	The 28 Member States of the European Union (as of 30 June 2017)
HHI	Herfindahl-Hirschmann Index
LNG	Liquefied Natural Gas
LRMC	Long-Run Marginal Cost
NRA	National Regulatory Authority
PCI	Project of Common Interest
PS	Project-Specific
SCC	Social Cost of Carbon
SME	Small and Medium Enterprises
SRMC	Short-Run Marginal Cost
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
US	United States of America
VoLL	Value of Lost Load
WTA	Willingness To Accept
WTP	Willingness To Pay

1 Introduction and main results

1.1 Context of the study

Trans-European gas infrastructure is one of the key sectors for which the European Union has provided specific regulation aiming at the reinforcement of the gas energy infrastructure with the aim to improve market integration, security of gas supply and enhancing diversification.

To this end, Regulation (EU) No 347/2013 (the Regulation) sets out the guidelines for the identification, analysis and selection of socio-economic beneficiary energy infrastructure projects called Projects of Common Interest (PCI), which benefit from regulatory and financial measures of the Regulation and the Connecting Europe Facility.

The Regulation requires that the European Networks of the Transmission System Operators (ENTSOs) for electricity (ENTSO-E) and for gas (ENTSOG) develop methodologies for an energy system-wide cost-benefit analysis (ESW-CBA) and for a project-specific analysis, both for the preparation of the Ten Year Network Development Plans (TYNDP) and the selection of PCIs. The methodologies shall be reviewed by the European Commission and the Agency for Cooperation of Energy Regulators (ACER) based on the Regulation, before they are approved by the European Commission.

The methodologies have multiple applications: they shall be applied for the preparation of TYNDP, and their outputs shall be used as a basis for the PCI selection process, cross-border cost allocation (CBCA) for eligible projects, and decisions about Union financial assistance under the Connecting Europe Facility.

The first version of the gas CBA methodologies were published by ENTSOG in 2015 and served as the basis for the adoption of the first and second PCI Union list. As the Regulation stipulates regular updates of the methodologies, this first experience has enabled the identification of paths for improvement. ENTSOG has therefore initiated an update of their methodologies.

This study analyses the existing methodologies and gives recommendations for the imminent update as well as for future updates (roadmap of improvements). This study intends to help ENTSOG to further improve their methodologies, as well as to provide the European Commission, ACER and members of the Regional Groups with information about existing shortfalls and recommendable improvements in the methodologies.

1.2 Objectives and approach

In this context, in September 2016 the European Commission launched a study to better identify the limits of the current CBA methodology for gas projects and the possibilities for improvement. Microeconomix, in collaboration with the Florence School of Regulation (part of the European University Institute), was thus mandated by the European Commission to identify recommendable improvements to the present ENTSOG methodology that would make it more suitable for the preparation of TYNDP, the PCI selection and CBCA processes.

The study was based on a consistent review of the 2015 methodology and of the voluntary improvements since proposed by ENTSOG[1]. It consisted of an in-depth analysis of the methodology with regard to the Regulation, the key economic principles and the features recommended in the theoretical and empirical economic literature on CBA. Extensive discussions were held with ENTSOG and the ACER gas infrastructure taskforce (GITF) to grasp the main issues and the viability of the envisaged improvements. The preliminary results of the review and a preliminary list of related improvements were also tested directly among stakeholders and decision-makers through a webinar and a survey which took place in March 2017.

[1] In particular, those implemented for TYNDP 2017 and for the third PCI selection process.

The present report features the final version of recommendations which derived from the initial review and the reactions received during the survey. Those recommendations were discussed with ACER GITF, and their key characteristics have already been recognised by ENTSOG, as its own consultation report on the update (May to June 2017) shows. The level of detail given in this report for each of them (regarding practical implementation, feasibility or literature review) is aimed at guiding ENTSOG in any future updates and improvements.

NB: The report and the recommendations were based on the review of the 2015 CBA methodology and ENTSOG's voluntary improvements up to 30 June 2017 (and the consultation report). They do not take into account any new feature or proposal published after this date. In case of any misalignment between the update of the methodology as proposed by ENTSOG and the present recommendations, the authors advise the European Commission and ACER to justify their appraisal by relying extensively on this report.

1.3 Identification of the key principles with which the gas CBA methodology should comply

As specified by the Regulation, the ESW-CBA methodology's primary aim is to support the realisation of TYNDPs, by providing a global assessment of the impacts of all projects and identifying future technical bottlenecks and opportunities. The gas modelling developed through the CBA methodology is a unique opportunity to improve the current TYNDP and to deliver useful and accurate data for all TYNDP users: project promoters and NRAs, but also investors in the gas industry.

The methodology is also supposed to guide decision-makers in their analysis of PCI candidates and PCIs. In particular, the outputs of the CBA process are intended to facilitate the PCI selection process for both project promoters and Regional Groups, by providing them with replicable methodologies and accurate and relevant results. The CBA outputs in terms of costs and benefits should enable (i) Regional Groups to finalise their assessment and decisions for ranking and selecting PCIs, and (ii) regulatory authorities (NRAs or ACER) to analyse investment requests (including CBCA).

In other words, the main purpose of the CBA methodology should be to deliver relevant and accurate information that can be used directly by decision-makers. This can be achieved by complying as much as possible with a series of key principles, which reflect the recommendations of the economic literature on CBA as well as the expectations of actual stakeholders and decision-makers. These are summarised in the following table.

Table 1. Key principles for the elaboration of the gas ESW-CBA methodology

A transparent, robust and opposable modelling tool	• The modelling should deliver a comprehensive and realistic representation of the gas markets, focusing not only on the networks' technical features but also on the representation of flow patterns, congestion and competition. • It should be based on opposable and transparent assumptions. Project promoters and regulatory authorities should be able to use and design consistent modelling tools which are coherent with the ESW-CBA modelling.
Measurement of all impacts of infrastructure projects	• The ESW-CBA is considered a socio-economic evaluation of the projects' impacts, implying that the scope of costs and benefits be as large as possible. These should encompass society as a whole as well as the right level of detail concerning their distribution within the value chain and within countries. • Evaluated benefits should include externalities and consider the categories highlighted in the Regulation: market integration, security of supply, competition and sustainability.
Targeted monetisation of the impacts	• The easiest way for decision-makers to compare costs and benefits is to use the same yardstick, which in economics is money. This can be complex for some indicators: it requires more or less complex modelling tools, and it involves putting a price on physical quantities whose value may by nature rely on assumptions that are not always easy to determine. • Monetisation should therefore be targeted at the most suited indicators: the impacts which can accurately and realistically be assessed through the modelling tool, and those which would induce the biggest risk of a decision reversal, were they not monetised.
Integration of uncertainties	• Decision-makers should be able to assess the reliability of the ESW-CBA methodology outputs and balance them against other sources of information and tools that they might use. Uncertainty and sensitivity analyses are thus mandatory. • Ideally, the assessment of projects through multiple scenarios should be replaced or complemented by a probability analysis.
Standardised, relevant and analysable output sets	• The outputs should be easy to analyse and extrapolate with no room for uncertainty. Their delivery should be standardised and made practical with adjustments where necessary to ensure comprehensibility. • Over-detailed and over-prescriptive output lists should be avoided in particular. A project fiche summarising the main CBA results is a good compromise.
Arbitrage between accuracy and computational complexity	• The right balance has to be struck between the achievement of the methodology's objectives and the incurred cost. • Theoretically powerful modelling and monetisation tools are not always necessary: the level of accuracy and detail that they achieve will not necessarily affect the decision process.

1.4 Proposed framework to improve the methodology

The framework for improvement proposed in this report derives from the review of the 2015 methodology from an economic and regulatory viewpoint. The review showed that the current methodology is inadequate in this regard. It is not transparent enough and too simplistic in its modelling and monetisation assumptions. This limits its ability to provide sound and unbiased outputs that are useful to decision-makers.

The final set of recommendations was established to cope with the flaws in the methodology. The recommendations were designed from an economic viewpoint, based on CBA methodology key principles, and relied on the Regulation to ensure full coherence. Special attention was paid to the comments received during the survey and to issues of relevance, feasibility, allocation of responsibility and timing. As such, the new set of recommendations looks to anticipate any issues that ENTSOG and decision-makers might encounter.

Fourteen recommendations are presented below to cover the main issues of the 2015 methodology. They are grouped into four key areas of improvement:

- **Key area #1: the modelling assumptions and model transparency**
  Market modelling is too simple and cannot assess all relevant issues. The assumptions should be adjusted or changed based on the analysis of the many examples of gas market models that are commercially available, including models that capture strategic behaviour. Increased transparency and guidance in applying the CBA results are also necessary.
  - Recommendation (1A): make urgent modelling adjustments to the model based on realistic assumptions regarding demand behaviour and gas infrastructure tariffs
  - Recommendation (1B): further refine the realistic modelling of gas flows by incorporating commercial constraints (e.g. long-term contracts) into the modelling
  - Recommendation (1C): improve the transparency by facilitating the understanding and the appropriation of the model by other stakeholders
  - Recommendation (1D): enable the modelling to simulate situations of market power and strategic behaviour

- **Key area #2: choice, measure and output delivery**
  The outputs should be more manageable for the users of the methodology to reduce the risk of bias and to produce a more robust and accurate analysis. This requires looking more closely at the relevance of each scenario and indicator and compiling an improved list of scenarios and indicators before running the simulations. The methodology should also tackle its limitations in terms of sensitivity analysis. Stakeholders should be able to better perceive the uncertainty of the methodology’s outputs to balance them in their own analysis.
  - Recommendation (2A): reduce the number of indicators by focusing on those which are most relevant to decision-makers and project promoters
  - Recommendation (2B): select the most relevant future scenarios and configurations, and provide a guideline for the selection of those key scenarios
  - Recommendation (2C): conduct a sensitivity analysis for the most critical parameters
  - Recommendation (2D): perform a more sophisticated probability analysis as part of the simulations and calculation of outputs

- **Key area #3: targeted monetisation and improvement of the quality of monetisation**
  This study argues for a partial and targeted monetisation. It enables a sharper focus on the most important indicators, whose monetisation will ensure more reliable decisions.

Guidance on the multi-criteria analysis is also necessary, as some of the indicators will remain quantitative/qualitative. In any case, efforts should be focused on the indicators which are already monetised, but whose assumptions have been proven inaccurate and/or not robust.

  - Recommendation (3A): identify and prepare indicators for monetisation, by focusing on those which would best support the decision processes and whose monetisation is economically robust
  - Recommendation (3B): improve monetisation of security of supply by carrying out a thorough study of the cost of disrupted demand
  - Recommendation (3C): improve monetisation of CO2 impacts, and in particular the proxy used as the CO2 price, instead preferring the social cost of carbon

- **Key area #4: alignment with the needs and purposes of decision-makers**
  The first three areas of improvement only focus on issues related to modelling and cost-benefit analysis *per se*: they are not enough to fix the methodology's difficulty of meeting decision-makers' expectations. The methodology should be improved to be fit-for-purpose.
  - Recommendation (4A): formalise the project fiche for output interpretation and display, and make it more practical
  - Recommendation (4B): enable the identification of clusters and competing projects, by proposing guidance and objective methods
  - Recommendation (4C): ensure the verification of PCI input data, as the current set was assessed as incomplete and unreliable by decision-makers

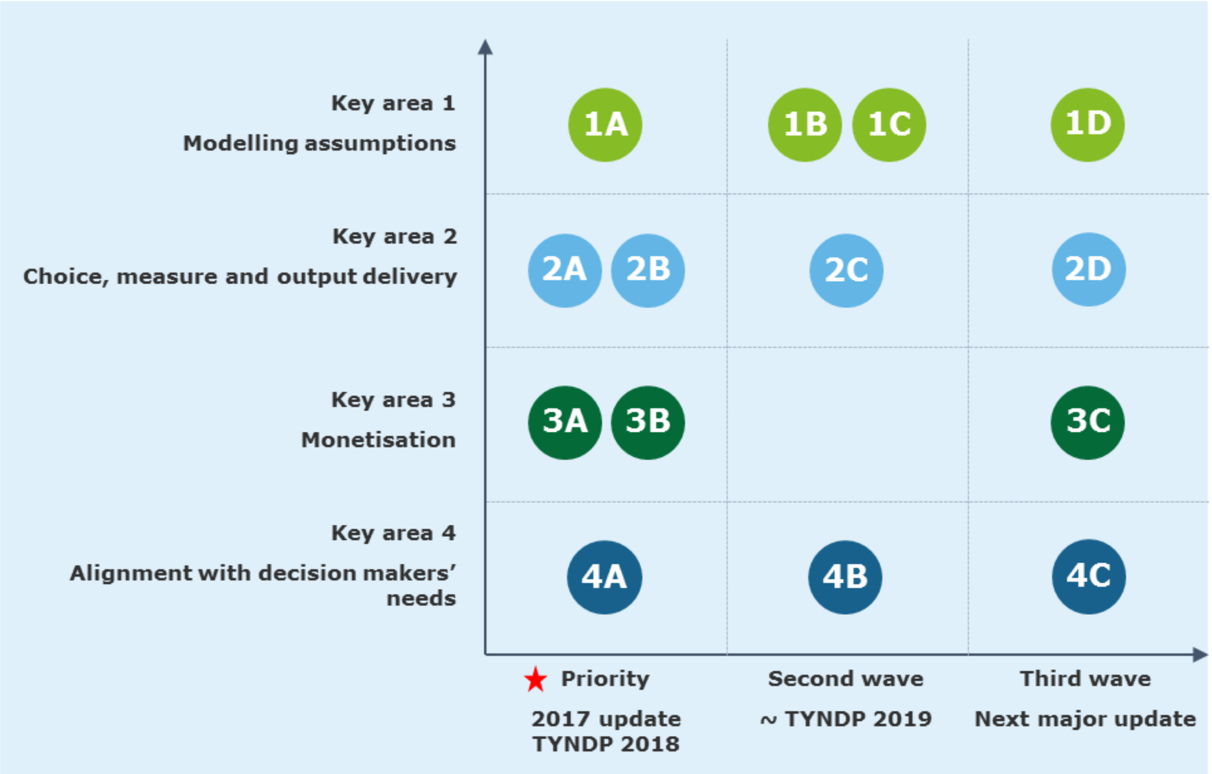
Those recommendations are grouped by order of priority (see table 2 hereafter), in order to guide ENTSOG toward the most coherent and efficient way of implementing the improvements:

- **Six priority recommendations are identified as urgent**, to be dealt with within the next year. A 2017 update is necessary for these improvements to have an effect on the preparation of TYNDP 2018 and the fourth PCI selection process.

- **Four recommendations are classified as part of a second wave**. They are important but should be realised after the priority recommendations. Some improvements will only be relevant if other parts of the methodology have already been improved and stabilised, and may take more time to be implemented.

- **Four recommendations are classified as part of a third wave of improvements**. They are to be postponed to a later date. They are not meant to solve the most critical issues observed in the 2015 methodology, but should be performed as soon as possible.

Table 2. Classification of proposed recommendations



1A ★	**Priority modelling adjustments**: recalibrate the modelling tool to simulate market behaviour, by improving demand assumptions and by modelling gas flows according to infrastructure and CB tariffs
1B	**Modelling of commercial characteristics**: go further into realistic gas flows modelling
1C	**Model transparency**: a single document gathering all information OR making the model accessible to all
1D	**Modelling of market power**: add a new layer to the market modelling to simulate market power impacts
2A ★	**Reduction of the number of indicators**: fewer, uncorrelated and well-defined indicators, following a critical review of the 2015 methodology's indicators and of the actual needs of Regional Groups
2B ★	**Selection of relevant future cases**: identification and highlighting of the most likely cases through a consultation process with decision makers. A maximum of three scenarios per study year
2C	**Extension of sensitivity analysis**: extension of the analysis to all critical parameters and better display of uncertainty factors
2D	**Probability analysis**: determine ex-ante density functions representing the likelihood of each critical parameter (thus replacing scenarios) and perform Monte-Carlo simulations
3A ★	**Preparation of indicators for monetisation**: identify the list of indicators to be targeted for monetisation, by taking into account feasibility, relevance and risk of double-counting
3B ★	**Monetisation of security of supply**: improve the monetisation assumptions through an in-depth study on the assessment of the cost of disruption per unit of energy in Europe
3C	**Improve monetisation of CO2 emissions' impact**: replace the CO2 price by the social cost of carbon
4A ★	**New project fiche**: continue to improve the proposed project fiche with new features
4B	**Enable the identification of clusters and competing projects**: guidance for stricter grouping rules of investment items, and better identification of competing projects through objective criteria list
4C	**Verification of PCI input data**: consistency check with national development plans, reference unit costs and other reference inputs. A minimum level of details should be expected from decision makers

1.5 How the framework for improvement addresses the shortcomings of the 2015 methodology

The recommendations to improve the ESW-CBA methodology were designed in order to address the shortcomings observed in the 2015 methodology, both at an economic and regulatory level. The following table highlights the numerous shortcomings which were identified and confirmed during the survey stage.

Table 3. Shortcomings of the 2015 gas ESW-CBA methodology

Limited accuracy of the methodology's modelling	• The current model is too simple and can only simulate the physical capabilities of the gas network interconnection points. • It does not ensure the reliable and realistic forecast of the market parameters: level of demand, substitution between gas and other energies, modelling of actual flows, formation of price, cross-border tariffs…
Unsatisfactory approach to monetisation	• The proposed set of benefit indicators is under-monetised: only two (or optionally three) of the indicators are assigned monetary values. • Distribution of benefits between countries is based on arbitrary assumptions • The quality of monetisation is put in doubt. In particular, if monetised, security of supply benefits are likely to be over-estimated (and with a bias, uniform assumption on unit cost of disruption) while CO2 emission benefits are likely to be under-estimated.
Overdetailed and over-prescriptive output series	• The unfiltered outputs return thousands of data points, many of which will be irrelevant because they do not address the needs of a specific Regional Group or stakeholder. There is also the risk of interdependencies and double counting between indicators. • Users of the methodology may not be able to process and balance the unfiltered outputs. Their decision processes may be biased and non-harmonised, leading to distorted and contradictory decisions.
Shortcomings compared to decision-makers' expectations	• The muddled delivery of the CBA outputs does not enable Regional Groups and other decision-makers to interpret them based on rational and bias-proof criteria, forcing them to envisage unstable and non-standardised reviews. • The methodology does not go far enough with regard to the verification and publication of project-specific data, such as investment costs or development and commissioning details. • The methods of identifying competing or complementary projects are too simple.
Limited stakeholder responsibility	• ENTSOG is responsible for modelling, data collection and validation, and monetisation techniques, but these tasks still show a lack of involvement from ENTSOG. This could be due to an issue of perception regarding their responsibility or their technical abilities.. • The lines of responsibility and task allocation between ENTSOG and the other stakeholders are not sufficiently enforced. Decision-makers should be encouraged to do more to help at both input and output level but lack guidance.
Justification, transparency and comparability are not enabled	• Assumptions for modelling and monetisation are under-justified and under-communicated. • The 2015 methodology does not go far enough in enabling all decision-makers to replicate the model and to combine comparable outputs from different tools.

2 Description of the framework to improve the CBA methodology

The review of the 2015 gas ESW-CBA methodology was commissioned by the European Commission to guide its discussions on a methodology update with ENTSOG and ACER. It consisted in identifying the methodology's capabilities and limitations, both economic and regulatory, before proposing recommendations to address these limitations. To this end, a consistent analysis was performed. It involved the review of the theoretical and empirical economic literature on CBA as well as the survey of other stakeholders and decision-makers on their perception of the 2015 methodology. The review relied on the involvement of ACER[2]. The review is not presented in the main body of the report but all details are available in Appendix A (section 4), including the current methodology's scientific and regulatory shortcomings.

The preliminary results of this review and a preliminary list of related recommendations were tested among stakeholders and decision-makers through a consultation report, published on 1 March 2017. The aim of this consultation was to gather feedback and additional ideas for the update of the CBA methodology. A related webinar took place on 10 March 2017 with more than sixty participants. Following these events, the study team received nine series of comments on the consultation survey, comprising two TSOs, two non-TSO project promoters, one NRA, one institution, one consultancy group, ENTSOG and the ACER GITF (see Appendix C – Replies to the survey on preliminary recommendations). The survey played an important part in collecting comments on the validity and extent of the proposals. The first draft of proposed improvements was well received by stakeholders, as all agreed on the principles of the recommendations. The survey helped identify the most important and urgent improvements, as well as the need for them to be practical and reasonable. ENTSOG also responded positively to the suggested improvements and proactively added them to its own consultation which took place from May to June 2017.

The two following sections focus on the outcome of the review and of the survey and present the finalised framework for improvement. Subsections 2.1 recapitulates the key economic principles which served to establish the list of recommendations. Subsections 2.2 and 3.1 to 3.4 describe the framework for improvement and the details for each recommendation.

2.1 Insight on the framework of a cost-benefit analysis applied to gas infrastructure projects

2.1.1 Objectives of the CBA methodology

The Regulation, the survey among stakeholders and the literature review on cost-benefit analysis enables to define more precisely the main objectives of the gas ESW CBA methodology. These are:

- To support the realisation of TYNDPs by providing a global assessment of the impacts of all projects and identifying future technical bottlenecks and opportunities. The gas modelling developed for the CBA methodology will provide useful and accurate data for all TYNDP users. In addition, any relevant data on costs and benefits of existing and future gas projects (including, but not limited to PCIs) should be included to improve TYNDP's transparency and significance in guiding future investments.

[2] See in particular: Agency's opinion No 06/2017 on TYNDP 2017, No 11/2015 on TYNDP 2015, No 4/2014 on gas CBA; Agency's Opinion, No 15/2015 on the draft regional lists of proposed gas PCIs 2015; the Agency's Energy Infrastructure Package Position Paper; the Agency's Opinion No 07/2017 on the interlinked electricity and gas network and market model; the Agency's Recommendations No 07/2013 and 05/2015 on investment request and cross-border cost allocation

- To guide decision-makers in their analysis of PCI candidates. The output of the ESW-CBA process is intended to facilitate the PCI selection process for Regional Groups, providing them with well-defined methodologies and accurate and relevant results. The outputs of the CBA in terms of costs and benefits should enable Regional Groups to finalise their decisions for ranking and selection of PCIs, ACER and NRAs. The results should also serve as a basis for analysis of investment requests and CBCA.

2.1.2 Key principles with which the ESW-CBA methodology should comply

The modelling and cost-benefit analysis of infrastructure projects are complex (see THINK 2013) as a result of the complexity of the European gas system. To be economically efficient, the ESW-CBA methodology should be designed and used based on several key principles, which will ensure its accuracy, stability, and capacity to satisfy/fulfil the main objectives. These principles are detailed hereafter.

A transparent, robust and opposable modelling tool

In short, the assessment of infrastructure projects requires the modelling of the entire European gas system and the comparison of several situations:

- On the one hand, counterfactuals where projects (one in particular, or several) have not been commissioned
- On the other hand, future scenarios where these new infrastructure projects are built and operational

To be useful to decision-makers, the modelling outputs should comply with their expectations in terms of comprehensiveness, accuracy and stability. The modelling should thus deliver a representative and realistic functioning of the gas markets, not only in terms of technical capabilities at cross-zonal boundaries but also in terms of flow patterns, congestion and competition assessments. This corresponds to the Regulation's objectives stating that the methodology should include both *"network and market modelling"* (Article 11 (3)). The economic literature shows that such models already exist and are used beyond the academic field (see Appendix 5.2). They represent a basic framework upon which the ESW-CBA methodology's model should be based.

This elaborate modelling should also be based on opposable and transparent assumptions, for the benefit of decision-makers[3]. The validation of the CBA methodology's outputs is crucial to ensuring that they can be trusted in the decision process. In particular, project promoters, Regional Groups and regulatory authorities should be able to develop other tools and decision-making processes that are comparable to the CBA outputs.

Measurement of all infrastructure project impact

Cost-benefit analysis means assessing the impact of a project in terms of its costs and benefits. These can differ according to the nature of the project purpose of the evaluation. Depending on the nature of the projects as well as the purpose of the evaluation, the expected level of details and the definition of those costs and benefits will not be the same.

In the case of the ESW-CBA methodologies, the cost-benefit analysis can be qualified as a socio-economic evaluation of the project's impacts on consumers, producers and shippers.

[3] In coherence with Annex V (3) of the Regulation: "*The methodology shall give guidance for the development and use of network and market modelling necessary for the cost-benefit analysis*".

This implies that the scope of costs and benefits is as large as possible and encompasses society as a whole, with the right level of detail concerning their distribution within the value chain (in particular between producers and consumers)[4]. Given the aims of the ESW-CBA methodology (as presented in the Regulation) and the expectations of European decision-makers, the scope should be limited to the benefits and costs for European stakeholders only[5].

This also implies that the benefits and costs are assessed at their full economic value. Externalities should in particular be integrated in the results, as they represent the share of costs (or benefits) not directly attached to stakeholders despite the causality of their actions. For example, the benefits of infrastructure projects in terms of security of supply, competition or environment should not be evaluated at their market value because the market prices for these categories might be distorted or even absent, as is the case for the valuation of demand disruption.

Based on the economic literature on (i) the impacts of gas infrastructure projects, (ii) the regulatory contents (see section 4.1.3) and (iii) recommendations by European decision-makers, the CBA should consider the following benefits:

- **Market integration**, which can be measured through the decrease in congestion, the price convergence and the increased flexibility enabled by the project. This is the most obvious benefit, which can mostly be measured directly by simulating the market behaviour of stakeholders in the new configuration and by assessing the new levels of gas prices. It delivers the change in socio-economic surplus for market players (consumers, producers, TSOs, shippers…).
- **Security of supply**, which can be measured through the reduction of the demand disruption risk and the general improvement of the gas systems' resilience and reliability. These benefits consist mostly of externalities, given that system security and disruption of demand cannot be evaluated through market prices.
- **Competition**, which corresponds to the benefits permitted by further diversification of gas sources, routes and counterparts. Economic literature shows that transmission constraints tend to accentuate the risk and the impact of market power, and those infrastructure projects, by relieving this tension, could enable a steep decrease in price even in cases with no gas flow. The benefits are (i) a welfare transfer from producers to consumers and (ii) the decrease in the deadweight loss caused by market power.
- **Sustainability**, which reduces greenhouse gas and conventional air pollutant emissions and contributes to renewable energy. These benefits are partly externalities, as CO2 emissions remain under-priced (see section 3.3.3) and the correlation between gas projects and renewable energy is not obvious.

Equally, the costs of the projects cannot be neglected. They are an essential part of the CBA and will eventually inform decision-makers about the justification and distributional impacts of PCIs.

Overall, the aggregation of all costs and benefits determines the so-called socio-economic value of a project. It normally encompasses all benefit categories, not limited to those which can be linked with market benefits or costs or which can be monetised (see hereafter).

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[4] This is coherent with the Regulation, as put in Annex V (13): *"the model shall allow for a full assessment of economic, social and environmental impacts, notably including external costs such as those related to greenhouse gas and conventional air pollutant emissions or security of supply".*

[5] This does not mean that third countries impacted by the projects should be excluded from the modelling, but only that the subsequent evaluation of costs and benefits will focus on Member States. This is coherent with the Regulation in Annex V:

(10) *"The area for the analysis of an individual project shall cover all Member States and third countries, on whose territory the project shall be built, all directly neighbouring Member States and all other Member States significantly impacted by the project."*

(11) *"The analysis shall identify the Member States on which the project has net positive impacts (beneficiaries) and those Member States on which the project has a net negative impact (cost bearers)."*

Targeted monetisation of the impacts

The relevance of the ESW-CBA methodology ultimately depends on decision-makers' ability to use and interpret its outputs. In particular, as one of its main purposes is to support the selection of PCIs, the decision-makers should be able to determine from the outputs whether the EU-wide benefits outweigh the costs. As for investment requests and CBCA decisions, they should also be able to allocate costs to the countries that are net beneficiaries (Annex V (11) of the Regulation).

The easiest way to compare benefits and costs is to measure them with the same yardstick: money. Ideally, expressing all indicators in monetary terms delivers a clear and unambiguous comparison of the costs and benefits[6]. Direct cost indicators can be monetised more easily thanks to CAPEX and OPEX estimates. However, the situation is more complex for externalities and benefits, which should relate to the criteria listed in Annex IV of the Regulation in terms of competition, market integration, security of supply and sustainability.

In theory, the benefits can be quantified and monetised through modelling, which throws up difficult questions regarding market power, shipper strategy, and details of demand and supply curve at national level. Monetisation also requires putting a price on physical quantities whose value is by nature variable or multiple and changes for each category of stakeholder. The monetisation of benefits is thus possible in theory, but is non-trivial.

Monetisation is often targeted at the most suitable benefit indicators, i.e. which can be assessed through a robust but normally dimensioned modelling tool. The monetisation effort should also encompass all the benefits where a biased perspective on their value could lead to inefficient outcome. Decision-makers could indeed be encouraged to give more weight to projects presenting benefits in terms of security of supply or competition, i.e. key pillars of the EU or regional energy policies. A monetised value for these benefit indicators would thus help reduce the risk of inefficient investment decisions.

Integration of uncertainties

Decision-makers should be able to assess the reliability of the ESW-CBA methodology outputs. This would enable them to balance the outputs against the other sources of information and tools involved in the selection processes (as well as other costs and benefits analyses for CBCA, business modelling and financial requests, etc.).

This requires the methodology to produce a thorough sensitivity analysis to test all relevant assumptions used in the modelling and the calculation and monetisation of outputs[7]. The CBA methodology, being a general exercise, will not be able to address project-specific risks, e.g. on the availability of financing or the presence of barriers to investments. Instead, uncertainty factors related to the CBA modelling should be identified and measured in order to determine a reasonable confidence interval.

Besides, as the modelling and the outputs involve the analysis of hundreds of different cases and scenarios (climatic, supply disruptions, project commissioning…, see section 3.2.2), the uncertainty regarding their occurrence should be correctly evaluated and highlighted. Results from these different scenarios could also be aggregated, e.g. through probability analysis, so that they could be used in subsequent decision-making steps.

[6] In alignment with Regulation in Annex V (4): *"The cost-benefit analysis shall be based on a harmonised evaluation of costs and benefits."*
[7] This also figures in the Regulation, in Annex V (11): *"Each cost-benefit analysis shall include sensitivity analyses concerning the input data set, the commissioning date of different projects in the same area of analysis and other relevant parameters."*

Standardised, relevant and analysable sets of outputs

As already mentioned, the relevance of the ESW-CBA methodology depends on the decision-makers' to interpret and use its outputs. Therefore, these outputs should be easy to analyse and extrapolate. The delivery of outputs and the guidance for their analysis will be standardised within the methodology, so that all decision-makers can follow and understand the project assessment. Ultimately, standardised delivery of CBA data in both form and content should then enable rational decision-making (Clinch, 2013).

This requires the output to be filtered and manageable upfront for decision-makers. While all sets of results can obviously be produced and included in the analysis, over-detailed and over-prescriptive output lists should be avoided in the main delivery to decision-makers. A project fiche summarising the main is advisable, as it enables a summary of the key data without forcing ENTSOG to filter the list of outputs itself (see section 3.4.1).

Arbitrage between accuracy and computational complexity

The right balance has to be struck between the achievement of the methodology's objectives and the incurred cost. Theoretically powerful tools for modelling or monetisation are not always useful in practice, as the level of accuracy and details they obtain will not necessarily affect the decision process.

2.2 Final framework for improvements to the ESW-CBA methodology

The following subsections present the final framework for improvements derived from the discussions with stakeholders and the response to the survey. Compared with the first set of proposed improvements, special attention was paid to making the improvement more reasonable and practical. Thus, section 2.2.1 presents the framework and the main criteria for the design and implementation of recommendations and related improvements. Section 2.2.2 summarises all proposed recommendations by focusing on practical questions and suggestions. A complete explanation for each recommendation is then provided in section 3.

2.2.1 Key criteria for the implementation of the improvements and the methodology update

The practical implementation of improvements requires anticipating any issues that ENTSOG and decision-makers may encounter. There is a key difference between a purely theoretical exercise and a more realistic one. In the former, a completely new methodology could be proposed, ignoring the political and technical constraints of European stakeholders. The latter, however, would take into account the current situation and improvement efforts.

Therefore, the new set of recommendations was established by carefully balancing the objectives and the requirements for each, and by taking into account the need for coordination between all stakeholders involved. More specifically:

- The improvements should (i) address the main economic and regulatory issues identified in the 2015 methodology (see Appendix A), (ii) seek to realign the methodology with its intended purposes in terms of PCI selection, CBCA and TYNDP elaboration, and (iii) aim to solve the simplistic modelling assumptions, the lack of monetisation, and the difficulty in filtering and using primary outputs without bias.

- The most urgent recommendations concern the 2017 update of the ESW-CBA methodology. They should be applicable for TYNDP 2018 and the PCI selection process of 2019. Other recommended improvements can take longer than a year to implement, and it is not advisable to run all improvements in parallel (see hereafter). Therefore, it is recommended to plan the roadmap for improvements in subsequent methodology updates as soon as possible.

- The benefits of the improvements should be weighed up against the costs of implementing them. Some improvements may be interesting from a scientific point of view but may be too complex to implement in practice. It is therefore necessary to assess the feasibility and practicality of the recommendations.

- The recommendations tackle the issues of responsibility and accountability. They look to increase collaboration between ENTSOG and other stakeholders in terms of data collection and verification, output selection, setting of criteria and agreement on key modelling assumptions. The recommendations aim to define the extent to which ENTSOG or the other decision-makers are accountable for the assumptions and the results they display and distribute.

- The improvements should be prioritised and grouped carefully. A focus on the most urgent improvements should be prioritised in order to make the methodology output more customer-focused. Furthermore, as the full value of some improvements only becomes apparent if they are preceded or accompanied by others, the recommendations should be coherent with each other. In carrying out the update(s), ENTSOG should not choose between the proposed recommendations but tackle them in the displayed order of priority.

- Finally, the recommendations always push for more transparency. This does not only involve improving transparency within the methodology. It also means ensuring that the implementation of the improvements is well documented and justified. In the case where an improvement cannot be carried out or is rejected, ENTSOG should be able to justify itself with the support of the economic literature. Lastly, transparency also includes guidance for decision-makers on how to use the results and where to expect shortfalls or uncertainties.

2.2.2 Key areas for improvement and proposal for a structure of recommendations

The recommendations detailed in section 3 cover the main issues identified in the 2015 methodology (see section 4.1.3 for more details). They are grouped according to priority and (referred to hereafter as 'key area'). The following paragraphs summarise the recommendations for each of the four key areas.

Key area #1: The modelling assumptions and transparency of the model

The recommendations aim to improve the market modelling, which is too simple and cannot assess all relevant issues. This means either adjusting or changing the modelling assumptions of the existing models. A complete overhaul and change of gas market model might be advisable to address all limitations at a time. ENTSOG can draw from the many examples of gas market models that are commercially available, including models that capture strategic behaviour[8]. Necessary improvements always involve more transparency and guidance for the parties applying the CBA results.

The recalibration of the model is essential to mitigate the risk of error while using the methodology's outputs. Some of the concerned improvements have to be prioritised, in turn helping improve the relevance and benefits of the other improvements.

Four recommendations are thus proposed and detailed in section 3.1. By order of priority, they are:

- (1.A) Make urgent adjustments to the model by making more realistic assumptions regarding demand behaviour (elasticity, substitution between gas and other energy sources) and gas infrastructure tariffs (cross-border transmission tariffs, LNG, storage, …). This priority aims to produce a more accurate simulation of gas flows and market behaviours. It will help orient the methodology away from being purely physical.
- (1.B) Further refine the realistic modelling of gas flows by incorporating commercial constraints (e.g., long-term contracts) into the modelling. This comes as a secondary improvement which could be postponed to the following update.
- (1.C) Improve transparency by facilitating the understanding and the appropriation of the model by other stakeholders and involve decision-makers in all steps of the model's implementation. This is also a secondary improvement.
- (1.D) Enable the modelling to simulate situations of market power and strategic behaviour. While the benefits of some infrastructure projects in terms of competition and market power mitigation cannot be denied, they only concern a few projects and thus do not justify a change of the overall methodology. However, this remains a current issue which could be tackled as part of a third wave of improvements.

[8] For more details, see section 5.2 in the appendices, on the literature review on gas market modelling.

Key area #2: Choice, measure and delivery of outputs

Another way to improve the methodology is to make the outputs user-friendly. This will reduce the risk of bias and non-harmonisation of the outputs' interpretation and will ensure a more robust and accurate analysis. This entails looking more closely at the relevance of each scenario and indicator before the simulations are run, instead of reacting ex-post by trying to synthesise data with the project fiche (see key area #4). Surveyed stakeholders insisted on the need to focus on a more meaningful and manageable list of indicators, which would also address the risk of double counting and interdependencies. The methodology should also tackle its limitations in terms of sensitivity analysis. Stakeholders should be able to easily identify uncertainty in the methodology's output and compare this with their own analysis.

Four recommendations are proposed and detailed in section 3.2. In order of priority, they are:

- (2.A) Reduce the number of indicators by focusing on the ones which are most relevant to decision-makers and project promoters, and address the risk of double counting. It is a priority improvement which will enhance the usability of results, thus increasing the relevance of the methodology.
- (2.B) Select the most relevant future scenarios and configurations which will be ultimately displayed in the project fiche, and provide a guideline for their selection. This is a priority improvement, which will help to make the interpretation of scenarios less biased.
- (2.C) Improve the analysis by conducting a sensitivity analysis for the most critical parameters
- (2.D) Perform a more sophisticated probability analysis as part of the simulations and output calculations. This secondary improvement will complement the previous ones.

Key area #3: Monetisation

Several measures responding to decision-makers' monetisation expectations are recommended. This study argues that a partial and targeted monetisation is the best solution to avoid too complex solutions while still ensuring better and more reliable decisions. This targeted monetisation should be complemented by an elaborated guidance on the multi-criteria analysis, as some of the indicators will remain quantitative/qualitative. In any case, efforts should be focused on the indicators that are already monetised but whose assumptions have been proven inaccurate and/or not robust.

Three recommendations are proposed and detailed in section 3.3. By order of priority, they are:

- (3.A) Identify and prepare indicators for monetisation by focusing on those which would support most the decision processes and whose monetisation is economically robust. This is a priority improvement.
- (3.B) Improve monetisation of security of supply. A thorough study of the cost of disrupted demand should be carried out; economic literature provides many practical examples to be used as reference. This is also a priority improvement.
- (3.C) Improve monetisation of CO2 impacts, and in particular the proxy used as the CO2 price, instead favouring the social cost of carbon. This is a third wave improvement, as the issue was not identified as critical by stakeholders and should only be addressed after more pressing issues.

Key area #4: Alignment with the needs and purpose of the decision-makers

The improvements in the first three key areas will facilitate the correct interpretation of results and increase decision-makers' trust in the methodology. These improvements focus mainly on the modelling and cost-benefit analysis assumptions. As a result, they do not fix the methodology's shortcomings with regard to decision-makers' expectations. However, the methodology will still be fit-for-purpose regardless of how responsibility is allocated.

Three recommendations are proposed and detailed in section 3.4. By order of priority, they are:

- (4.A) Formalise the project fiche for output interpretation and display, and make it more practical. This can be done by taking into account the ENTSO-E proposal, the comments on ENTSOG's own proposal and the recommendations from ACER. This is a priority recommendation that will enhance the outputs' interpretation.
- (4.B) Enable the identification of clusters and competing projects by proposing guidance and objective methods to compare PCI candidates and infrastructure projects. This is a second wave improvement.
- (4.C) Ensure the verification of PCI input data, as the current set was assessed as incomplete and unreliable by decision-makers. A consistency check with national development plans, reference unit costs and other reference inputs should be performed. This is a third wave improvement.

The following table classifies all improvements by theme and order of priority:

Table 4. Classification of proposed recommendations

	Priority improvements	Secondary wave	Third wave
Key area 1 Modelling assumptions	(1A) Priority modelling adjustment	(1B) Modelling of commercial constraints (1C) Model transparency	(1D) Modelling of market power
Key area 2 Choice, measure and delivery of outputs	(2A) Reduce number of indicators (2B) Select the most relevant future scenarios	(2C) Extended sensitivity analysis	(2D) Probability analysis
Key area 3 Monetisation	(3A) Sort out indicators for monetisation (3B) Correct monetisation of security of supply		(3C) Correct monetisation of CO2 impact
Key area 4 Alignment with decision-makers' needs	(4A) Formalise project fiche	(4B) Enable identification of clusters and competing projects	(4C) Ensure the verification of PCI input data

3 Final recommendations to improve the gas ESW-CBA methodology

3.1 Recommendations for key area #1: The modelling assumptions and model transparency

3.1.1 [1A] Priority modelling adjustments

NB: This is a priority improvement

ENTSOG's current model is based on the Jensen solver. It was adapted by ENTSOG to enable TYNDP analyses, and then further developed for the CBA methodology. As explained in section 0, this modelling simulates gas flows with a "least cost-route criteria", thus enabling the identification of physical bottlenecks and infrastructure-related limitations. However, it cannot realistically reflect the functioning of the European gas market. The resulting gas flows therefore should not be used to calculate the modelled-based indicators (see section 4.2.4) because they are no more accurate than an arbitrary choice of value. Decision-makers currently cannot use them to predict the future impacts of infrastructure projects, even allowing for a large margin of error.

The improvements in modelling consist of an in-depth recalibration of the modelling from network-oriented to market-oriented. This entails either changing the modelling assumptions of the existing tools or drawing from the many examples of gas market models that are commercially available, including models that capture strategic behaviour. A complete overhaul and change of gas market model might be possible as a means of addressing all recommendations together. The goal of these improvements is to better reflect the reality of the European gas markets' functioning, and to enable an assessment of the uncertainty regarding the results.

In order to structure and simplify the efforts of ENTSOG, the present recommendation only deals with the urgent modelling improvements that should be performed for the next update of the methodology. These are 1) improving the modelling regarding demand assumptions and behaviour and 2) improving the modelling regarding infrastructure tariffs. These improvements come first, even before the other priority recommendations detailed hereafter (list), as they determine the efficiency and relevance of all others. They are necessary to ensure the accuracy and reliability of the methodology's outputs.

The next two recommendations (1B and 1C) are related to the same issue; they complement each other directly: they both aim to achieve a complete modelling of the European gas system. They are less urgent because their complexity potentially requires greater effort, and because they will not help achieve better results for all the PCI projects.

Details of the expected improvements in demand behaviour

The current modelling tool relies on the assumption that gas demand is inelastic and that there is no cross-elasticity between gas and other energies. The substitution of coal and gas within the thermal gap is not studied in the calculations, despite appearing in the methodology. These assumptions constitute oversimplifications, considering that the horizon of analysis extends to at least twenty years, and that the tested future cases can involve some significant variations of the gas commodity or retail price. This leads to a distorted measurement of the projects' impacts in terms of energy bill, unserved demand, and marginal price convergence within the EU.

We propose two measures: first, the methodology should introduce non-zero price elasticity of demand or justify why demand is assumed as inelastic. Economic literature provides for extensive information on the topic of gas demand elasticity, and the available gas market models generally integrate an assumption on demand elasticity. These could be the ground for the proposals in the methodology. Thereby, ENTSOG could refer directly to the values for elasticity published in the literature. Alternatively, it could rely on the institutional work already in progress at the European level (European Commission, ACER, CEER) on the characteristics of gas demand.

Second, the substitution between coal and gas under supply stress conditions needs to be reconsidered. At the very least, a separate analysis of the substitution potential might be carried out and joined to the CBA outputs to indicate the limitations of the modelling tool and the risk (and scope) of such a substitution. The improvement should be based on the interlinked model developed jointly by ENTSOG and ENTSO-E, which should be itself improved if it does not reach its initial objectives. The model should internalise the substitution mechanisms between both fuels with regard to the commodity price, the emission levels, the opportunity costs and the other political constraints.

Details on the expected improvements regarding infrastructure tariffs

Market behaviour and flows are heavily influenced by market characteristics, in particular market spreads and infrastructure tariffs (transport, storage, LNG). They affect the flow patterns as well as the system's ability to cope with extreme situations (e.g. supply disruption, high demand). Yet these constraints are disregarded in the current models; it is therefore vital that the modelling tool be corrected to take into account the influence of these drivers on commercial flows and supply decisions. Furthermore, the current modelling shows arbitrary simplification choices: pipeline interconnections are thus represented as several smaller connections with increasing weights (proxy for cost of use)[9]; this is a modelling trick to reflect a spread of gas disruption risk across all balancing zones. This is unrealistic and causes significant distortions.

Transportation, LNG and storage tariffs (based on SRMC, LRMC or existing entry exit tariffs) should therefore be considered in modelling the commercial behaviour of market payers. The use of weights added to shares of pipeline capacity would better be replaced by more explicit modelling of market assumptions regarding demand, marginal cost of supply and marginal cost of using pipelines and contractual constraints. The objective should be to model costs and tariffs, which are as representative as possible and show the actual risk that they influence the final flows and the impacts of some projects. The modelling should then reflect how these tariffs are reflected in the market prices: these will depend on the level of long-term booking and the competitive situation at each interconnection point.

As regards the proper way to consider tariffs, two solutions could be envisaged. Firstly, ENTSOG could internalise them directly in the modelling. This would enable a forecast of stylised tariffs over the next decades. Of course, those tariff levels would not necessarily reflect the actual levels because they are based on stylised assumptions and modelling. However, it would still enable a better inclusion of tariffs into the simulations than at present. Besides, it would be coherent with the objective of the methodology, which is to calculate indicators through the simulation of both network and market sides of the gas system.

Secondly, as an alternative, ENTSOG could use the existing tariffs as a proxy for projections. It should look for synergies with tariff transparency obligations under the tariff network codes, which will require TSOs and ENTSOG to publish a standardised level of transmission tariffs at

[9] The nominal physical pipeline capacity (100%) would be represented in the model by ten slices of ten percent of the nominal pipeline capacity; the first slice would have weight of one, next slice would have a weight of two and so on. The objective function would then minimize the weights of the used pipelines to spread out the flows over all pipelines (and avoid unevenly distributed flow patterns).

interconnection points[10]. It should also look at other gas models used for CBA with a similar function (see Appendix B, section 5.2 for more details).

General details on the expected improvements

To carry out these improvements, ENTSOG should use or base its work on the gas market models that are already used commercially to solve such issues. For example, models such as Gasmod[11], Gastale[12] or EGMM[13] all include tools and assumptions regarding demand elasticity, cross-border tariffs, commercial constraints (see recommendation 1B) but also market power (see recommendation 1D). Some of them are already used by project promoters themselves, thus hinting at collaboration opportunities between them and ENTSOG. In any case, ENTSOG should rely on the lessons and principles put forward by the economic theory. To this end, Appendix B (section 5.2) provides preliminary feedback from the economic theory which could be useful to ENTSOG for its current update and in the discussions on the best way to proceed.

Organisation and feasibility

The improvements are urgent and should be implemented as a priority. They should feature in the in the finalised 2017 methodology update; some of their characteristics and the market tool itself could in theory be finalised in 2018, prior to their use for TYNDP 2018. We recommend that ENTSOG launch in the next few months a working group with ACER and the European Commission, (i) to identify the most relevant modelling improvements and (ii) to discuss the necessary efforts and pathways.

Some proposed alternatives to carrying out these improvements are non-trivial. It is particularly the case for infrastructure tariff modelling / inclusion in the model. Indeed, it can be very challenging to forecast the impact of network development on future tariffs. This could probably be seen as a long-term improvement and the easier solution of using existing tariffs for projections should be favoured for the short-term.

In this regard, ENTSOG's final modelling choices should balance the costs and benefits of the market modelling improvements. ENTSOG should however try to rely on the economic literature and the available gas models as much as possible, which could prove extremely helpful in saving time and money. The final choices should also be approved by ACER and the European Commission, possibly through a consultation.

3.1.2 [1B] Modelling of commercial characteristics

The modelling should be further refined once it has been improved and infrastructure tariffs and demand behaviour can be taken into account. As a first step, the commercial constraints and the traders' behaviour should be taken into account.

Details on the expected improvements

The modelling tool and the modelling assumptions should be adjusted further. The objective is to reflect the existence of long-term contracts, trading behaviour and interruption clauses. To this end, ENTSOG should still rely on the existing gas market models used for CBA, as well as the

[10] Article 31 of COMMISSION REGULATION (EU) 2017/460 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0460&from=EN

[11] Holz, F., Hirschhausen, C., Kemfert, C., 2008. *A strategic model of European gas supply (GASMOD)*. Energy Economics, 30 (3), 766-788.

[12] Boots, M. G., Rijkers, F. A. M. & Hobbs, B. F. 2004. *Trading in the Downstream European Gas Market: A Successive Oligopoly Approach*. The Energy Journal, 25 (3), 73-102.

[13] http://rekk.hu/modeling/gas_market_modeling

economic literature. Collaboration with dedicated economists specialised in gas market modelling should help build a coherent global model that encompasses all expected improvements.

Organisation and feasibility

This recommendation is secondary and should only be performed once all priority improvements have been implemented in the methodology. This postpones potential implementation to at least 2019.

The improvement should not be particularly difficult, as it would be based on the work already performed to refine the modelling tool and the modelling assumptions. Data collection regarding contract features and trading behaviour may however be expected.

3.1.3 [1C] Model transparency

The ESW-CBA methodology allocates the responsibilities for calculating indicators without strictly defining how to calculate them. Some indicators are calculated by ENTSOG as part of the TYNDP assessment of projects using the TYNDP-step modelling tool. Other indicators are calculated by project promoters themselves, often using data from the TYNDP.

To ensure that all projects and outputs are comparable, whichever modelling tools are used and whoever uses them, the modelling assumptions need to be consistent, which is not guaranteed by the current methodology. Besides, transparency and guidance regarding the modelling tool and the methodology's assumptions should be reinforced. The analysis of the 2015 methodology and of TYNDP 2017 shows that information is often spread across multiple documents and remains incomplete (see box 1). What appears to be missing, for example, is the complete documentation on the use and modification of the Jensen solver. The current methodology seems to summarise all assumptions but does not ensure replicability.

Box 1. Issues met during the study to review the gas CBA methodology

The reviewers of this paper hence had to rely not only on the official 2015 methodology but also on the contents of the TYNDP Appendix and ENTSOG's own explanations. In particular:

- In the documentation, the logic behind the methodological choices is not very clear, especially for modelling and scenario selection ((e.g., why four climatic cases? What justification is there of their weight in the evaluation?)
- Some elements regarding the assessment of secondary indicators also remain unclear: the 2015 methodology seems to state that the complementarity between coal and gas is taken into account, but it is merely the case in reality.
- The 2015 methodology neither acknowledges nor plans future improvements and does not clearly display its shortcomings. It should warn its readers, to prevent bias and incorrect interpretation.
- Above all, the CBA methodology severely lacks guidance on the interpretation of its outputs. It does not provide Regional Groups with the basic elements for a (partly) harmonised decision process across Europe.

Details on the expected improvements

The improvements are simple and involve gathering all information and assumptions in a single document, preferably within the methodology. ENTSOG should also communicate more prior to its decisions regarding the CBA or the TYNDP processes. This documentation, that should be self-standing, should be available to the concerned authorities and stakeholders and serve as guidance. The documentation should allow the correct interpretation of results, which essentially includes the justification of certain assumptions and simplifications. It should provide guidance to the decision-makers for their own calculations and modelling processes.

An alternative improvement would be to select ENTSOG's modelling tool and make it accessible to all project promoters and relevant authorities to do the calculations. The interrogated stakeholders replied positively to this last proposal, noting that the use of a single model would greatly simplify the CBA-related tasks and would strengthen the relevance of the results.

Organisation and feasibility

This recommendation is secondary and should only be performed once all priority improvements have been implemented in the methodology. This postpones the potential timeline for implementation to at least 2019. However, the details regarding better transparency should be applied as soon as 2017.

The improvements are theoretically very feasible for the most part. In particular, the compilation of information in a single document could be achieved in a matter of months. However, the use of a single modelling (managed by ENTSOG) throughout the CBA and PCI processes entails problematic and expensive new tasks for ENTSOG. This would require launching a complete new consultation and implementation process and would imply to remake the complete model from scratch, taking into account the needs of all stakeholders.

3.1.4 [1D] Modelling of market power and strategic behaviour

While market power is included in the list of potential criteria in the Regulation, both ENTSOs overlook it in their respective ESW-CBA methodologies. The rationale for not considering market power is similar for both sectors: infrastructure projects should not be assessed according to their capacity to cope with market-based issues for which other (regulatory, market-based) solutions may exist.

The reviewers disagree in the case of the European gas system, where market power is exercised primarily in the context of a limited number of gas producers, either internal or external. Natural gas supply is undeniably an oligopoly where some market players might be able to exert their market power in setting the price through their import and production strategies. Furthermore, economic literature has shown that market power in some European regions is exacerbated by infrastructure constraints, implying an impact when a new route or LNG terminal is built. The extreme cases even show projects that are beneficial despite being never used. Such projects do not change the actual physical gas flows but mitigate the strategic behaviour of market players. In turn, this yields a significant decrease in the deadweight loss caused by market power, as well as a welfare transfer from producers to European consumers.

Therefore, when relevant, the effects of new infrastructure on market power and competition should be measured and displayed through an appropriate indicator. This indicator might then be monetised.

It should be noted that ENTSOG has already addressed the market power impact. There are multiple indicators within the 2015 methodology which comply with the Regulation criteria.

However, while all indirectly deal with the diversification of gas sources and price dependency, they do not enable the decrease in market power to be measured according to single indicator.

As a voluntary improvement during TYNDP 2017, ENTSOG also proposed going further in the analysis of strategic behaviour: the Import Price Spread Configuration Analysis (section 6.3.4.2 of the TYNDP main report) looks at capturing these impacts. It consists in studying a new supply configuration, based on the results of the European Commission Quarterly Reports regarding the differences in pricing policies for each supplier. From this ENTSOG determines the minimum level of supply diversification that is necessary to make these spreads disappear. It assumes that the price spread results from monopolistic behaviour and will disappear as soon as a certain level of alternative supply is reached.

This new proposal by ENTSOG is a step in the right direction and succeeds in capturing the effects of market power. The reviewers however notice that it remains an ex-post evaluation which is subject to unjustified assumptions (e.g., economic link between the import price spread calculation and market power, choices for monetisation, …). An alternative, recommended hereafter, would be to simulate market power within the main modelling. This would enable an assessment of the progressive decrease in market power when alternative supply increases.

<u>Details on the expected improvements</u>

The present improvement implies adding another layer to the new modelling tool, developed through recommendations 1A and 1B. This additional layer will fix assumptions about the level of competition within each market (e.g. Cournot, monopoly, perfect competition) and the strategic behaviour of market players. Different scenarios on the impact of new infrastructure capacities on prices should then be simulated to obtain a range of potential competitive impacts.

To implement this additional layer, ENTSOG should once again rely on the economic literature and the existing models, such as Gasmod[14] or Gastale[15]. Appendix 5.2 also illustrates the opportunities at that level. The layer should at least take into account the specific role of LNG terminals, which multiply the number of possible suppliers.

As market power and competition issues do not concern all markets or infrastructure projects, the reviewers suggest that the subsequent analysis of a market power indicator (and the potential monetisation) is restricted only to the regions where Regional Groups require it.

<u>Organisation and feasibility</u>

This is a third wave improvement, which should only be carried out after all priority and secondary recommendations have been addressed. In particular, a more mature modelling framework should be implemented.

This does not mean that the issue of market power does not exist, but the complexity of modelling market power properly makes its implementation alongside other efforts impractical. Furthermore, most surveyed stakeholders, while recognising its relevance, underline the difficulties associated with the recommendation and do not deem it to be a priority. However, it should be noted that most of Regional Groups' members did not respond to the consultation and may have a different opinion.

[14] Holz, F., Hirschhausen, C., Kemfert, C., 2008. A strategic model of European gas supply (GASMOD). Energy Economics, 30 (3), 766-788.
[15] Boots, M. G., Rijkers, F. A. M. & Hobbs, B. F. 2004. Trading in the Downstream European Gas Market: A Successive Oligopoly Approach. The Energy Journal, 25 (3), 73-102.

3.2 Recommendations for key area #2: Choice, measure and output delivery

3.2.1 [2A] Reduction of the number of indicators

NB: This is a priority improvement

The 2015 CBA methodology discusses thirteen outputs, which are largely aligned to the outputs that are described in the Regulation (see dedicated section 4.1.3 in Appendix A, and in particular table 9). The table provides an overview of the outputs defined by ENTSOG and to which criteria the indicators relate.

Table 5. Indicators in the 2015 CBA methodology

Indicator	Market integration	Competition	Security	Sustainability
N-1			x	
Bi-directional contribution	x		x	
Import route diversification	x	x	x	
Supply source price diversification	x	x	x	
Supply source dependence		x	x	
Remaining flexibility	x		x	
Disrupted demand			x	
Price convergence	x	x		
Gas supply	x	x		
Coal for power generation				x
CO2 emission from power generation				x
Qualitative comments by project promoter	x	x	x	x
Infrastructure environmental impact				x

Even though there is no consensus on the right number of indicators, every (main) indicator should provide information that is not already provided by another. The indicators currently proposed in the methodology do not follow this logic and several risks of double counting are identified.

In particular, taking the example of the indicator on *cooperative supply source dependence* and on *uncooperative supply source dependence*, it seems likely that only one of those indicators is necessary. Likewise, indicators on security of supply can be partly redundant: The "*N-1*", *remaining flexibility* and *disrupted demand* indicators are certainly correlated from an economic point of view. In the "competition" category, there are also similarities between *price convergence*, *supply source dependence* and *import route diversification*.

In any case, a higher number of indicators will frequently lead to double counting, which obscures the assessment of individual projects and their comparison. The present recommendation is aimed at preventing this risk and proposes simplifying the list of outputs.

Details on the expected improvements

The updated methodology should contain fewer, uncorrelated and well-defined indicators. Therefore, all indicators proposed in the 2015 methodology should be critically reviewed. Their degree of separation and the risk of double counting should be measured, and ENTSOG should argue for maintaining or eliminating them.

Then, ENTSOG's selection of new indicators should target those which:

- Are relevant for most projects. The indicators which are significant only for a single Regional Group (out of four) could be dealt with separately. It could be difficult to assess ex-ante the indicators' relevant, but experience and feedback from the 2015 CBA methodology should enable ENTSOG and the decision-makers to make their selections more fit-for-purpose.
- Might be significant drivers in the eventual ranking of projects, meaning that their omission would distort the results and the Regional Groups' choices. In particular, one could argue that indicators which would present similar results for all projects, although interesting more generally, could be discarded (see box 2 for more details on the lessons from economic literature on output representation).
- Minimise the risk of double counting.
- Correspond to the criteria set in the Regulation and other guidelines and recommendations (see table 9 in Appendix A).
- Correspond to the other objectives of the ESW-CBA methodology, in particular regarding the need for monetisation (see recommendation 3A in section 3.3.1).

Box 2. The academic contribution on the representation of outputs

The Think[1] report took stock of the state of the art on CBA of energy infrastructure investment. It outlines three sorts of effects that a CBA can consider. The first sort of effects is the (direct) energy market effects, which include the consumer surplus, the producer surplus (generation cost savings), the infrastructure costs and other market effects like improved liquidity. The second sort of effect is the externalities of the energy market, which encompasses the reduction of carbon emissions, the improved integration of RES in the energy system, earlier adoption of innovative technologies and social and environmental costs. Finally, projects can measure more macro-economic effects, like increased employment and economic growth.

The Think report argues that several of the effects can be safely omitted without distorting the relative ranking: (i) some effects are negligibly small and thus have little informational value, or (ii) some effects would be the same order of magnitude for all projects, thus the relative assessment of the projects would be affected. Furthermore, output reporting must be done carefully to minimise double counting of effects or highlight where it occurs, e.g. valorising the reduction of emissions through a carbon price and the separate reporting of the volume of saved emissions. The need for transparency in output reporting is highlighted. According to the report, transparency can be achieved most effectively by monetising all relevant outputs. Furthermore, the different monetised cost and benefit indicators need to be reported in a disaggregated format and not as a single number like the overall net present value of the

The new outputs will need to be clearly defined and their risk of interdependency will have to be evaluated and clearly stated for decision-makers.

As a suggestion, the following indicators should figure in the updated methodology:

- Socio-economic welfare, calculated directly through the modelling and taking into account as many impacts as possible
- A single indicator measuring, for a given scenario, the project's capacity to improve security of supply. Ideally, in line with recommendation 3B, this indicator should be monetised
- Physical dependency, e.g. through the N-1 factor, in the absence of a relevant weighting of disrupted demand scenarios
- A supply dependency indicator, in the absence of a relevant weighting of supply decisions and market power risks
- Sustainability of the energy system through an indicator reflecting the impact of gas on power generation and the environment

NB: note that, given the dual function of the CBA methodology, an alternative recommendation would be to reduce the list of indicators to a minimum for the CBA exercise, while still enabling representing all indicators in the TYNDP.

Organisation and feasibility

ENTSOG should deliver the improvement by discussing closely with ACER and the European Commission on the selection of relevant indicators. Working groups and an official consultation could be organised.

The critical review and clarification of the output indicators should be implemented immediately, with a view to implementing the new indicators as soon as the 2017 update and TYNDP 2018. The definition of new or redefined indicators might require a sustained effort considering that modelling techniques improve over time, but could perhaps be performed in the coming months.

3.2.2 [2B] Selection of relevant future cases

NB: This is a priority improvement

The 2015 CBA methodology defines a large number of simulation cases to reflect various eventualities. These cases are based on combinations of scenarios regarding global energy characteristics (gas demand, electricity system characteristics, CO_2 price…), climatic extremes, supply scenarios, price configurations, supply failure occurrences, etc. For each of the thirteen main indicators, hundreds of future cases could be simulated and tested. In reality, the methodology already affords some choice as to which combinations of scenarios are used to assess each project. However, this still leads to tens or a hundred of different future cases for each quantified indicator.

The ability of the methodology's users to manage the number of data throws up a critical issue. By crossing the number of indicators with the number of future cases, thousands of different outputs have to be regarded to extract exhaustive and robust findings and draw relevant decisions. One might then question whether those users are able to select and filter this much data and whether the decisions made are sufficiently accurate and robust.

As a particular concern, the stakeholders might not be able to assess the level of uncertainty underpinning each specific scenario. By ignoring these future cases', the stakeholders have to rely on their own judgement to identify the future cases they want to prioritise. This leads to potentially inaccurate and counter-intuitive results.

The related risk of biased interpretation is further increased by the number of different stakeholders who will use the ESW-CBA outputs. As each will have to interpret the series of outputs through their own methodological choices, there will be no harmonisation between decisions taken at the European level, inducing severe risks of simultaneous contradictory decisions.

Details on the expected improvements

The CBA is an evaluation of projects' future merits. To capture the inherent uncertainty linked with this evaluation, the most and least likely scenarios need to be identified, investigated and highlighted. It is vital that the methodology's users are able to distinguish and separate which future cases matter the most for their needs, and which are the most probable.

Through a consultation process, ENTSOG and the stakeholders need to agree on the selection and definition of a limited number of relevant cases before the evaluation process begins. Preliminarily, a guideline should be included within the CBA methodology's appendices, specifying how to select them. As a suggestion, a maximum of three reference scenarios per study year could be considered by ENTSOG.

As for the other cases (simulated but not corresponding to the selected three per study year), the related information should be saved in a separate file containing all the outputs, as is already the case. It will enable the Regional Groups, if necessary, to pick extra scenarios for their own analyses.

Organisation and feasibility

ENTSOG should be responsible for writing the scenario selection guidelines and for organising consultations with decision-makers (at least with the European Commission and ACER).

Efforts should begin immediately to implement the selection of reference scenarios with the 2017 update and TYNDP 2018. They should be seen as an extension of the work already carried out by ENTSOG and ENTSO-E on the joint definition of global scenarios and parameters (gas demand, CO2 price, etc.). Feasibility is thus assessed as high.

Note that this recommendation serves to improve the methodology's treatment of uncertainty. The selected scenarios then become part of the sensitivity analysis, and they will provide ranges for potential benefits. Complete sensitivity analysis on all parameters and inputs will however still require additional efforts by ENTSOG: this is recommendation 2C.

3.2.3 [2C] Extended sensitivity analysis

Uncertainty analysis is a basic requirement of cost-benefit analysis insofar as the inputs and the model are characterised by a risk of error: this is related in part to the difficulty in accurately predicting most of the inputs and outputs over several decades: levels of demand, tariff and price setting, market players' behaviour. More generally, uncertainty is determined by the availability and accuracy of input data, the identification of the variables and parameters with the greatest effect on CBA outputs, the simplifying assumptions taken in the model, and any arbitrary or partial information that would be collected from specific stakeholders.

To cope with this possibility of error, uncertainty analysis is performed by identifying the potential output variability. For example, for the ESW-CBA methodology, it involves assessing the reasonable levels of benefits of infrastructure projects, as well as the related levels of uncertainty for each of them. Projects that are more uncertain will be less popular with Regional Groups and other decision-makers. Uncertainty analysis also helps assess the general robustness of the whole CBA process.

The 2013 THINK report on cost benefit analysis[16] suggested a three-sided approach to uncertainty assessment:

- First, a sensitivity analysis, to identify the most critical parameters. This involves calculating the impact on the results of an arbitrary variation in inputs. In theory, sensitivity analysis does not presume input levels' probability.
- Second, setting ranges for these critical parameters, based on the definition of several reference and extreme scenarios.
- Third, a stochastic modelling based on probability density functions defined for all critical parameters.

The 2015 methodology complies with the requirements of the Regulation (Annex V(11)) and implements a mix of the first two approaches:

- It provides a sensitivity analysis for project-related indicators, such as costs and commissioning dates.
- It provides a multi-scenario analysis for the other input parameters used in the TYNDP.

The methodology's way of treating uncertainty is a good start, but it now needs to go further to respond to decision-makers' needs. In particular, ACER has highlighted the need for an extended sensitivity analysis to be applied to all critical parameters. In parallel, and as detailed in the next recommendation, the reviewers insist on the importance of a proper probability analysis.

Details on the expected improvements

To achieve greater transparency and better information, the CBA methodology should improve its guidance on uncertainty analysis for the CBA methodology's users. Uncertainty factors should be better displayed and analysed to draw a reasonable confidence interval from the CBA outputs. The following box shows the list of uncertainty factors as suggested by ACER.

[16] THINK, 2013. *Cost benefit analysis in the context of the energy infrastructure package*.

Box 3. Uncertainty factors for gas infrastructure projects as identified by ACER in its Recommendation No 5/2015

Paragraph 1.2

[…]

'In the Agency's view, a "sufficiently mature" project is a project fulfilling all of the following conditions:

a) Sufficient certainty about the costs assessed by the project-specific CBA […]
b) Good knowledge of the factors affecting expected costs and their ranges
c) As regards investment costs, a cost uncertainty range should be identified. The maximum investment cost should not exceed the minimum investment cost by more than 20%. If cost uncertainty is higher, the project promoters should illustrate the underlying factor(s) and justify why they do not adversely affect the maturity of the project
d) Reasonable foresight of the benefits assessed by the project-specific CBA […]
e) Reasonable knowledge of factors affecting benefits and their ranges, also with regard to different scenarios and sensitivity analyses
f) Permitting procedures having started in all hosting countries […]'

Sensitivity analysis should then be extended to all the CBA's key assumptions and critical parameters and not only focus on project-related characteristics. This should be in parallel to the already-performed scenario analysis, but which studies the impact of value combinations for the different parameters. In contrast, the aim of the sensitivity analysis is to take one parameter at a time and determine the related effect of its probable variation on the project benefits.

<u>Organisation and feasibility</u>

ENTSOG should be in charge of implementing these changes in the methodology. The improvements are not technically difficult but could require many calculations and interpretation of the results, once the extended sensitivity analysis has been performed.

It is a second wave recommendation: while relevant, it should only come after the priority improvements have been implemented. Finalisation for TYNDP 2019 is recommended.

3.2.4 [2D] Probability analysis

The uncertainty regarding inputs and future cases can be further tackled by implementing a proper probability analysis of inputs and scenarios. By estimating the accurate probabilities of occurrence of each future case and of each assumption, the methodology would enable a stochastic modelling of each critical parameter. It would simulate each possible combination of scenarios and inputs, with a global probability weight attached to each of them: the method is known as Monte-Carlo simulation[17]. For every indicator, this would yield a probability density function, thus enabling the decision-makers to appraise their expectation and the potential deviation. It would significantly improve the interpretation of outputs, as the number of scenarios to consider would drop, and the decision-makers would be able to evaluate the projects with regard to the most probable configurations and scenarios. It would also reduce the risk of error and bias in the choice of reference scenarios and in their interpretation, as their vision of the future would be more realistic (see box 4).

[17] This method is often used in asset valuation to evaluate the net present value of activities and investments whose returns are uncertain.

Box 4. The advantages and drawbacks of probability analysis

The probability analysis directly addresses the limits of a sensitivity analysis performed through a selection of extreme or reference scenarios. Conclusions on probability cannot be drawn from a juxtaposition of several scenarios. Decision-makers cannot know how to weight each of them. Besides, the number of parameters or scenarios chosen in the methodology is essentially arbitrary and is not representative of the whole range of possibilities. Finally, there is a significant risk of bias by the decision-makers, as those will tend to give more weight to the extreme scenarios and cases, even though they are highly unlikely. Conversely, they could also decide to attribute the same weight to all scenarios, which is another mistake.

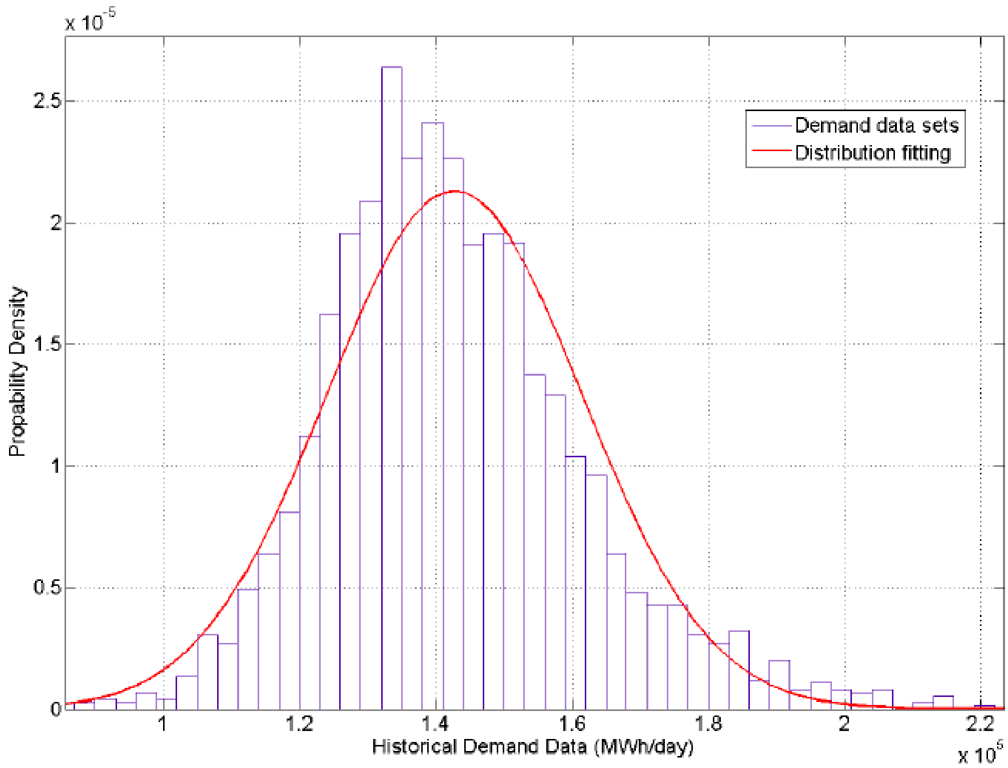
On the contrary, the probability analysis aims to take into account the uncertainty of parameters and scenarios. It quantifies their probability and thus enables a probability density function of the desired outputs to be drawn. The method does not consider only a handful of scenarios and parameters, but all probable configurations.

Details on the expected improvements

Instead of envisaging one or several values for each parameter (demand, supply prices, etc.), the methodology will have to fix ex-ante continuous density functions, which will represent their inherent uncertainty. For example, for any given year, there will be only one probability density function for demand, instead of the average summer day, average winter day, 2-week high demand case[18] and 1-day design case[19] used by ENTSOG. The lowest and highest points where the curve crosses the horizontal axis will represent the demand with the lowest positive probability of occurrence: it is 99.99% certain that demand will not be lower, or higher, than these thresholds. Meanwhile, the vertical maximum of the curve represents the level of demand with the highest chance of occurrence. The following figure illustrates the above.

[18] ENTSOG designs the 2-week high demand case as the highest demand on fourteen consecutive days, with a chance of occurrence of one every twenty years.
[19] The design case has an extremely low chance of occurrence, as it represents the level of demand which would exactly correspond to the network's maximum capacity.

Figure 1. **Illustration of a probability density graph (for electricity demand)**



Source: Tolis, A. & Rentizelas, A., 2011. *An impact assessment of electricity and emission allowances pricing in optimised expansion planning of power sector portfolios*. Applied Energy, volume 88, issue 11, November 2011, Pages 3791-3806

This will require ENTSOG to collect new sets of information in order to assess the probability of its inputs and scenarios. This will not be trivial, as estimation of prices, market behaviours, and future investments over the next 20 years will be contradicted in time by the actual figures. However, even in the hardest cases it should still be possible to propose equi-probable ranges or simplified density functions. Those will not be any less correct than the currently proposed fixed values, and they will enable decision-makers to consider all the possible values within the defined ranges without bias.

In simpler cases, ENTSOG can begin its work on probability analysis by simply weighting the existing scenarios and extreme values. It is by no means perfect, and it is only a transitory solution before a proper assessment of the probability density function. For example, a preliminary demand density function could be assembled by putting probability weights on the average summer day, average winter day, 2-week high demand case and 1-day design case (see next table).

Table 6. Illustration of a simplified probability density function based on ENTSOG's existing scenarios

Average summer day	183 days of occurrence each year (ENTSOG's assumption) Chance of occurrence = 183/365 = 0.50137
Average winter day	182 days of occurrence for each regular year (ENTSOG's assumption) 168 days of occurrence for each year when the 2-week high demand happens (1 every 20 years according to ENTSOG) 181 days of occurrence for each year when the design case happens (1 every 50 years, Microeconomix's assumption for this illustration) Chance of occurrence = 182/365*(1-1/20-1/50)+168/365*1/20+181/365*1/50 = 0.4637
2-week high demand	14 consecutive days every 20 years (ENTSOG's assumption) Chance of occurrence = 14/365*1/20 = 0.001918
1-day design case	1 day every 50 year (Microeconomix assumption) Chance of occurrence = 1/365*1/50= $5{,}47*10^{-5}$

Source: Microeconomix

Once the density functions of each critical parameter are set, Monte-Carlo simulations can be run quite simply. As many simulations will be performed as possible configurations, and the number of times each specific simulation is run will match its chance of occurrence. The outputs will then be represented as density functions. The average and deviation values will be particularly useful for decision-makers to interpret the findings of the probability analysis.

<u>Organisation and feasibility</u>

This recommendation is secondary and should only be performed once all priority improvements have been implemented in the methodology and after at least one feedback. This postpones the potential implementation date to at least 2019.

The collection of information for setting the density functions cannot be carried out directly by ENTSOG. Indeed it requires directly consulting the most relevant stakeholders, in particular project promoters and Regional Groups. ENTSOG should however remain a proactive force and an arbitrator for the final choices.

Another critical issue concerns the modelling tool and ENTSOG's ability to run a Monte-Carlo analysis and to deliver the related results quickly enough. An appraisal of the costs and benefits of such an improvement should thus be performed prior to its implementation. It is not possible now to presume a potential outcome, given the longer-term nature of the recommendation and ENTSOG's untested technical abilities.

3.3 Recommendations for key area #3: Monetisation

3.3.1 [3A] Preparation of indicators for monetisation

NB: This is a priority improvement

The gas ESW-CBA methodology should be improved to ensure a better monetisation of indicators in terms of European social welfare, and thus of related metrics quantified in the methodology. At the current stage, the decision-making process is based on an implicit monetisation of non-monetised indicators, which is less transparent and therefore less desirable. When it comes to informing the decision-makers for the purpose of cost allocation, non-monetised benefit indicators are not useful since they cannot be put on an equal footing with the monetised benefits to determine the net beneficiaries. When the indicators use different yardsticks, e.g. money and energy or other physical quantified indicators or metrics, a cost allocation taking into account benefits is simply not feasible.

The work on monetisation should however be coherent with the complexities of such an exercise in terms of feasibility, efforts and input data requirements. When the indicators support the selection of projects of common interests, a combination of monetised and non-monetised benefits can best inform decision-makers. Monetisation efforts must then be targeted at the most relevant indicators: on the one hand, the benefits that can be assessed through a robust methodology, possibly via the modelling of the gas markets, and on the other hand, the benefits for which an absence of monetisation would cause potential distortions in decision-making.

Thereby, the recommendation complements recommendation 2A on the correct selection of (monetised or not) indicators. The selection of indicators for monetisation should be coherent with the reduction of the list of indicators, and both exercises should be based on the same principles. Furthermore, ENTSOG should try to improve its methodology by targeting the changes that will most likely avoid bias in decision-making. Both the choice and monetisation of indicators should be oriented toward those which will enable projects to be differentiated on an objective, unbiased basis.

<u>Details on the expected improvements</u>

The main recommendation is to make a clear distinction between a set of indicators that should and could be monetised, and another group of indicators for which monetisation brings limited benefit. The definition of two groups should be made according to the opinion of decision-makers and the findings from previous PCI selection, CBCA and CEF processes. In particular, findings and elements regarding the risk of double counting and the technical feasibility and options to monetise the different indicators should be considered. The list of to-be-monetised indicators should include all indicators that can be technically monetised, and whose monetisation would be valued by decision-makers. As already mentioned in the report, monetisation is particularly interesting for the indicators which have an actual impact on decision-making. Thus, the indicators which present very contrasting values from one project to another (and in particular between competing projects) are worth monetising because they will enable a comparison with the main "EU welfare" indicator on an equal footing. In addition, the indicators presenting a risk of bias by the decision-makers should also be monetised, as they will help mitigate this risk and establish more objective procedures. For example, security of supply and competition are worth monetising because the current CBA methodology tends to overestimate and under-estimate them respectively.

As an illustration, the following classification of the 2015 methodology's list of indicators is proposed hereafter. It is a purely illustrative exercise, and it should not be considered as a final recommendation. It should help feed the discussion and aid ENTSOG and decision-makers in their work

Table 7. **Preliminary reading of the 2015 list of indicators regarding their relevance for monetisation**

Indicator	Should it be monetised?	Comments
N-1	No	Specific institutional objective which has no direct equivalent in monetary terms
Bi-directional contribution	No	No need for monetisation
Import route diversification	No	Double counting with other competition indicators
Supply source price diversification	Yes	Should be adapted to enable proper assessment and monetisation of market power impact
Supply source dependence	No	Double counting with other competition indicators
Remaining flexibility	No	Double counting with other indicators, but good for qualitative assessment
Disrupted demand	Yes	Not the case in the 2015 methodology. See recommendation 3B.
Price convergence	No	Double counting with other competition indicators
Gas supply	Yes	This is the main monetised component, calculated with the modelling
Coal for power generation	Yes	Economic substitution of fuels, requires adjustment of market modelling (key area 1)
CO2 emission from power generation	Yes	Current monetisation should be improved. See recommendation 3C.
Qualitative comments by project promoter	No	Qualitative assessment
Infrastructure environmental impact	No	Not applicable to all projects, difficulty in monetising the corresponding externalities

The following box gives another alternative for a list of monetised benefits. It is based on ACER's feedback on the preliminary recommendation survey.

Box 5. The benefit indicators suggested by ACER and the proposals for their monetisation[20]

As part of its response to the survey on the preliminary recommendations to update the methodology, ACER proposed a preliminary guidance on the way to improve the CBA in a practical way. In particular, it recommended considering the following seven monetised benefit categories:

	Benefit category	Monetization recommendation
1	Variation (increase) of European social welfare by saved cost of gas to EU countries, based on a zonal representation of the gas market	Monetisation is expected ; benefits should be calculated by applying appropriate zonal modelling of gas markets
2	Variation (increase) of social welfare, related to internal congestion (for specific projects, when relevant)	Monetisation is expected ; benefits should be calculated by applying appropriate zonal modelling of gas markets
3	Variation (reduction) of disrupted demand, under normal conditions	Monetisation is expected: benefit should be calculated as [reduction in disrupted demand] * [value of disrupted demand]
4	Variation (reduction) of disrupted demand, under stress conditions	Monetisation is expected: benefit should be calculated as [reduction in disrupted demand] * [value of disrupted demand]
5	Variation (reduction) of fuel costs due to fuel substitution effects, related to gasification of new areas, including the variation (reduction) of CO2 emissions	Monetisation is expected; benefit should be based on project-specific analyses of local fuel demand and prices
6	Variation (reduction) of fuel costs due to fuel substitution effects, related to power generation, including the variation (reduction) of CO2 emissions	Monetisation is expected; benefit should be calculated via a simulation of the future power market conditions
7	Variation (increase) of social welfare accounting for market power effects and competition (for specific projects)	Monetisation will be pursued where market power effects are deemed relevant

In addition to the selection of indicators to monetised, the improvement should also anticipate the identification of the monetisation methods and assumptions. In particular, it should distinguish between 1) monetised indicators to be calculated through the modelling, and which will thus be part of the overall social net present value of the project, and 2) indicators to be monetised ex-post by applying proxies and unit price to physical indicators. In order to keep this recommendation as simple as possible, the specific details of each indicator's monetisation should not be tackled here. Recommendations 1D (section 3.1.4), 3B (section 3.3.2) and 3C (section 3.3.3) can be seen as complementary in this respect.

In any case, the monetisation improvement should also be aimed at making it "better". It should take into account the technical limitations and the risk of inaccuracy linked with monetisation. The improvement should therefore remain reasonable, and monetisation should not be undertaken if it is not guaranteed as robust and non-opposable. Uncertainty analysis could also be performed on the monetisation assumptions by applying the same principles detailed in recommendations 2B, 2C

[20] Note that the list of benefit indicators suggested by ACER reflects multiple recommendations of this report, in particular market modelling improvements (recommendations 1A to 1D) and monetization of security of supply (recommendation 3B)

and 2D. Furthermore, the monetisation effort should be harmonised and coordinated with the market modelling improvements (see section 3.1).

Organisation and feasibility

ENTSOG should deliver the improvement by discussing closely with ACER and the European Commission their envisaged choices for targeted monetisation. An official consultation or workshop on the issue should be organised, and ENTSOG should not be held accountable for the final choice of selected indicators. It should however be proactive in its monetisation proposals.

The list of monetised indicators should be finalised in the coming months, before the finalisation of the 2017 update. It should serve for the 2018 TYNDP and the fourth PCI selection process. For new indicators to be monetised, the changes should be implemented by 2017 or 2018, with a final deadline set at 2018 year-end. This should be coherent with the following recommendations 2B and 2C.

Drawing up a list of indicators to monetise and of the proper methods to monetise them should be feasible. It involves extensive discussions between stakeholders and a literature review, but it does not involve any technical challenges. The subsequent monetisation phases will require more complex work from ENTSOG. It could also require the participation of other stakeholders (either as data providers or as the teams in charge of a specific monetisation).

3.3.2 [3B] Monetisation of security of supply

NB: This is a priority improvement

The “Disrupted demand under stress” and “disrupted demand” indicators are not monetised in the 2015 ESW-CBA methodology, as ENTSOG identified strong technical difficulties in assessing the level of the Cost of Disruption per Unit of Energy (CoDU). In particular, the methodology referred to possible inconsistencies in the assessment if each Member State proposed their own level of CoDU, and difficulties in coping with the variability of such a cost with regard to the type of affected customers, the magnitude and the disruption duration.

As voluntary improvements for TYNDP 2017 and for the next update of the ESW-CBA methodology, ENTSOG proposes monetising these indicators through a uniform “VoLL” (Value of Lost Load) unitary cost. The VoLL is fixed at EUR 600/MWh for the complete time horizon, and corresponds to a division of the total EU28 GDP by the gross inland energy consumption in EU28.

This current assumption is simplistic and cannot represent an accurate view of the impacts that gas disruption can have both on Europe as a whole and on each individual Member State. As mentioned by ENTSOG in CBA 2015, the cost of disrupted demand shows significant variation according to the Member State and the type of consumer (industrial, residential). It is also extremely sensitive to the characteristics of the disruption event: time of year, size and duration of the event, frequency, etc. Furthermore, the value proposed of EUR 600/MWh seems far too high and induces a risk of overestimation of security of supply benefits.

Details on the expected improvements

The proposed approach for evaluating the VoLL as a single value should be discarded and replaced. To this end, ENTSOG should order, realise or help frame a new and in-depth study on the drivers and the reasonable values for the cost of disruption per unit of energy (CoDU) in Europe (see organisation and flexibility part hereafter). This new study would consider and review the different possibilities for measuring the CoDU, and in particular the non-market valuation methods already used in economics such as the revealed preferences (through econometrics) and the stated preferences (through surveys), which enable the willingness-to-pay (WTP) for gas supply or gas customers' willingness-to-accept (WTA) disruptions to be measured. To support ENTSOG (or the mandated party) in its work, in Appendix B (section 5.1) the present report provides a synthesis of the tools and methods that exist in the economic literature. It refers in particular to two key documents: the CEER guidelines for the estimation of the cost of disruption in the electricity sector[21], and the 2011 report by London Economics on the estimation of CoDU for gas[22].

Secondly, the study on CoDU estimation should be used by ENTSOG and decision-makers to agree on values to be used in the TYNDP and in the CBA methodology. Differentiation of CoDU per country should at least be possible. The CoDU will then be applied directly to the measured volumes of disrupted demand.

Meanwhile, conserving the physical indicators in parallel to monetised ones is strongly recommended; many stakeholders have insisted on it. It will help decision-makers compare disrupted demand and other monetised indicators on an equal footing, while still being able to grasp the meaning of the indicator in a purely objective and accurate way.

Organisation and feasibility

This is a priority improvement and it should be tackled as soon as possible. Given the deadlines for the update and the fact that the values for CoDU will only come after the modelling is performed, it should be possible to finalise the update while working in parallel on the CoDU study. Hence, the update would be approved in the beginning of 2018 but the work on CoDU could continue for several weeks or months, with a secondary approval afterwards. The results should be used for TYNDP 2018.

Notwithstanding the political sensitivity of putting a value on unserved demand, improvements on CoDU estimation can be implemented immediately. As already mentioned, and as detailed in the appendix, several approaches for identifying possible VoLL numbers exist, more refined than those currently available to ENTSOG, ranging from preference surveys to econometric approaches.

As regards task allocation, ENTSOG is not necessarily the best-equipped party to carry out the study. It could be performed by an external consultancy, independently commissioned. The eventual decision should be made and discussed internally between stakeholders. A consultation process should be carried out afterwards, based on the report, to propose and validate the final values for CoDU.

3.3.3 [3C] Improve monetisation of CO2 emissions' impacts

The 2015 methodology monetises the impact on CO2 emissions by considering the IEA forecasts for CO2 quota market prices. The methodology thus wrongly assumes that the current design of the market price captures all environmental externalities and is a correct estimation of the marginal social cost of emitting carbon dioxides. Indeed, economic literature and empirical findings on quota schemes show that the current market prices are under-valued and are several times lower than the Social Cost of Carbon (SCC). This is due to (i) market failures and (ii) the inherent limitation of quota schemes in terms of time and spatial scopes.

As a result, the current estimation of a CO2 emission cost by ENTSOG is underestimated and biased. The unrealistic estimation of related outputs is reinforced by the choice in the methodology to consider different price trajectories, each corresponding to a different global scenario. In short,

[21] CEER, 2010. *Guidelines of Good Practice on Estimation of Costs due to Electricity Interruption and Voltage Disturbances*.
[22] London Economics, 2011. *Estimating the Value of Lost Load (VoLL).*

the methodology currently assumes that the unit cost of emissions would increase more in the Green evolution scenario than in the Slow progression scenario, which is counterintuitive.

Details on the expected improvements

The methodology should base the monetisation of environmental impacts on the SCC[23]. Contrary to CO2 market price, the SCC reflects the full economic marginal cost of emitting one more ton of CO2 into the atmosphere. It is calculated by summing and discounting the estimated impact over a very long period (more than 100 years) and over the most extensive list of impacted stakeholders.

As an alternative to a single indicator, ENTSOG may propose two complementary indicators:

- The current one, corrected to reflect the market price of emissions.
- The societal benefits that are not internalised in the expected CO2 market price, measured as the difference between the SCC and the market price.

ENTSOG should base its estimations for European SCC on existing studies (see the regulatory impact analysis by the US Federal Government[24], the Stern report commissioned in the UK[25], or the "tutelary" CO2 value report published by the French prime minister's strategic committee[26]). These studies base their estimations on behavioural studies and surveys, and are used by government and regulatory agencies for their policy impact analyses. While their scope and intrinsic assumptions may vary, they all show the same influence on some major parameters (e.g., a social discount rate) and all reflect the current under-valuation of CO2 market prices. A preliminary suggestion of the reviewers would thus be to do all calculations (for all global scenarios) with a central value for SCC, and then to cope with the related uncertainty of measures in the sensitivity analysis stage of the methodology.

Note that the Regulation does not explicitly reveal its preferred version of the CO2 price, only mentioning a general "carbon dioxide price".

Organisation and feasibility

This is a third wave improvement that will only be useful when the effect of substitution between gas and other energies is modelled accurately. Furthermore, its significance in the eventual PCI selection is limited.

Notwithstanding the political difficulty in defining a value, the monetisation of changes in CO2 emissions is immediately possible. However, one must be careful not to double count the benefit by using both the EU ETS value in the market modelling of fuel substitution and a tutelary value for a separate indicator.

[23] Even though improved monetization of CO2 emissions would be welcome, the impact of advancements in this regard should not be overestimated as most emission related benefits are to be found in the electricity sector.
[24] United States Government, 2010. *Technical support document: social cost of carbon for regulatory impact analysis.* Interagency working group on social cost of carbon. Executive order 12866
[25] Stern, N., 2006. *Stern review on the economics of climate change*
[26] Centre d'analyse stratégique, 2009. *La valeur tutélaire du carbone*

3.4 Recommendations for key area #4: alignment with the needs and purposes of the decision-makers

3.4.1 [4A] New project fiche

NB: This is a priority improvement

To deliver on its intended purposes, the CBA methodology must provide meaningful outputs that are represented in a clear and useful way.

So far, around a dozen indicators for hundreds of future cases and several reference years leads' have been delivered in the format of a database with thousands of outputs. In this format, the information has not been sufficiently clear for Regional Groups and other stakeholders to interpret the data.

Improved reporting of the most important outputs facilitates the overall interpretation of the results and increases the overall transparency of the CBA assessment of the projects of common interest.

A widely suggested tool to improve the representation of the outputs, including by ENTSOG, ACER and ENTSO-E, is a project fact sheet that summarises the main impacts of a project based on the CBA assessment: the so-called *project fiche*.

As part of its voluntary improvements, ENTSOG has already proposed a project fiche template which was used for the third PCI selection process (see Appendix D, section 7). While it does not change the list of outputs to be calculated, it still represents an improvement in the way the outputs are visualised. In particular, the indicators were linked to the infrastructure needs defined by the regional groups in a step preceding the call for PCI candidates. However, ENTSOG should revise the content of the *project fiche* in line with the recommendations of this study.

Details on the expected improvements, organisation and feasibility

The template "project fiche" offers a welcome starting point for a representative project fact sheet. It summarises the main project information regarding the project description, the project costs and the project benefits. The following table shows the recommendations to improve the project description (points 1 and 2), and the economic benefits' publication (point 3). They cover priority improvements that could be part of the 2017 update. There are no specific comments on the presentation of the simulation's outputs.

Table 8. Recommendable improvements to the project description and the benefits' publication

1.	**Mark the infrastructure need(s) addressed**	The marking of the infrastructure needs that the project aims to address allows easier classification of projects and interpretation of the outputs. Feasibility: The improvement requires no changes to the existing modelling tools and must be implemented for CBA/ TYNDP 2018
2.	**Name the potentially competing projects**	The project description section of the fact sheet requests that potentially complementary projects be identified. The project description should also discuss the potentially competing projects. Feasibility: The improvement requires no changes other than those specified in recommendation 4B.
3.	**Improve the economic benefits**	The economic benefits section should report the total benefit and the disaggregated effects which include the market related benefits and the externalities dealing with security and sustainability. Note that ACER is of the view that the list of benefits to be monetised should be revised. Recommendation 3A alternatively suggested extending to six the number of indicators of the 2015 methodology which could be monetised. Furthermore, the presentation of economic benefits should also display the results from the uncertainty analysis as well as the probability analysis, should recommendation 2D be carried out.

3.4.2 [4B] Enable the identification of clusters and competing projects

The value of PCIs depends on all other infrastructure projects that are implemented. When selecting projects, it is important to understand which other projects need to be in place to capture the full potential and which projects should not be developed together in case of negative synergies.

The methodology foresees a rudimentary approach to signalling potential project interaction by checking each project against different infrastructure development scenarios. However, this approach does not identify which projects interact positively or negatively with each other.

As a result, the Regional Groups perform the identification of complementary and competing projects by hand, based on a pragmatic approach that disregards objective criteria in favour of an overall consideration of the issue. Note also that the methodology does not include any guidelines to assist Regional Groups in such an approach, thus resulting in a serious risk of non-harmonisation and errors.

A less visible issue concerns the case when a competing project is already included in the TYNDP. In such a case, and regardless of its application for PCI status, the project will distort the assessments in terms of marginal impact of all other projects through the cost-benefit analysis. This is particularly critical if the project included in TYNDP is eventually less likely to be implemented and is less serious than the projects still applying for the PCI list.

Details on the expected improvements

The methodology should prescribe stricter grouping rules for investment items that take into account the maturity of investments and the common purpose of investment items.

For competing projects, project promoters should indicate alternative projects that could affect the project's viability. Additionally, if the Regional Groups define the regional needs before projects are to be submitted, project promoters can indicate which need the proposed project is addressing.

These measures complement the existing approach to signalling project interaction, which can then lead to supplementary analysis for a subset of projects.

At a more complex level, the modelling tool could propose to run and identify automatically those interacting projects.

Organisation and feasibility

The rudimentary approach based on the comparison of a project's impacts for several infrastructure scenarios could be refined in the short term, but any structural approach to the analysis project interaction is non-trivial. Modelling tools and automated analysis can help if resources are invested to do so. Regardless of feasibility, this is a second wave recommendation that should only be tackled after all priority improvements have been achieved.

Experiences on dealing with project interaction could be shared with ENTSO-E.

3.4.3 [4C] Verification of PCI input data

The assessment of PCI candidates by Regional Groups relies only partly on common datasets validated directly by ENTSOG or through consultation processes and the collaboration with ENTSO-E on the interlinked model. Several inputs are however project-specific and are directly provided by the project promoters. This concerns, for example, the investment and operating costs of the project, the estimated revenue streams and the timeline for building and commissioning.

The accuracy of both the common assumptions and those of the project promoters needs validating. Regional Groups indicate that on too many occasions they have to analyse or compare projects for which the indicated inputs are not reliable, in particular regarding the commissioning date, or are simply missing. The latter case especially concerns data on investment costs, which are often not delivered by the TYNDP-step of the methodology for confidentiality reasons while the Regulation states that unit cost could be used.

Details on the expected improvements

A consistency check with national development plans, reference unit costs and other reference inputs should be performed. Official documentation from ACER and national regulators is already available and could be used to perform this task.

In addition, safeguards and criteria should be implemented in the methodology as to a minimum level of details to be provided by the project promoters. It should foresee an ex-ante rejection or specific categorisation for a project that does not satisfy those criteria. In any case, it is vital that, when comparing or selecting projects, Regional Groups are able identify which projects are the most at risk of not being carried out (even if those projects are already at the most advanced infrastructure level from ENTSOG's viewpoint).

Organisation and feasibility

The responsibility for the check also has to be clarified. The consensus[27] seems to indicate the NRAs or ACER as the most suited parties. On the other hand, ENTSOG is institutionally not in a position to challenge project promoters. The check could then be set annually as part as the work leading to TYNDP finalisation and listing of project candidates. All projects whose inputs are highlighted as insufficient (with regard to new compliance criteria defined in the updated methodology) could be sent for a short regulatory supervision. In case of any litigation or disagreement between project promoters and regulators, the intervention of the European Commission could be envisaged.

The feasibility of the publication and use of the details on project costs should not be an issue. While the Regulation recognises that recipients (regulators or regional groups) of project analyses must preserve commercially sensitive information, it neither limits their diffusion nor regards project costs as commercially sensitive. Therefore, it does not conclude on their confidentiality requirements. Note that projects using mature technologies should not be seen as commercially sensitive within the terms of the Regulation: it is the reviewers' opinion that the reference unit investment costs published by ACER should closely reflect those costs[28].

This recommendation is a third wave improvement. It is not a priority and it could be contemplated for the following update of the methodology.

[27] Based on the received comments on the preliminary recommendations survey.
[28] ACER, 2015. *Report on unit investment cost indicators and corresponding reference values for electricity and gas infrastructure*

4 Appendix A – Review of the 2015 methodology

4.1 Regulatory dispositions concerning the ESW-CBA methodology in gas

The ESW-CBA methodology was developed by ENTSOG according to the requirements of Regulation (EU) No 347/2013. Under this Regulation, the formal objectives of the methodology are (article 11) to "*enable a harmonised energy-system wide cost-benefit analysis at Union level of projects of common interest […]"* and to be *"applied for the preparation of each TYNDP*".

Beside these main objectives, the Regulation sets out a number of features and criteria that the ESW-CBA should observe.

4.1.1 Use of CBA and CBA results

First, the Regulation specifies where and when the CBA methodology or results should be used: (i) for the applications of candidate PCIs, (ii) for investment request and cross-border cost allocation (CBCA) when necessary, and (iii) for financial assistance requests under the Connecting Europe Facility.

The CBA methodology is thus an essential tool[29] for the establishment of regional lists (Annex III.2). "Promoters of projects […] wanting to obtain the status of PCI shall submit an application for selection to the Regional Group, [which shall include the] assessment of the project regarding the priorities [(in Annex I)], [the] analysis of the fulfilment of criteria defined in Article 4, and, [above all for the matter of this review], the **project-specific cost-benefit analysis** […] based on the [ESW-CBA] **methodology developed by ENTSOG**" (No 1). Note that "the main results of the cost-benefit analysis on the basis of the [ESW-CBA] methodologies, except for any commercially sensitive information, should be published on an infrastructure transparency platform easily accessible to the public" (article 18).

Besides, concerning cross-border cost allocation, "the basis for the discussion on the **appropriate allocation of costs** should be the analysis of the costs and benefits of an infrastructure project **on the basis of a harmonised methodology for energy-system-wide analysis**." Note that "[For a project of common interest with cross-border impacts] and sufficiently mature in its development, project promoters […] shall submit an investment request, [including] the request for cross-border cost allocation to the national regulatory authorities […], in particular the project-specific cost-benefit analysis consistent with the [ESW-CBA methodology]" (Article 12 (3)). As a consequence, "**in deciding to allocate costs across borders, the economic, social and environmental costs and benefits of the projects in the Member States concerned and the possible need for financial support shall be taken into account**" (Article 12 No 4). CBCA thus relies particularly on the outputs of the ESW-CBA.

The CBA methodology is also used when deciding on incentives for PCIs with higher risks in terms of development, construction, operation or maintenance, in order to provide their promoters with appropriate renting incentives. "The decision […] for granting those incentives shall consider the results of the [ESW-CBA], and in particular **the regional or Union-wide positive externalities generated by the project**" (Article 13 (2)).

[29] Note that while Regulation 347/2013 seems to provide that the ESW-CBA methodologies are entry points to the identification and analysis of PCI candidates, those methodologies fundamentally remain informative tools to guide decision-makers in their assessment of PCI candidates. Thus, these latter also take into account other data and criteria before making their final decisions for identification of PCIs and the subsequent incentives or CBCA.

The CBA results are also inputs in the process for investment requests and financial support, as the discussions between TSOs and national regulatory authorities on these investment requests are based on the project-specific cost-benefit analysis (recital 37). Similarly, the CBA results are inputs for request of financial assistance. Hence, "**[PCI] projects […] are eligible** to the Union financial conditions [if among other criteria], **the project specific cost-benefit analysis [based on ESW-CBA methodology] provides evidence concerning the existence of significant positive externalities such as security of supply, solidarity or innovation**".

4.1.2 Technical requirements of the CBA methodologies

Regulation 347/2013 also states technical principles that the ESW-CBA methodology should satisfy. These principles are presented in Annex V of the Regulation. In particular, "the methodology should give guidance for the development and use of both network and market modelling necessary for the CBA" (No 3), "the cost-benefit analysis should be based on a harmonised evaluation of costs and benefits" (No 4) and "the methodology should include a sensitivity analysis concerning the data set, the commissioning date of different projects and other relevant parameters" (11). Note that the Regulation does not specify which other relevant parameters to consider, thus requiring additional input from stakeholders. "The methodology should [also] identify the Member States on which the project has net positive or negative impacts" (11). Furthermore, Annex III.2 also reminds that "recipients [of project cost-benefit analysis] shall preserve confidentiality of commercially sensitive information" (2), not specifying which pieces of information it may concern.

The Regulation also establishes that "national regulatory authorities cooperating in the framework of the Agency shall establish and make publicly available a set of indicators and corresponding reference values for the comparison of unit investment costs for comparable projects […] [and those] reference values may be used by [ENTSOG] for the cost-benefit analyses carried out for subsequent 10- year network development [plan]."

The Regulation also specifies the indicators that the ESW-CBA methodology should assess. These indicators are presented in detail in Annex IV with a list of criteria to be evaluated for all PCI candidates (general criteria and specific criteria in the gas category, namely market integration, security of supply, competition and sustainability). For each criterion, the Regulation details the list of indicators that should be measurable using the methodology. However, regardless of exceptions (e.g., impact of new capacity on HHI index), it generally does not specify which measurement methods should be used to assess these benefits, nor does it specify the rules for further monetisation.

Lastly, the Regulation gives indications regarding the conditions for ranking or not PCI candidates. "Each regional group shall [hence] assess each project's contribution to the implementation of the same priority corridor or area in a transparent and objective manner. Each group shall determine its assessment method on the basis of the aggregated contribution to the criteria […]. This assessment shall lead to a ranking of projects for internal use of the Group" (article 4). Annex III.2(11) also states that "the Regional Group shall [then] rank the proposed projects taking into account the assessment of the regulators". Nevertheless, "Neither the regional list nor the Union list shall contain any ranking**.** A later ranking at Regional Group level is only allowed "if, based on the regional lists received, and after having taken into account the Agency opinion, the total number of PCIs on the Union list would exceed a manageable number, the Commission shall consider, after having consulted each Group concerned, not to include in the Union list projects that were ranked lowest by the Group concerned according to the ranking" (Annex III.2(14)).

4.1.3 Guidance concerning outputs and their representation in the CBA analysis

The Regulation includes a set of output indicators in Annex V, which describes the requirements of the energy-system wide cost benefit analysis, and in Annex IV, which describes the indicators for measuring the specific criteria for projects of common interest.

Annex V (7)

- For gas, the cost-benefit analysis shall at least take into account the results of market testing the impacts on the indicators defined in Annex IV and the following impacts:
  (a) disaster and climate resilience, and system security, notably for European critical infrastructures as defined in Directive 2008/114/EC;
  (b) congestion in the gas network.

Annex IV (1)

- (c) for gas transmission, the project concerns investment in reverse flow capacities or changes the capability to transmit gas across the borders of the Member States concerned by at least 10 %, compared to the situation prior to the commissioning of the project;
- (d) for gas storage or liquefied/compressed natural gas, the project aims at supplying at least two Member States directly or indirectly or at fulfilling the infrastructure standard (N-1 rule) at regional level in accordance with Article 6(3) of Regulation (EU) No 994/2010 of the European Parliament and of the Council (1);

Annex IV (3) Concerning projects falling under the categories set out in Annex II.2, the criteria listed in Article 4 shall be evaluated as follows:

- **Market integration and interoperability** shall be measured by calculating the additional value of the project in terms of integration of market areas, price convergence, and the overall flexibility of the system, including the capacity level offered for reverse flows under various scenarios.
- **Competition** shall be measured on the basis of diversification, including the facilitation of access to indigenous sources of supply, taking into account: diversification of sources, diversification of counterparts, diversification of routes, the impact of new capacity on the Herfindahl-Hirschmann index (HHI) calculated at capacity level for the area of analysis as defined in Annex V.10.
- **Security of gas** supply shall be measured by calculating the additional value of the project related to the short and long-term resilience of the Union's gas system. It should also be evaluated through the enhancement of the remaining flexibility of the system to cope with supply disruptions to Member States under various scenarios. A last indicator is the additional capacity provided by the project measured in relation to the infrastructure standard (N-1 rule) at regional level, in accordance with Article 6(3) of Regulation (EU) No 994/2010.
- **Sustainability** shall be measured as the contribution of a project to reducing emissions, to supporting the back-up of renewable electricity generation or power-to-gas and biogas transportation, taking into account expected changes in climatic conditions.

Table 9. Overview of outputs mentioned in the Regulation

Other	Market	Competition	Security	Sustainability
Disaster and climate resilience	Contribution to market integration	Diversification of supply sources	Remaining flexibility to cope with disruptions	Emission reductions
Congestion	Contribution to price convergence	Diversification of counterparts	N-1 increase	RES integration (power to gas, biogas)
		Diversification of routes		
		HHI capacity level		

The Regulation also provides indirect guidance concerning the outputs of the CBA, for instance in Annex V regarding the spatial granularity of the outputs and the need for computing the outputs for a range of inputs to check the robustness of the figures.

Annex V (7): The analysis shall identify the Member States on which the project has net positive impacts (beneficiaries) and those Member States on which the project has a net negative impact (cost bearers). Each cost-benefit analysis shall include sensitivity analyses concerning the input data set, the commissioning date of different projects in the same area of analysis and other relevant parameters.

4.2 Description of the 2015 methodology

4.2.1 General description

The gas ESW-CBA 2015 methodology was published in 2015 by ENTSOG and was initially applied for the adoption of the second PCI Union list in 2015. It was also used, with some voluntary improvements, for the elaboration of TYNDP 2017 and the 2017 PCI selection process.

The objective of the methodology is to support the assessment of PCI candidates. It implies:

- For each candidate, evaluating its alignment with the general and specific criteria set by the Regulation
- Supporting project promoters, Regional Groups, the European Commission, Member States, NRAs and other stakeholders in their work related to the selection of PCIs, subsequent investment request/cross-border cost allocation and financing decisions under the Connecting Europe Facility. In particular, those stakeholders should be provided with guidance on modelling the European gas system and a project's impact on it, as well as a series of qualitative and quantitative outputs characterising the project's impact. Those data are to be provided by ENTSOG or by the project promoters through the direct use of the methodology.

As a simplified description, the methodology consists of an ensemble of guidance, assumption description and process requirements to be followed by ENTSOG and project promoters in applying the methodology running the ESW-CBA and the project-specific CBA (PS-CBA). The methodology hence describes:

- Data requirements and the assumptions and sources related to all inputs
- The modelling assumptions to simulate the impacts of projects on the European gas system
- The expected delivery of outputs for each indicator and other deliverable
- The description of all scenarios and cases (climatic, supply, infrastructure, global context) under which the gas system will be simulated to assess projects
- Details on application of the methodology by its users.

The next paragraphs will briefly describe each of these dimensions[30]. As explained further in section 4.4, they show that the 2015 methodology is too simplistic in many aspects related to modelling and monetisation. Numerous shortcomings in the methodology limit its practicality for supporting the TYNDP, the selection of PCIs, the preparation of investment requests and CBCA procedures

4.2.2 Inputs

The data set used for the gas system modelling and the assessment of PCI impacts consists of a series of inputs at their current level and forecasts over a 21-year time horizon, possibly through different scenarios (see next subsection).

The data set is structured in the methodology into two categories depending on the responsibility for providing and validating them:

- System-wide data is provided by ENTSOG, based on assumptions from renowned international sources (International Energy Agency …). In particular, the data set is aligned with the process for elaborating the TYNDP report. It gathers: the gas demand, the part of electricity demand to be covered by gas or coal (the "thermal gap"), the yearly average

[30] For more details, the readers can refer to the official 2015 CBA methodology and all related documentation, available at: http://www.entsog.eu/publications/cba-methodology.

prices of commodities (coal, gas, electricity) and CO2 emissions ("global context" data), the supply potential from import sources, etc.

- Project-specific data which has to be provided directly by project promoters, at both technical (development steps and commissioning, capacity …) and financial (costs, projected cash flows …) levels.

Table 10. List of input data in the 2015 methodology

Category	Type	Data items	Level of definition
System-wide data	Gas demand to power residential, commercial and industrial	Yearly Average Summer Day Average Winter Day 14-day Uniform Risk 1-day Design Case Average Winter Day 14-day Uniform Risk 1-day Design Case	Zone
	Global context	Yearly average import price of gas Yearly average price of coal Yearly average price of oil Yearly average price of CO_2 emission	Europe
	Supply potential from import sources	Maximum historical deliverability on one day Maximum historical deliverability on 14 days Minimum Intermediate Maximum	Source
	Existing Infrastructures (capacity)	Transmission UGS LNG Terminal	Zone
	CO_2 emission factor of primary fuels	Gas Coal Oil	Europe
	Efficiency of power plant	From gas From coal From oil	Country
	Range of use for fuel in power generation	For gas For coal	Country
	Other	Social discount rate	Europe
Project-specific data	General and technical	Capacity increment Expected commissioning rate FID status PCI status according latest selection	Project
	Financial	CAPEX per country OPEX Financial discount rate Depreciation period	Project

4.2.3 Modelling assumptions

The modelling assumptions described in the methodology correspond to the approach which is used by ENTSOG in its supply outlooks and TYNDP report. The approach, and the modelling tool on which ENTSOG bases its calculations, are grounded on the open-access Jensen solver developed for the Texas University of Austin.

This "Network Flow Programming" approach consists in modelling the physical capabilities of the European gas network interconnections by identifying the least-cost routes to ensure equilibrium between supply and demand at each node, with one node per balancing zone. The modelling seeks to define a feasible flow pattern that can minimise the following objective function: ***total EU cost of commodities (CO2, gas, coal…) + weight of infrastructure use***, by using the available cross-zonal capacities.

The optimum found through the simulation thus delivers:

- A flow pattern which should ensure equilibrium at the least cost
- The identification of bottlenecks and the quantification of unserved energy in stressed situations, if European countries looked to spread it across Europe (in the cooperative approach)
- The total cost of commodities associated with the supply of gas. Note that infrastructure costs are not included in the final gas bill calculated for the European system.
- The marginal price at each node[31]

Beyond the main modelling assumptions, one finds in particular:

- The assumption of perfect competition and market functioning, with no strategic behaviour
- The assumption of inelastic demand

4.2.4 Outputs and indicators

The main output measured through the methodology is the so-called 'European social welfare' (ESW) resulting from a given combination of demand, supply, and infrastructure development parameters. It is a direct output of the model's objective function and is calculated as ***cost of gas supply + cost of coal supply + cost of CO2 emissions***. The monetised impact of a gas project in terms of social benefits is then extracted by comparing the ESW for the situation with and without the project's commissioning.

The other indicators assessed through the methodology consist of:

- Capacity-based indicators, which deliver the direct impact of a given PCI on a given country. They only require capacity and demand data to be calculated. The indicators are 'Import Route Diversification', 'N-1 for ESW-CBA' and 'Bi-directional project indicator'.
- Modelling-based indicators, assessed through the gas system simulation. These reflect the "indirect cross-border impact of infrastructure" related to the impact of PCI candidates on gas flows. The indicators are 'Remaining flexibility', 'Disrupted demand', 'Uncooperative supply source dependence', 'Cooperative supply source dependence', 'Supply Source price diversification', 'Supply Source price dependence' and 'Price convergence'.

Note that the 2015 methodology, except for an optional "monetisation of demand disruption" (as described in Section 7.12.2), does not provide tools for the monetisation of this second list of indicators, which are transmitted as such for the PCI selection process.

[31] Note again that this marginal price only takes into account the cost of commodities.

4.2.5 Scenarios and future cases

The modelling approach is based on several combinations of inputs and assumptions which are simulated and compared to obtain a robust vision of each PCI candidate's impact. Each of these combinations represents a possible future, and corresponds to a different set of assumptions on the forecast of inputs to the modelling. The combinations ultimately require the choice between three infrastructure scenarios, two global context scenarios (and the corresponding gas demand scenarios and visions on electricity generation), three supply potential scenarios and one supply stress scenario for each supply source, thirteen price configuration scenarios, and two scenarios regarding the commissioning or non-commissioning of the assessed PCI candidate.

For each PCI candidate, a hundred different future cases are thus simulated through the modelling. According to ENTSOG, this makes it possible to determine the uncertainty regarding the future values of all inputs. This also enables a calculation of the indicators and outputs for the PCI candidate, as those are often obtained by comparing several scenarios. The focus on key scenarios is then left to the discretion of the Regional Groups, which are driven to filter themselves through the data and select the scenarios that are most relevant to their needs. Note that ENTSOG nonetheless provides some summarised findings as part of its TYNDP analysis (and, from 2017 on, with their proposed project fiches).

4.2.6 Application and organisation

Structurally speaking, the methodology is applied two steps.

First, in the TYNDP step, ENTSOG is responsible for gathering data sets necessary for running the ESW-CBA for the entire set of projects which have been submitted to the TYNDP. To become a PCI candidate, it is a prerequisite to have been included in this list as submission to the TYNDP. Beyond all inputs and assumptions to characterise the gas system for a given year, ENTSOG is required to collect all relevant technical data related to gas infrastructure projects, to use in the gas system modelling. Following this scenario development phase, ENTSOG is responsible for running the modelling and for assessing the impacts of "different levels of development infrastructure" along each scenario and each indicator. The outcomes from the TYNDP step are twofold: on the one hand, at an aggregated level they "constitute the major part of the TYNDP" (page 7). On the other hand, at a disaggregated and confidential level they are transmitted to each individual project promoter for the subsequent project-specific step.

In the following project-specific 'PS' step, project promoters build on the output data coming from the TYNDP step. The assessment of a project at this stage is done by the corresponding project promoter. It comprises other indicators, and in particular economic and financial performance indicators which were not available before that stage. The final analysis also includes a qualitative analysis of the results and the appraisal of potential additional benefits. Note that in the 2015 CBA methodology the PS step, "according to the Regulation, only applies to projects having reached sufficient maturity according to each Promoter indication" (page 10) but also is also used "for the calculation of the incremental impact of each PCI candidate" (page 8). Legally, this means that two distinct types of process exist: the mandatory PS step of the CBA for mature projects, and another unclear assessment depending from one mature project to another. This latter is compulsory for the project promoters' own business model assessment and for their application for financing, e.g. through CEF or CBCA possibilities. Comparability between these two processes is not ensured, as project promoters do not benefit of the same level of information to replicate the modelling tool, and as their needs are disconnected from the requirements of the methodology's PS step.

After that second step, ENTSOG is responsible for gathering all output from the PS step (including CAPEX and OPEX) and for transmitting them to Regional Groups as a "common presentation of results supporting [their] interpretation of the PS step" (page 63). In particular, the consolidation of results for a given PCI candidate includes an output table gathering all relevant data and results as well as a synthesis document containing the description of the project and the qualitative analysis.

4.3 Assessment of the 2015 methodology from a regulatory point of view

Position in regulation	Content	Compliance of 2015 CBA	Shortcoming it refers to (section 4.4)	Recommendation that addresses it (section 3)
Chapter IV, Article 11 (1)	"[…] ENTSO for Gas shall publish and submit to Member States, the Commission and the Agency their respective methodologies, including on network and market modelling, for a harmonised energy system wide analysis at Union level […]"	**Yes**		
Chapter IV, Article 11 (1)	"Prior to submitting their respective methodologies, […] the ENTSO for Gas shall conduct and extensive consultation process involving at least the organisations representing all stakeholders […]"	**Yes**		
Chapter IV, Article 11 (4)	"Within three months of the day of receipt of the last opinion […] the ENTSO for Gas shall adapt [its] methodology taking due account of the opinions received […]"	**Yes**		
Chapter IV, Article 11 (5)	"[…] The ENTSO for Gas shall publish [its] methodology on [its] website. They shall transmit the corresponding input data sets […]"	**Partially**	Transparency and comparability are not enabled Documentation is missing or is spread across ENTSOG's website	[4C] Verification of PCI input data

Position in regulation	Content	Compliance of 2015 CBA	Shortcoming it refers to (section 4.4)	Recommendation that addresses it (section 3)
Chapter IV, Article 12 (3a)	"[…] a project-specific cost-benefit analysis consistent with the methodology drawn up pursuant to article 11 and taking into account benefits beyond the borders of the Member State concerned; […]"	**Yes**	Unsatisfactory approach regarding monetisation: Several criteria are not entirely monetised and it is not clear whether a country is a winner or a cost bearer.	[3A] Preparation of indicators for monetisation
Annex V (1)	"The methodology shall be based on a common input data set representing the Union's electricity and gas systems in the years n+5, n+10, n+15 and n+20 where n is the year when the analysis is performed."	**Yes**		
Annex V (1b)	"[…] data set shall comprise at least : […] scenarios for demand, imports, fuel prices (including coal, gas and oil), carbon dioxides prices, the composition of the transmission network and its evolution, taking into account all new projects for which a final investment decision has been taken and that are due to be commissioned by the end of the year n+5."	**Partially**	Limited accuracy of the methodology's modelling. - "[…]does not ensure a reliable and realistic forecast of the market parameters (**level of demand**, substitution between gas and other energies, modelling of actual flows, formation of price, cross-border tariffs…) […]" - Over detailed and over-prescriptive list of outputs - Scenarios for demand, fuel prices, supply characteristics are not totally justified and are too numerous	[1A] Priority modelling adjustments [4C] Verification of PCI input data

Position in regulation	Content	Compliance of 2015 CBA	Shortcoming it refers to (section 4.4)	Recommendation that addresses it (section 3)
Annex V (2)	"The data set shall reflect Union and national law in force at the date of analysis. The data sets used for electricity and gas respectively shall be compatible, notably with regard to assumptions on process and volume in each market. […]"	**Partially**	Limited accuracy of the methodology's modelling. "[…]does not ensure a reliable and realistic forecast of the market parameters (level of demand, **substitution between gas and other energies**, modelling of actual flows, formation of price, cross-border tariffs…) […]"	[1A] Priority modelling adjustments. To take into account the cross-elasticity between gas and other energies. [4C] Verification of PCI input data
Annex V (3)	"The methodology shall give guidance for the development and use of network and market modelling necessary for the cost benefit analysis"	**Partially**	Limited accuracy of the methodology's modelling Transparency and comparability are not ensured : "[…]Not only are assumptions for modelling and monetisation questionable or missing, they also are under-justified and under-displayed"	[1A] Priority modelling adjustments. To enable the modelling of the European gas market not only from a physical point of view but also in a market based approach. [1B] Modelling of commercial characteristics [1D] Modelling of market power and strategic behaviour [3A] Preparation of indicators for monetisation [3B] Monetisation of security of supply [3C] Improve monetisation of CO_2 emissions' impacts

Position in regulation	Content	Compliance of 2015 CBA	Shortcoming it refers to (section 4.4)	Recommendation that addresses it (section 3)
Annex V (4)	"The cost-benefit analysis shall be based on a harmonised evaluation of costs and benefits for the different categories of projects analysed […]"	**Partially**	Over-detailed and over-prescriptive series of output; which prevent an efficient comparison of two projects.	[2A] Reduction of the number of indicators [2B] Selection of relevant future cases [4A] New project fiche
Annex V (5)	"The cost benefit analysis shall at least take into account the following costs: capital expenditure, operational and maintenance expenditure over the technical lifecycle of the project and decommissioning and waste management costs, where relevant. The methodology shall give guidance on discount rates to be used for the calculations."	**Partially**	Shortcomings compared to decision-makers' expectations […] [does] "not go far enough with regard to the verification of project-specific data, such as investment and operational costs or development and commissioning details."	[4C] Verification of PCI input data
Annex V (7a)	"[…] the cost benefit analysis shall at least take into account […] disaster and climate resilience and system security […]"	**Yes**		
Annex V (7b)	"[…] the cost benefit analysis shall at least take into account […] congestion in the gas network."	**Partially**	Limited accuracy of the methodology's modelling "[…]does not ensure a reliable and realistic forecast of the market parameters (level of demand, **substitution between gas and other energies**, modelling of actual flows, formation of price, cross-border tariffs…) […]"	[1A] Priority modelling adjustments [1B] Modelling of commercial characteristics [1D] Modelling of market power

Position in regulation	Content	Compliance of 2015 CBA	Shortcoming it refers to (section 4.4)	Recommendation that addresses it (section 3)
Annex V (9)	"The detailed method used to take into account the indicators referred to [previously] shall be elaborated after formally consulting Member States and the organisations representing all relevant stakeholders"	**Yes**		
Annex V (10)	"The methodology shall define the analysis to be carried out, based on the relevant input data set, by determining the impacts with and without each project. This area for the analysis of each individual project shall cover all Member States and third countries, on whose territory the project shall be built, all directly neighbouring Member States and all other Member States significantly impacted by the project."	**Partially**	Over-detailed and over-prescriptive series of output. Indeed, the multiplicity of outputs without clear analysis to highlight correlations and uncertainties prevents an efficient analysis.	[2A] Reduction of the number of indicators [2B] Selection of relevant future cases [4A] New project fiche [4B] Enable the identification of clusters and competing projects
Annex V (11)	"The analysis shall identify the Member States on which the project has net positive impacts […] and those Member States on which the project has negative […] impact."	**Partially**	Unsatisfactory approach regarding monetisation: multiple criteria, which are not all monetised, make it difficult to define a country as a winner or a cost bearer.	[3A] Preparation of indicators for monetisation [3B] Monetisation of security of supply [3C] Improve monetisation of CO2 emissions' impacts

Position in regulation	Content	Compliance of 2015 CBA	Shortcoming it refers to (section 4.4)	Recommendation that addresses it (section 3)
Annex V (11)	"[…] Each cost benefit analysis shall include sensitivity analysis concerning the input data set, the commissioning date of different projects in the same area of analysis and other relevant parameters".	**Partially**	Shortcomings compared to expectations of decisions makers, regarding their ability to trust the results and access the input data.	[1C] Model transparency; to access fully and easily input data. [2C] Extended sensitivity analysis [2D] Probability analysis [4B] Enable the identification of clusters and competing projects
Annex V (13)	"[…] the model shall allow for a full assessment of economic, social and environmental impacts, notably including external costs such as those related to greenhouse gas and conventional air pollutant or security of supply."	**Partially**	Shortcomings compared to decision-makers' expectations	[3C] Improve monetisation of CO2 emissions' impacts [4B] Enable the identification of clusters and competing projects

4.4 Assessment of the 2015 methodology from an economic viewpoint

The assessment of the 2015 methodology with regard to the key CBA principles (in section 2.1.2) shows some methodological choices and simplifications which limit its ability to fulfil its main purpose and be useful to decision-makers. Numerous shortcomings in the methodology limit its practicality for supporting the TYNDP, the selection of PCIs, the preparation of investment requests and CBCA procedures. These shortcomings are summarised hereafter, by following as much as possible the framework for cost-benefit analysis in section 2.1, while reflecting the Regulation's legal requirements.

4.4.1 Limited accuracy of the methodology's modelling

The modelling assumptions of the 2015 methodology were criticised by involved stakeholders in the consultation for this study. The current model is used primarily to simulate the physical capabilities of the gas cross-zonal network with the aim to identify bottlenecks and infrastructure needs in a perfect market situation. It thus minimises the consideration of market-related assumptions and does not ensure a reliable and realistic forecast of the market parameters (level of demand, substitution between gas and other energies, modelling of actual flows, formation of price, cross-border tariffs…). These are nevertheless are critical for both cost-benefit analysis and cost allocation between Member States. On this subject, the regulation states in Annex V (1b) that "*the data set shall comprise at least: […] scenarios for demand, import, fuel prices (including coal, gas and oil) , carbon dioxide prices […]*".

In particular, the modelling tool remains simplistic in its simulation of gas flows. **While market behaviour and flows are heavily influenced by transmission and cross-border tariffs as well as commercial commitments (e.g. long-term contracts), these constraints are disregarded in the current model, which just accounts for a second-order term "weight of infrastructure use" and is largely focused on computing the least cost route between two points**. The same disregard exists with regard to strategic behaviour by market players: while the impact of new infrastructure projects on market power might lead to a significant decrease in commodity price levels, the model simply does not value this potential benefit. ENTSOG justifies this position by stating that infrastructure projects should not be assessed with regard to their capacity to cope with market-based issues, for which other, less expensive solutions may exist (regulatory, market-based).

This position may also account for the **simplistic assumptions adopted for demand characteristics**: by considering a perfect market functioning with a flat demand curve and the absence of substitution between gas and other energy sources, the model is able to work from a strict physical viewpoint and to put aside all uncertainties linked with market modelling choices.

Although demand may be partly inelastic and may require a long lead-time to switch fuels, these issues are worrisome as they reduce the accuracy of the model and its outputs, and thus their reliability. Any use of the outputs resulting from the current model might indeed lead to severely distorted decisions, favouring projects that are beneficial in theory but may prove to be useless in practice due to the market context (at least in the short-term). In parallel, projects that (particularly in the short-term) might relieve the risk of market behaviour and improve market functioning and competition will tend to rank low in the 2015 methodology's assessment.

In conclusion, **the methodology provides simplistic modelling assumptions, which do not comply with the objectives of the Regulation for both network and market modelling** (Annex V, (3)). **The modelling assumptions should be adjusted accordingly to make the**

whole exercise more realistic, by relying more strongly on existing models or developing a new one.

4.4.2 Unsatisfactory approach regarding monetisation

Overall, the proposed set of benefit indicators appears to be under-monetised. Only two out of the eleven quantitative indicators are assigned monetary values: EU bill / "calculation of saved costs" (corresponding to gas savings due to diversification, new gas sources, counter partners and routes) and CO2 emissions (related to potential savings of both "CO2 emission from power generation" and "other fossil fuels in isolated areas"). Among the most notable absences, "the ESW-CBA methodology does not oblige promoters to monetise [demand disruption]" (page 59).

The methodology fails to elaborate whether monetisation of other indicators (e.g. impacts on market behaviour, impacts on non-GHG emissions, and other impacts on the environment or on society) would be valuable to decision-making. As a result, it leaves decision-makers without guidance on which criteria to prioritise and balance against the currently monetised benefits[32].

The relevance of the 2015 methodology is even lower for procedures in terms of investment requests and CBCA for which monetisation is necessary to identify beneficiaries and cost bearers (as provided by article 12 (3) and annex V (11) of the Regulation). The methodology is expected to identify which countries benefit from the projects in terms of social welfare and which are net costs bearers. The EU-bill indicator currently proves to be a very doubtful method of measuring the benefits of projects for each country: the way it is distributed onto each Member State is based on some purely arbitrary assumptions that do not reflect realistic economic mechanisms and are under-justified[33].

Beyond the extent of monetisation, the quality of monetisation assumptions is also doubtful. The review of the 2015 methodology and of the 2017 voluntary improvements shows that the attempts to monetisation are questionable and should be improved. In particular, the 2017 proposal for a monetisation of disrupted demand is too simplistic and inaccurate, displaying a single cost of disruption rate for the whole EU, based on questionable assumptions (see section 3.3.2 for more details). It might lead to distortions in decision-making, then favouring projects aimed at improving security of supply. The monetisation's quality of the CO2 emissions' indicator is also debatable: the methodology uses the CO2 market price to evaluate the externality instead of the Social Cost of Carbon (see section 3.3.3 for more details).

These accuracy issues have led stakeholders to wonder about the value of monetising additional indicators. From a practical point of view, further monetisation is only interesting if based on robust economic inputs. Moreover, past and current efforts to monetise indicators should be balanced against the accuracy of the underlying model. Robust monetisation techniques only make sense if they are applied to accurately quantified indicators and outputs.

In conclusion, the current monetisation assumptions are limited and are not satisfactory. In addition, they are applied to a simplified model, thus yielding even more inaccurate and biased

[32] Targeted monetization should then be followed by a robust multi-criteria analysis, which would enable the objective comparison of projects based on all measured indicators. ENTSOG put forward a similar vision in its update consultation. However, it argued that multi-criteria analysis should replace monetization. From an economic point of view, multi-criteria analysis is yet a useful way to complement CBA when all indicators cannot be monetized, and it should not be seen as a replacement solution (see European Commission's guide to Cost Benefit Analysis, 2008).

[33] For example, pipeline interconnections are represented in the model as several smaller connections with increasing weights (proxy for cost of use); this is a modelling trick to reflect a spread of gas disruption risk across all balancing zones. This is an unrealistic representation of the infrastructure tariffs at the border and it induces strong distortions.
As another example, the proposed improvement for cost of disruption per unit of energy is completely arbitrary and does not rely on any scientific explanation.

outputs. **As things stand in the 2015 CBA methodology, the use of monetised results by decision-makers may lead to a risk of critical mistakes**. ENTSOG should address these shortcomings by **correcting inaccuracies and enabling wiser targeting of monetisation**.

4.4.3 Overdetailed and over prescriptive series of outputs

The 2015 CBA-ESW methodology provides three capacity-based indicators, seven modelling-based indicators and two[34] more indicators for monetary analysis. These thirteen indicators are calculated considering different combinations of:

- three infrastructure scenarios,
- two global context scenarios,
- two gas demand scenarios,
- two visions on electricity generation,
- three supply potential scenarios for each supply source (meaning tens of supply scenarios),
- thirteen price configuration scenarios,
- four climatic cases,
- and one supply stress scenario per supply source.

Each of these possible combinations represents a different set of assumptions on the forecast of modelling inputs, i.e. a possible future case for simulation. While some simplifications are undertaken in the methodology (in particular scenarios for electricity generation, global gas demand, global context are merged), each indicator is still calculated for up to hundreds of different combinations / future cases.

By considering these many future cases and indicators, the unfiltered outputs return thousands of data points, many of which will be irrelevant because they do not address decision-makers' needs. It also induces risks of interdependencies and double counting between indicators: in theory, it is not a problem as long as decision-makers are able to identify those risks and to adjust the analysis of indicators. However, in practice it should be possible to anticipate any error and bias in the assessment and interpretation by decision-makers[35]. What is currently missing is a pre-selection by ENTSOG of the most relevant scenarios for each Regional Group, or alternatively a correct probability weighting of each scenario.

Another critical issue concerns the ability of the methodology's users to process and balance these unfiltered outputs. In particular, Regional Groups need to grasp the level of uncertainty regarding each future as well as the correlation between each output and its level of priority. This requires an extreme level of data processing and analysis. It might also lead to an issue regarding harmonisation of processes, results and decisions, as each user of the methodology will process these outputs in a different way.

4.4.4 Shortcomings compared to expectations of decision-makers

In its current version, the methodology is limited in its ability to fulfil its main purpose: guiding decision-makers in their analysis of PCI candidates and projects through the PCI selection process, investment request and cross-border cost allocation.

Decision-makers are not able to rely on the methodology and its results if they cannot be validated as accurate and comprehensive enough from a methodological perspective, which does not fully

[34] A third monetized indicator is now proposed in the context of the 2017 voluntary improvements/
[35] In Annex V (10), it is clear that *"[…] the methodology shall define the analysis to be carried out […]"*, which is impossible given the current outputs of the methodology. Also, Annex V (4) asking for a harmonised evaluation of different projects is not respected.

respect Annex V (3). Moreover, the muddled delivery of the CBA outputs prevents Regional Groups and other decision-makers from interpreting them based on rational and bias-proof criteria, which is required by Annex V (10) and Annex V (13).

The review has also identified other issues further altering the alignment of the methodology with the purposes of decision-makers. For example, and as confirmed by responding stakeholders, the methodology and its application do not go far enough in verifying project-specific data, such as investment and operational costs or development and commissioning details. All this data is stated as mandatory in Annex V (1b); it is clearly indicated in Annex V (10) that "*[…] each cost benefit analysis shall include sensitivity analyses concerning the input data set […]*". A consistency check with national development plans, reference unit costs and other reference inputs is thus lacking, and safeguards and criteria are due to be implemented to ensure the provision of a standard minimum level of inputs.

Another issue concerns the identification of complementary or competing infrastructure projects within the CBA. For example, complementary projects' identification should be straightforward but is still treated informally: there is no objective method for the grouping of projects and the assessments for grouping them are often performed based on insider's perspective and intuition. The approach to identifying competing projects is as rudimentary; it involves checking each project against different infrastructure development scenarios, while the study of the interaction between projects remains superficial. There is no objective or harmonised methodology to ensure comparable assessments between all projects and all Regional Groups, and there is thus a major risk of error and bias in the Regional Groups' decision-making.

4.4.5 Limited stakeholder responsibility

To summarise, the review shows the contradiction between the Regulation's intent, the decision-makers' expectations and the limitations of ENTSOG to comply and deliver the most suited methodology possible.

ENTSOG will need to increase the development efforts to meet the legal and practical expectations in terms of modelling, data collection and validation, as well as output presentation. The issue is as strategic as it is technical: ENTSOG is responsible for delivering the cost-benefit analysis. It should not continue aiming its model and methodology at mainly displaying non-monetised indicators obtained from a physical simulation of the gas cross-zonal networks.

Regulation (EC) 715/2009 is clear in assigning the responsibility of a CBA-based TYNDP to ENTSOG. The Regulation also makes ENTSOG responsible for achieving a useful and accurate CBA methodology, while stakeholders provide input (apart from ACER/EC opinion and EC approval). ENTSOG is responsible for fixing the assumptions for the monetisation of benefits (i.e. security of supply, market power) as well as for assessing its scenarios' probability. After all, while comparing and ranking PCI candidates is ultimately the task of Regional Groups, they should be able to rely largely on outputs from the application of the CBA methodology.

Decision-makers, on the other hand, currently tend to undervalue the merits of the CBA methodology as their involvement in the CBA remains limited. However, it is the task of ENTSOG to guide decision-makers to understand and/or verify its results, the data and assumptions of the model. Otherwise, decision-makers may fail to reap the benefits of the methodology's outputs.

4.4.6 Justification, transparency and comparability are not enabled

The capacity of decision-makers to rely on the CBA's outputs is also hindered by the lack of justification for some elements of the methodology. Not only are some assumptions for modelling and monetisation questionable or missing, they are also under-justified and under-displayed. The

2015 CBA methodology document accordingly presents the main structure of the methodology but does not as far as explaining to decision-makers the significance and the rationale of the choices made by ENTSOG. The substitution between gas and electricity in the model, or the definition of supply source stress scenarios are good examples.

Furthermore, the 2015 methodology does not go far enough in enabling all decision-makers to replicate the simulations. To ensure comparability of results and analyses, the models used directly by decision-makers should be coherent with that of ENTSOG, implying that all details of the latter are shared and explained in informative and comprehensive ways. In particular, the existence of non-comparable PS CBA for mature projects and specific assessments for non-mature projects is troubling and inefficient.

4.4.7 Conclusion on the shortcomings of the 2015 methodology

The 2015 CBA methodology has been a first step in facilitating the selection of PCIs. It is fair to say that the modelling and monetisation steps were developed by ENTSOG by prioritising simplicity. ENTSOG fails to take responsibility for making most of the critical choices and assumptions, which are crucial for robust results.

These shortfalls have decreased the decision-makers' trust. They rely on the methodology to provide them with key data and information which will help to achieve more objectivity, whereas the reality shows that the current application inflicts difficulties in analysing the results. If the methodology is designed and operated without taking the decision-makers' point of view, they are less likely to rely on the CBA assessment.

4.5 Identification of recent and future progress by ENTSOG

NB: the final version of this report takes into account all information up to 30 June 2017.

ENTSOG has already anticipated the methodology's update and presented its first voluntary improvements as part of TYNDP 2017. Those improvements concerned in particular:

- New infrastructure scenarios ("levels") which would enable the projects' impact compared to counterfactuals to be measured more accurately
- A new monetisation method for disrupted demand
- A new approach to measuring impacts in terms of market power, with the import price spread configuration analysis

ENTSOG also prepared the methodology's update by carrying out its own consultation process, which ran from 19 May to 16 June 2017. Hence, ENTSOG has framed its reflection on the possible improvements around the following key topics:

- Simplification, including simplification of the document and of indicators
- Increased focus on Project-Specific CBA, including grouping of projects and a new project fiche which will be used for the third PCI selection process (see Appendix 7)
- Complementary monetised and quantified benefits, including treatment of market power, CO2 emissions, security of supply, …
- CBA for investment request and CBCA

Those key topics are well aligned with the reviewers' perception of the most urgent issues for improvement. The following framework for improvement is thus entirely coherent with both the reviewers' analysis and the efforts already made by ENTSOG.

5 Appendix B – Literature review

5.1 Literature review: monetising security of supply and disrupted demand

The Internal Energy Agency defines energy security as "the uninterrupted availability of energy sources at an affordable price". As the European Union is a net energy importer and as its import dependency ratio is growing, security of supply appears to be crucial for its citizens. Hence, security of supply is one of the five key elements[36] of the current EU energy policy. The European Commission recently re-insisted on the key role of security of supply in the completion of the European Energy market through its Winter Package (2016)[37], in the section on security of gas supply[38].

Security of supply encompasses several factors, one of which is the level of disrupted demand[39]. Disrupted demand is when supplied energy is lower than the total level of demand during a given[40] period. Disrupted demand may have a considerable effect on a country's economy, especially when it concerns electricity or gas. The consequences are twofold:

- On a macroeconomic scale, disrupted demand has a direct effect on the GDP of the country concerned. It is linked with the dependence of its industry on the missing community. Disrupted demand, when resulting from a cut from an export country can also deteriorate long-term economic relations (for example, Russian cut during Ukraine's crisis in 2009).
- On a microeconomic scale, disrupted demand has a direct negative effect on the consumer surplus. The impact particularly depends on consumer's ability to substitute gas with other energy sources.

Economists have experienced many difficulties trying to assign a monetary value to disrupted demand and to security of supply more generally. A consensus[41] consists in estimating the Value of Lost Load.

The Value of Lost Load (VoLL) is a monetary indicator which represents the costs associated with an interruption in gas or electricity supply. However, the VoLL is hard to estimate because it cannot be observed on a market. There is no supply or demand for disruption in natural gas or electricity supply, hence no prices are "naturally" formed. Thus, if the VoLL cannot be directly observed through the market, then it is necessary to use techniques known as "non-market valuation".

Under some specific circumstances, the VoLL might be derived from market prices. This is particularly the case for electricity. As European electricity markets have become mature and more and more competitive, market mechanisms are now able to provide prices which reflect the value of security of supply. This is particularly the case during peak periods, when the merit order makes it necessary to call for expensive power supply capacity (such as import or gas-fired power plant).

[36] With the completion of an internal market (2), energy efficiency (3), decarbonization (4) and competitiveness (5)
[37] http://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition
[38] Documents are available at http://ec.europa.eu/energy/en/content/winter-package-security-gas-supply
[39] Others factors of security of supply are: prices and whether the economy can adapt to a shock on their level; the level of infrastructure and therefore the probability of congestion; the level of reserves.
[40] The defined period is subjective and may vary according to the legislation of the area (country, economic zone etc.).
[41] See T. Schröder and W. Kuckshinrichs: Value of Lost Load: An Efficient Economic Indicator for Power Supply Security? A literature review (2015)

During these periods, prices reach levels which are considered the price that society is willing to pay to avoid electricity disruption. If prices are growing too high, some economic actors might prefer to reduce their electricity consumption.

For the first time in TYNDP 2017, ENTSOG has proposed considering the VoLL to monetise security of supply benefits of PCI candidates. It does so by aggregating the VoLL at European level with a simple estimation method: ENTSOG hence divides the EU GDP by the energy gross inland consumption. This calculation gives a VoLL of EUR 600 per MWh for the whole EU scope. However, the economic literature shows that the rationales and methods used by ENTSOG to come up with this is value should be questioned. For example, the geographic uniformity of TYNDP 2017's VoLL does not make sense economically. It is also important to note that the VoLL cannot in principle be calculated for an entire country. Instead, it has to be calculated for each economic agent of the country according to their uses of gas and their preferences and capacity for substitution. Furthermore, the value of EUR 600 per MWh is very high compared to values which have been calculated in VoLL studies. For example, London Economics (2011)[42] estimates a VoLL for industrial users between EUR 21.83 and 31.17 per MWh[43].

An incorrect estimation of the cost of disrupted demand in Europe could lead to the incorrect prioritisation of a certain project. This in turn could misrepresent the importance of disrupted demand in terms of European common interest. Thus, if ENTSOG must assign a monetary value to disrupted demand, it is crucial to improve the current proposed methodology and to estimate values as accurately as possible.

In this synthesis, we choose to highlight the existing literature on non-market valuation in order to give insights on the most popular methods. Secondly, we focus on key elements which must be taken into account in a cost analysis for disrupted demand. Then we examine existing VoLL studies, focusing on the London Economics report (2011). Lastly, we choose to highlight CEER guideline in order to show that our work synthetises the main aspects of CEER recommendations.

5.1.1 Non-market evaluation methods identified in the economic literature

Studies into non-market valuation have emerged through environmental economics, which in particular looks at ways to assign a monetary value to environmental externalities. Pearce (2002)[44] discusses the history of environmental valuation in global welfare analysis. He concludes that the two main contributions of environmental economics to the broader economic literature are (i) the inclusion of this valuation in the welfare calculation and (ii) the methods by which to perform this valuation.

According to Pearce, there are two main ways of estimating non-market value:

- The indirect approach, also known as the market-based approach (revealed preferences – macroeconomic approaches – production function). This consists of direct observations (with data) of consumers' or producers' behaviours (the value of using electricity instead of gas to heat a house – investment in back-up generation).
- Stated preference techniques (or direct approach). These consist in building a hypothetical market and asking questions (survey based) to consumers in order to ascertain the value that they attach to those goods and services.

As discussed hereafter, those two methods have been analysed in the context of VoLL estimation for power supply. Schröder & Kuckshinrichs (2015)[45] investigated the state of the art about VoLL

[42] London Economics: Estimating Value of Lost Load, final report to OFGEM (2011)
[43] Based on following conversion rates: 1therms=0.033 MWh and 1GBP=1.149euros (01/06/2017)
[44] Pearce, D., 2002. *An Intellectual History of Environmental Economics*, Annual Review of Energy and Environment
[45] See 41

calculation in the literature. They identified advantages and disadvantages for each cost evaluation method. SINTEF (2010)[46] also studied these two dimensions for each technique.

5.1.2 Survey methods (stated preferences)

Also known as bottom-up approaches, stated preference methods consist in collecting a large amount of data through surveys. There are several types of survey, depending on the typology of questions asked. Three different stated methods can be derived and are described hereafter.

Survey method #1: direct costs

The data used is based on surveys. End-users are asked to evaluate the damage they would experience in a series of disrupted demand scenarios (e.g., multiple blackout scenarios for electricity). This technique suits industrial and commercial users because different damage categories from the different company activities are studied. Ajodhia et al. (2002) summarise this method in three points:

- Identifying the cost categories
- Weighting each category with an economic value
- Determining the interruption costs by adding up the individual damage costs

The direct cost method was used in the US in particular by Centolella et al. (2006) to estimate the VoLL (electricity) for nine industry sectors as well as for private households. The WTP was then derived from survey results[47].

Table 11. Advantages and disadvantages of the direct costs method

Advantages	Disadvantages
In principle, good estimation of monetary costs because customers normally know their own costs best	Non-monetary costs are not covered
Very suitable for industrial and commercial users	It requires a large effort from the respondent to answer the survey
The possibility to study several scenarios is not excluded	If respondents know that their response will be useful for the regulator, strategic behaviours may occur (overestimation of costs)
	It might be difficult for private users to find an economic value for uncertainties, annoyance and stress relating to energy interruption

Sources: SINTEF (2010), T. Schröder et al. (2015) and Microeconomix analysis

Survey method #2: contingent valuation

This method consists in asking people to assign a monetary value to non-marketable goods. The studies presented to respondents are based on hypothetical scenarios of a supply interruption. Respondents are asked to estimate the prices they are willing to pay to avoid disruption or the price they are willing to accept to compensate a disruption. Scenarios must be detailed and

[46] Study on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, SINTEG Energi AS (December 2010)
[47] For example, outage cost estimates for mining was $77,53 per Kw for one hour interruption on a summer afternoon and $42,09 for manufacturing.

accepted by respondents. WTP and WTA are then estimated with econometric studies, based on the survey's results.

As an illustration, contingent valuation was used in Norway by Kjølle et al. (2008) for all economic sectors (industrial & commercial users, household, public services, large customers etc.).

Table 12. Advantages and disadvantages of the contingent valuation method

Advantages	Disadvantages
Contingent valuation seeks to evaluate total costs for each population category. It includes non-monetary costs	It is difficult to include risk aversion in the studies. Theoretically, WTP and WTA should be equal. In reality, WTP is generally significantly lower than WTA.
It is possible to consider making up for loss of production (industrial users)	This method is highly **expensive** to conduct.
Interruption parameters such as time, frequency etc. can be included through different scenarios	Since real payments are not made, strategic behaviours may occur. (c.f. direct costs)
	It may be difficult for people to assign a monetary value to a hypothetical scenario
	The response "zero" might be problematic to treat

Sources: SINTEF (2010), T. Schröder et al. (2015) and Microeconomix analysis

<u>Survey method #3: conjoint analysis</u>

This method consists in asking people about their preferences between several interruption scenarios. They may be asked to rank scenarios (if there are several) or to choose their favourite of two hypothetical situations. Scenarios may depend on several factors, such as seasons, time, length of interruption etc.). Costs are then estimated with econometric studies, based on the respondent's choices.

New Zealand Electricity Authority (2013) used the conjoint analysis in order to calculate the VoLL for household and industrial & commercial users in New Zealand. For example, for Auckland respondents, for 8 hours outage, they found an average VoLL of $14,900[48].

[48] Residential = 11,980$; Small non-residential = 56,815$; Medium non-residential = 27,992$; Large non-residential = 3,906$.

Table 13. Advantages and disadvantages of the conjoint analysis method

Advantages	Disadvantages
Non-monetary costs are directly included	Sophisticated econometric models are needed, which requires expertise and extra costs
It seems more realistic to ask people to choose between scenarios rather than ask them to evaluate their WTP & WTA directly. Respondents will find these kind of survey easier.	Questions are challenging to design. Indeed, it might be difficult to ascertain the right value for each scenario.
This technique leads directly to an evaluation of people utilities via the observations of their preferences. A cost function based on several attributes can thus be estimated.	Studies have to include "status quo" choices (i.e. "do nothing"). Ratings are not necessarily comparable between two individuals.

Sources: SINTEF (2010), T. Schröder et al. (2015) and Microeconomix analysis

More generally, it is important to note that the VOLL depends on the regional and sectorial composition and the role of electricity and gas in the economy. The VOLL also differs as a function of time, location of the interruption, notification and frequency of interruption (c.f. part 3). A consented approach to calculating the VOLL at national level should be established following the guidelines of CEER[49] (c.f. part 2). CEER also stated that revealed preference methods could be implemented for industrial and commercial users, as data is available accordingly.

5.1.3 Revealed preferences (market-based)

Revealed preference methods can be classified using top-down evaluation techniques. It consists in using available macroeconomics data to evaluate agents' market behaviour.

Revealed preferences method #1: preventive costs

This method consists in measuring customers' expenditure to prevent the consequences of supply interruptions. Typically, respondents are asked to reveal their investment in back-up generation (electricity producers) or in any equipment bought to protect against interruption risks.

Preventive methods have not been widely used and discussed yet. One can quote the VoLL study for industrial users in India by Bose et al. (2006).

Table 14. Advantages and disadvantages of the preventive costs method

Advantages	Disadvantages
Data is easy to collect. Available market data can be used.	Customers' costs can only be seen as a likely range: the estimation is not precise.
Real market behaviours can be directly observed. Unlike others methods, it is not based on hypothetical scenarios or hypothetical statements.	Non-monetary costs are not included since studies focus only on investment costs and not on operational costs.
The preventive costs method is a way to obtain the option value of gas and electricity.	

Sources: SINTEF (2010), T. Schröder et al. (2015) and Microeconomix analysis

[49] Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, Council of European Energy Regulators (December 2010)

<u>Revealed preferences method #2: production function cost method</u>

In this approach, also called macroeconomic methods, electricity and gas are interpreted as input factors for both firms and private households. Economic costs of electricity and gas outages are then derived from the loss of generated "output", where it is defined by the utility people gain from leisure activities. Nevertheless, the relation between availability of energy and leisure is not straightforward. These techniques were explained to the European Commission by Booze and company in 2013. According to Frontier Economics (2015), this study is not relevant for VoLL calculation. Indeed, "*The methodology only captures the effect [of gas outages] on a daily basis with no reference to euros per MWh gas not served*"[50].

5.1.4 Conclusion on analysed methods

According to the CEER guidelines (see section 5.1.7), stated preference methods are better suited to households and small users. Indeed, data needed for revealed preference techniques is not available to them. Thus, revealed preferences should only be applied to industrial and commercial users.

The striking feature that emerges from methods of non-market valuation studies is their deep complexity. When it comes to apply these methods, this complexity is exacerbated by other factors such as the duration of disruption or the type of users which are useful to identify for calculating the VoLL. These other issues are studied in the next section.

Table 15. Synthesis of methods and relevant criteria

	Direct costs	**Contingent valuation**	**Conjoint analysis**
Monetary costs	☺☺	☺☺	☺
Non-monetary costs	☹	☺☺	☺
Suitable for industrial users	☺☺☺	☺	☺
Suitable for household	☹	☺	☺
Strategic behaviours avoided	☹	☹	☺
Taking different scenarios into account	☺	☺	☺
Cost of implementation	☹	☹☹	☹

[50] Study to support the definition of a CBA methodology, prepared by Frontier Economics for European Commission (2014)

5.1.5 Other relevant elements to be considered by ENTSOG for the update

As introduced in the previous subsections, variety in methods is not the only issue for a regulator to consider when calculating the VoLL. These issues have been clearly identified by T. Schröder et al. (2015) and SINTEF (2010).

Type of users

It is clear from the previous analysis that it is relevant to separate economic actors into different categories according to their use of gas. The most commonly split for end-users is the separation between industrial and commercial users on the one hand and individual users on the other. However, it appears that even in these categories, a distinction has to be made between types of users. Thus, it would be recommended to follow the guidelines edited by SINTEF (2010) and taken over by CEER in his guidelines (see section 5 below for more details on CEER's guidelines). The categories should follow the European community classification NACE 2[51] as follows:

- Households
- Commercial Services
- Non-electricity industrial producers
- Electricity industrial producers
- Public services
- Infrastructure
- Large customers

Time and seasonal effects

It is also clearly necessary to propose several durations for situations of disrupted demand. Damage can become more and more significant as the duration of interruption of supply increases. It is particularly the case for industrial users. The effect of time is exacerbated since the natural gas demand is inelastic in the short term.

In addition, natural gas cycles follow seasons. In the summer, when natural gas demand collapses because of high temperatures, countries attempt to stock as much gas as possible. In the winter, when countries need gas for heating and for power generation, countries destock their gas. Thus, the VoLL for gas will not be the same according to the seasons.

Another aspect of time is the interval of time at which the VoLL needs to be calculated. For the TYNDP of ENTSO-G, it seems obvious that the VoLL has to be calculated several times, in order to capture the effects of new transport capacities. ENTSOG should clarify a guideline for VoLL calculation (e.g., every two years).

All of these elements (methods, type of users, time) have been applied in several studies. We highlight the most relevant ones which could prove useful for orienting the ESW-CBA methodology update.

5.1.6 Reference studies for ENTSOG's consideration

There are some studies which can be analysed and serve as examples for ENTSOG in its goal to assign a monetary value to disrupted demand. In our opinion, the most detailed and accurate is the one prepared by London Economics (3.1) which chooses to follow CEER's guidelines as much as possible.

[51] For more details, see http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2&StrLanguageCode=FR

The SINTEF report (2010) prepared according to CEER's guidelines also shed light on previous applications of several methods for monetisation of security of supply. Its main conclusions were:

- Methods used vary widely between countries
- Studies on all economic agents (i.e. household, large customers, industry, public services, commercial services) are quite rare
- The most commonly used method is the "direct worth" method, followed by "contingent valuation"
- Contingent valuation and conjoint analysis seem better suited for household, whereas direct worth is directed at industrial and commercial users

London Economics Report

The value of lost load (VoLL) is calculated by category of user. For the natural gas industry, usually two categories can be defined:

- VoLL for domestic and SME gas users (1)
- VoLL for industrial and commercial users (2)

Methods for each category are not the same. For Small and Medium Enterprises (SME), one has to estimate the Willingness To Pay (WTP) and Willingness To Accept (WTA) using different methodologies described in the literature. They are described hereafter.

For industrial and commercial users (I&C), it appears easier to calculate the VoLL. It represents the lost gross profit from not producing plus any cost related to starting or stopping their industrial process.

Table 16. Details on the VoLL method used by London Economics

<table>
<tr><td rowspan="1">VoLL for domestic and SME</td><td colspan="2">London Economics uses stated preferences methods in order to estimate the VoLL for domestic and SME users. Results are obtained using contingent valuation and choice experiment techniques. Thus, it follows the recommendation from the CEER. Domestic and SME gas users are separated because they do not use gas for the same purposes. The WTP and WTA are then estimated for each category (domestic & SME users) using conditional logic methods based on the survey results.

<u>Reminder:</u> The WTP measures the monetary value (price) that a consumer is willing to pay for a good. The WTA measure the minimum amount of money that a consumer is willing to accept to abandon a good.</td></tr>
<tr><td rowspan="3">VoLL for industrial and commercial users</td><td colspan="2">In order to estimate the VoLL for industrial and commercial users, London Economics chooses to separate the electricity industrial and commercial users and non-electricity I&C users.</td></tr>
<tr><td>Electricity I&C producers</td><td>It should be noted that electricity is a non-storable good. Thus, any disruption to gas-fired generators would mean a total loss of production.
In addition, when calculating costs associated with gas disruption for power generators, it is important to take into account the starting cost of the power plant, etc. As gas prices, electricity prices, carbon emission prices and thermal efficiency coefficients are available on the market, estimation of the lost value can be done using revealed preference methods.
Therefore, for electricity I&C producers, the intrinsic value of the spark spread for VoLL is calculated using a real option methodology. Indeed, as the spark spread option is a European call, its value can be estimated using standard techniques (such as Black-Scholes).</td></tr>
<tr><td>Non-electricity I&C producers</td><td>For non-electricity I&C producers the value at risk for each segment of industrial production is calculated. The value at risk is calculated using the formula:
$$VoLL=GVA/GU*100$$
Where GVA = Gross Value Added ($ per year)
GU = Gas Use (therms per year)

The value at risk has to be estimated by category of industrial non-electricity producers. For example, non-ferrous metal industries will use more gas than construction; therefore, its VoLL will be necessarily much higher.</td></tr>
</table>

In conclusion, the method proposed in the London Economics study should be applied by a National Regulatory Authority to estimate the VoLL in its country. Here we describe only the main points of the methodology to show that the CEER guidelines can be applied roughly, but that the work required is substantiale.

<u>Synthesis of other studies</u>

Table 17. **Selected examples of other studies for VoLL calculation for electricity interruptions**

Study	Country	Methods	Type of users	Value of VoLL
Bliem (2009)[52]	Austria	Stated preferences (choice experiment approach)	Industrial & commercial Households	No monetary value is assigned to the VoLL. Authors just show statistical trends (such as WTP increased when duration increased)
Hoch & James (2011)[53]	Australia	Direct costs	Business (agricultural, commercial and industrial) Residential customers	Total social disruption costs = $ 1000 per MWh
Electricity Authority of New Zealand [54]	New Zealand	Conjoint analysis (Discreet choice)	Residential Agricultural Commercial Large industrial	The study has not been completed yet
Carlsson et al. (2008)[55]	Sweden	Stated preferences (choice experiments)	Private households	WTP varies between EUR 1 and 13 per MWh according to outages duration, season and day of the weeks
Praktiknjo (2014)[56]	Germany	Stated preferences and Monte Carlo Simulation	Private households	WTA comprised in average between EUR 147,2 and 27,4 per MWh depending on the interruption's duration. WTP comprised between EUR 82,5 and 6,1 per MWh

[52] Economic Valuation of Electrical Service Reliability in Austria – A Choice Experiment Approach, Markus Bliem (2009)
[53] Valuing Reliability in the National Electricity Market, Hoch and James for Oakley Greenwood (2011)
[54] New Zealand Electricity Authority, 2013. Investigation into the Value of Lost Load in New Zealand – Report on Methodology and Key Findings.
[55] Does it matter when a power outage occurs? – A choice experiment study on the willingness to pay to avoid power outages, F. Carlsson and Peter Martinsson, Energy Economics (2008)
[56] Stated preferences based estimation of power interruption costs in private households: An example from Germany, Praktiknjo (2015), Energy

Table 18. **Other attributes considered in identified studies**

Study	Frequency	Season	Duration
Bliem (2009)	☺	☹	☺
Hoch & James (2011), Australia	☺	☺	☺
Electricity Authority of New Zealand, synthesis by Hoch & James (2011)	☺	☺	☺
Carlsson et al. (2009)	☺	☺	☺
Praktiknja (2015)	☹	☹	☺

N.B: These studies illustrate the variety of methods that have been used to assign a value to disrupted demand and to show the complexity of the process. To the best of our knowledge, London Economics is the most thorough study because it is able to put a figure on VoLL for each studied category. There is a much more exhaustive list of studies in T.Schröder et al. (2015). SINTEF (2010) also provides a very detailed list of recent studies on VoLL. It also gives some basic statistical insights into these studies. For example, 44% of studies of VoLL for industrial users were performed using the direct costs method.

5.1.7 Guidelines on estimation of costs due to power and voltage disruption[57]

CEER is the "Council of European Energy Regulators". It is the voice of Europe's national energy regulators at EU and international level. Through CEER, national regulators cooperate and exchange best practice. The aim of the CEER is to promote a competitive European Energy market. In this regard, CEER publishes its recommendations through guidelines. In order to help NRAs in their cost estimations of electricity interruption, CEER published the guidelines on estimation of costs due to electricity interruptions and voltage disturbances. These guidelines are the result of SINTEF (2010) work ordered by CEER.

These guidelines were drawn up with two objectives: (i) provide a set of recommendations for NRAs on how to develop nationwide cost-estimation studies and (ii) improve the effectiveness of future studies.

CEER's guidelines on VoLL identified the main issues to be facing National Regulatory Authorities when conducting a nationwide cost estimation study regarding security of supply. The study would be adapted to country-specific characteristics in aspects discussed, such as:

- The NRA should explain the objective of the cost-estimation study
- The NRA should make clear the industrial classification and the customer types
- The NRA should explain the choice of scenarios (time of disruption / seasons etc.)
- The NRA should explain the choice of valuation methods

[57] Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, Council of European Energy Regulators (December 2010)
Available here : https://www.ceer.eu/documents/104400/-/-/7dec3d52-934c-e1ea-e14b-6dfe066eec3e

CEER endorses stated preferences in order to estimate the VoLL **for SMEs**. CEER also provides a list of methods for cost-estimation. We explained these methods in our reports in order to provide insights into their strengths and weaknesses. CEER recommends using different methods for each type of consumer in order to check the reliability of the results (for example, collect monetary costs with one method and collect non-monetary costs with another).

5.2 Literature review: gas market modelling

5.2.1 Reminder of the 2015 gas ESW-CBA methodology's shortcomings

In its methodology, ENTSOG clarifies the way it simulates the European gas system for TYNDP as well as the PCI selection process. Its work is based on a model which represents, in essence, the entire gas system. This simplification of reality should be based on relevant assumptions to highlight the realistic likely impacts of an infrastructure project for PCI selection. Effects should be expected ex-ante (i.e. highlight which relevant effects should be considered for the future project) and evaluated ex-post (results from the model)[58].

As shown in our commentaries about the 2015 version of the ESW-CBA methodology, the model used by ENTSOG suffers from several shortcomings. The model only focuses on identifying further bottlenecks and infrastructure needs (i.e. it is oriented toward simulating the network capacities). Yet, it cannot explain or predict all the impacts that may arise from the construction of a new gas infrastructure. For example, the model should be able to highlight:

- Changes in social welfare (resulting from the changes in the form of the competition for example)
- Potential externalities (positive or negative)

The economic literature points to the deficiency of the current market modelling. In their publication on cost-benefit analysis for gas infrastructure projects[59], Keyaert & Glachant (2014) highlight several issues which arise when evaluating the impact of a gas infrastructure project on European market[60]. As a reminder, three main recommendations to improve market-modelling assumptions for the ESW-CBA have been proposed:

(i) Support market modelling with more realistic demand assumptions (1A)
(ii) Correct how commercial constraints and infrastructure tariffs impact flow setting (1A and 1B)
(iii) Include strategic behaviours (1C)

5.2.2 The contribution of economic literature on gas system modelling

An analysis of the economic literature highlights the distinction between:

- Models aiming to represent the network (for example, TIGER or ENTSOG's current model)
- Models aiming to represent the market, with network characteristics included as constraints

The second kind of model fits very well with our model-related recommendations to improve the ESW-CBA methodology. As explained hereafter, several models are already used commercially and directly tackle these issues.

Furthermore, as market models directly incorporate network constraints as a parameter, they can be seen as an evolved form of network models. New infrastructures will have to be incorporated as

[58] For example, for a gas project in Lithuania, whether the project is going to increase social welfare through import capacity (ex-ante explanation) and evaluate after the simulation whether the project has successfully increased social welfare.

[59] Note that the Oxford Institute for Energy Studies investigated European Grids using the TIGER model, which, was a network-oriented tool, is similar to ENTSOG's. They concluded that the use of the model could be very beneficial to European regulators, but they also highlighted its weaknesses as regards the evaluation of social welfare.
See: Petrovich, B., Rogers, H., Hecking, H., Weiser, F., 2016. European gas grid through the eyes of the TIGER: investigating pipeline flows by modelling history. The Oxford Institute for Energy Studies

[60] Authors' recommendations for CBA in gas projects are based on five main criteria: (i) time horizon (ii) project interaction (iii) monetisation models (iv) ranking of the projects.

new constraints, and their effects on the gas market (in term of social welfare especially) will be directly visible via changes in results.

The next subsections present the general conclusions of some theoretical gas market models for Europe. They illustrate how recommendations 1A, 1B and 1D have already been investigated in economic literature and how ENTSOG could benefit from the feedback and the contribution of this literature to carry out improvements. Nevertheless, they also show the deep complexity of gas market modelling: therefore, even when implementing a new model, ENTSOG should remain very careful about its model assumptions[61].

5.2.3 Selection of models available in the economic literature

Three different models are presented hereafter by highlighting their main assumptions, their main contributions and their weaknesses: GASTALE, GASMOD, and GAMMES[62]. A summary of model characteristics is then performed with regard to the improvements in the gas ESW-CBA methodology that we propose.

It should be highlighted that the three models feature many common assumptions but can be distinguished by their main purpose and by their conclusions.

[61] Indeed, if the model is not built correctly (i.e. if it does not try to explain what is relevant for PCI selection), results (and therefore the selection) could still be biased.
[62] Another model is interesting enough to be quoted. It is the European Gas Market Model (EGMM), elaborated in 2010 by REKK. As its main version is not available publicly, a brief summary of its main characteristics can be found here : http://rekk.hu/downloads/events/2017_EGMM_Qatar_Kotek_slides.pdf

Model #1: GASTALE – An oligopolistic model of production and trade in the European market[63]

Table 19. Main characteristics and assumptions of GASTALE

Authors & Research Institute	M.G. Boots, F.A.M Rijkers and B.F. Hobbs from Energy Research Centre of the Netherlands (ECN)
Date	2004
Purpose	To analyse the role of the downstream trading market and its interactions (in term of competition) with producers
Main assumptions	
Production costs, demand and capacity constraints	• Production costs increase with use • Production costs are based on long-term marginal cost • Transportation is included via a modelling of the transport from production to market • Cross border capacities are modelled via a congestion optimal price
Market structure	Two scenarios are studied in the model : • One with an oligopolistic Cournot competition in both upstream and downstream markets • One with an oligopolistic Cournot-Stackelberg competition upstream and perfect competition downstream

Source: Microeconomix analysis[64]

Table 20. Advantages and disadvantages of GASTALE

Advantages	Disadvantages
• Infrastructure tariffs are internalised • Market power is modelled via Cournot competition and **double marginalisation**, which result from the double oligopoly • Demand elasticity is included in the demand function at a realistic level (data from Pindyck, 1979). • Cross-border capacities directly included in the model • Supply is directly modelled (link with market power)	• No distinctions between short and long run operations • Storage is not modelled • No substitution between gas and other fuels is possible

Source: Microeconomix analysis

GASTALE is one of the first gas market models to attempt to represent the entire gas system with realistic assumptions on competition, market power and cross-border capacity. The model's conclusions depend on the type of competition in upstream and downstream markets.

When there are two successive oligopolies, the model shows that prices are higher and therefore consumer surplus is weaker than where oligopoly exists only at one level. The model also shows that the oligopoly in the downstream market results in more distortion than an upstream oligopoly, mainly due to the high concentration of traders. Finally, the model shows that abolishing monopolistic structure is key in the downstream gas market, as prices converge to perfect competition prices when the number of traders grows in the downstream market.

[63] Note that we only focus here on the first version of Gastale, but that Y. Smeers (2007) identified 3 versions of GASTALE

[64] Based on: Boots, M. G., Rijkers, F. A. M., Hobbs, B. F., 2004. *Trading in the downstream European gas market: a successive oligopoly approach*. Energy Journal, 25 (3), 74-102

These conclusions, although very interesting for the European Commission in the 2000s (when unbundling was not yet a prerogative), do not address the problems we have identified in the ESW-CBA analysis very well. GASTALE is only interesting for its competition representation, but the form of its demand function is not satisfactory, as it does not allowed for a possible substitutions between gas and other fuels.

GASTALE is one of the first models that attempted to model the competition in the European gas market, and it probably gave way to others such as GASMOD, which will be presented briefly hereafter.

Model #2: GASMOD

Table 21. Main characteristics and assumptions of GASMOD

Authors & Research Institute	Von Hirschhausen, Holz & Klemfert from German Institute for Economic Research (DIW)
Date	2005
Purpose	To show the best representation of European gas market in term of competition structure
Main assumptions	
Competition scenarios	Three scenarios for the representation of upstream and downstream markets : • Cournot competition in both • Perfect competition in both • Perfect competition downstream – Cournot upstream
Market representation	Two-stage game: • Imports to Europe + domestic production (which is an endogenous variable in the model) at the first stage (upstream) • Trade within Europe (downstream) • No vertical integration between upstream and downstream Capacity constraints are represented via a maximum export/import capacity.
Information	Game Theory Model which assumes complete and perfect information: • Producers have perfect information about demand on the downstream • Traders in the second stage are price takers. Prices results from the exporters' sub-game in the first stage

Source: Microeconomix analysis[65]

[65] Based on: Holz, F., Hirschhausen, C., Kemfert, C., 2008. *A strategic model of European gas supply (GASMOD)*. Energy Economics, 30 (3), 766-788

Table 22. Advantages and disadvantages of GASMOD

Advantages	Disadvantages
• Strategic behaviours are directly taken into account • Infrastructure restrictions enable the identification of potential intra-European bottlenecks; it is potentially very useful for ENTSOG for PCI selection and TYNDP • Shows the welfare decrease due to the effect of double-marginalisation by comparing oligopoly scenarios with the perfect competition scenario	• Static model (investments are not allowed) • No representation of long-term agreements • No work on a specific demand function: the demand is assumed to be inelastic as the elasticity level is very low. Authors stated that "*they prefer a non-linear to a linear demand function because this allows for a non-negative demand for every price. We assume the demand elasticities to be rather low in absolute term which reflects a certain inelasticity of the natural gas demand*" • No distinction between different types of gas consumption (i.e. power generation, industrial, etc.)

Source: Microeconomix analysis

GASMOD, although dating back ten years, has some interesting properties. First, it attempts to model the European gas market with realistic assumptions (i.e. Cournot competition, no vertical integration, capacity constraints), going further than ENTSOG representation. **Conclusions of the model show that competition scenarios are influenced by infrastructure capacity restrictions.** The model also points out where investments are needed by showing bottlenecks. This type of results needs to be highlighted in the future model of the ESW-CBA. One of GASMOD's weaknesses however concerns its limitations regarding demand assumption.

Model #3: Gas Market Modelling with Energy Substitution (GAMMES)

Table 23. Main characteristics and assumptions of GAMMES

Authors & Research Institute	I. Abada, V. Briat, A. Gabriel and O. Massol from French Petroleum Institute and New Energy (IFPEN)
Date	2011
Main assumptions	• Takes into account long-term contracts in an endogenous way • Producers sell their gas to traders who sell it back to end-users through long-term agreements • The end-user market is under a Nash-Cournot competition • A storage and transport Operator is included in the model in order to model infrastructure tariffs • Producers can directly sell their gas to end-users by skipping traders • Market power can be exerted by traders via spot market or long-term agreements • The demand function takes into account the possible substitution between gas and other fuel : **this assumption is the main innovation of the GAMMES model**

Source: Microeconomix analysis[66]

[66] Based on: Abada, I., Gabriel, S., Briat, V., Massol, O., 2011. *A generalized Nash-Cournot model for the northwestern European natural gas markets with a fuel substitution demand function. The GAMMES model*. Les cahiers de l'économie – n°84

Table 24. Advantages and disadvantages of GAMMES

Advantages	Disadvantages
Market power is included	Very complex to manipulate
Fuel substitution is possible through the specific demand function developed specifically for the model. This possible substitution enables market power to be exerted. If gas market participants try to push-up prices, consumers would switch to another fuel.	Pipeline and storage operators are assumed to not have market power because storage and transport costs are exogenous. It is more complex in reality. It seems that market power can be exerted through transmission rights[67]
Long-term agreements are part of the model, which is a realistic assumption: 70% of gas in Europe is sold via those contracts.	Ambiguity of the cost production function (SRMC, LRMC?)
Intra- and extra-European physical network are taken into account by the introduction of a pipeline operator which aims to minimise transmission costs	
Three sectors are differentiated for gas demand: • Power generation • Industrial • Residual	

Source: Microeconomix analysis

This last model is the most recent, focusing on the demand function and its characteristics. It is a good example of what ENTSOG should apply when trying to model the gas market.

GAMMES is very ambitious in its main assumptions. In its general characteristics, it represents almost all of our recommendations for market modelling improvement. The work done on the demand function is interesting, enabling the study of substitution between gas and other fuels. It is thus a good example of the kind of work that should be done by ENTSOG[68].

[67] For more details, see: Bushnell, J., 1999. *Transmission Rights and Market Power*. The Electricity Journal

[68] More details on the GAMMES model can be found here : http://www.cgemp.dauphine.fr/fileadmin/mediatheque/centres/cgemp/conference%20programmes/Massol_et_al._2013.pdf

Summary of the analysis of the three models

Table 25. **Summary table of the three theoretical models with regard to the suggested improvements of the ESW-CBA methodology**

	GASMOD	GASTALE	GAMMES
1A: Support market modelling with more realistic assumptions			
Fuel substitution	☹	☹	☺
Introduction of a non-zero price elasticity	☹[69]	☹	☺
1A-1B: Correct how commercial constraints and infrastructure tariffs impact flow setting			
Consideration of SRMC, LRMC, entry-exit tariffs	LRMC	LRMC	☹
Long-term agreements (contractual & commercial constraints)	☹	☹	☺
Transport tariffs	☺	☺	☺
1D: Advance market modelling to include strategic behaviour as part of supplementary analysis			
Oligopoly representation via Cournot-based competition	☺	☺	☺
Direct comparison between perfect competition and oligopoly competition in the model	☺	☺	☹[70]
Representation of market power	☺	☺	☺

Source: Microeconomix analysis

[69] In GASMOD, elasticity is assumed to be much lower, which, according to the authors, reflects the relative inelasticity of gas demand.
[70] Comparison between GAMMES and the EU gas market model is included in the original paper, which can be seen as a compa rison with a perfect competition model.

6 Appendix C – Replies to the survey on preliminary recommendations

Beside ACER GITF and ENTSOG, seven parties replied confidentially to the consultation: several TSO and non-TSO project promoters, one national regulatory authority, one institution and one consultancy firm.

Respondents mostly agree with the study team's identification of the methodology issues. They all agree that the current methodology should be revised and improved significantly. They all generally agree on the principles of the recommendations and on the main issues regarding the current version of the ESW-CBA methodology. In particular, they highlight:

- A strong criticism of the modelling assumptions when it comes to market and monetisation and the risk of heavy distortions of the results
- The need for a better and more economically robust monetisation of benefits
- The need to reduce the number of indicators and outputs and/or select them more wisely for the project fiche and the decision-making process
- The need for a better verification of PCI input data
- The need for a better identification of clusters and competing projects

They also mostly agree with the listed recommendations: their comments are mostly focused on suggestions for alternatives or more in-depth analysis.

There were some disagreements with the review and between stakeholders, in particular concerning the monetisation of benefits. While the respondents recognised the value of monetisation in theory, they were concerned that monetisation would be based on inaccurate modelling outputs or wrong and subjective monetisation assumptions.

The following subsections anonymously summarise each respondent's viewpoint. The respondents are listed from [1] to [7] in no particular order. It should be noted that most respondents have only commented on the topics which needed a specific contribution (special relevance, feasibility perception, advice on practical implementation…). Note that the comments were made on the o recommendation sets which were published in the March 2017 survey:

- Recommendation set #1: Monetisation of benefits
- Recommendation set #2: Capacity to interpret and use the results
- Recommendation set #3: Alignment with PCI selection, CBCA…
- Recommendation set #4: Modelling assumptions

6.1.1 Respondent [1]

[1] perceives the study as a very elaborate work and agrees that there is room for improvement in the CBA methodology document. [1] widely agrees with the generally sketched aims of the review process, although it sees certain details differently. In particular, some of the proposals would increase the accuracy of the whole exercise but would make it less simple.

Within and besides their comments on the report, [1] also suggests using other existing methodologies as a basis for the improvements for the CBA methodology or as examples for proposing other improvements (e.g., monetisation assumptions, monetisation per country and aggregation of indicators…). [1] stresses that recommendations should be more practical instead of just ideas: some of them originated from ACER and COM opinions and have already been discussed with ENTSOG or stakeholders. A good example or template to follow would be that of recommendation R1D on the monetisation of CO2 emissions, which gives an excellent, practical implementation of the recommendation.

On recommendation set #1, [1] agrees on the need for better monetisation, but highlights that this goal should not be reached by monetising “more indicators”. Instead, the “ultimate” monetised indicator, which is the NPV of project benefits by country, should be monetized in a more accurate way. Meanwhile, the indicators which are generated for the purpose of multi-criteria analysis should remain for that sole purpose. Note that part of them originated from pre-CBA TYNDP times. They do not measure monetary terms but other infrastructure characteristics. They could be aggregated to obtain a single project indicator via normalising each indicator on a scale of 1 to 5 or 1 to 100. However, aggregation of artificially monetised indicators to obtain a new NPV is not recommended. [1] agrees with recommendations on CO2 emissions and security of supply, for which [1] stresses the need to consider the observed chance or probability before including it in the NPV. It also raises the question of who should order or pay the study, and the timing of such a work. On the other hand, [1] weights the recommendation for a monetisation of market power, stating that ENTSOG has already made important efforts and that going further might not be easy or might face be hindered by a lack of available data.

On recommendation set #2, [1] states that the fact that all thousands of indicators/outputs do not address the specific needs of some RG is exactly the reason why the Regional Groups should define for themselves the policy/scenario framework according to which projects they would like to analyse. ENTSOG could not make the policy decision instead of the Regional Groups or other stakeholders, but is responsible for producing results that might be interesting to all groups or stakeholders. That being said, [1] tends to agree with the practical ideas in the recommendations of simplifying the number of indicators and scenarios for a “faster” reading, while still enabling a complete data provision. [1] however highlights the issue of complexity underlying the recommendations, and thus proposes more practical alternatives.

On recommendation set #3, [1] agrees with the recommendations to a point but suggests more details and examples are necessary. [1] also comments on the commercial sensitiveness of project costs, stating that the Regulation does not define them as sensitive or not sensitive. It would be a great step toward publication of costs if the Regulation were more specific. However, practically speaking, it seems that more and more promoters have agreed to publish their CAPEX estimates. As regards the recommendations on competing projects and cluster identification, [1] recognises the ambition but warns of a very high complexity, concluding that players in the industry are able to judge which projects are actually competitors with each other in most cases without further analytical help.

On recommendation set #4, [1] partially agrees with all recommendations but again highlights their underlying complexity and the need for more practical details. [1] recommends using the optimisation of a SxD Marshall cross per countries as a basis for all these improvements, but also suggests referencing other publically available models which could be used by ENTSOG.

6.1.2 Respondent [2]

[2] finds the document highly interesting and the result of a thorough work. They support any effort to improve this process. The comments made on the recommendations concern mostly the points where [2] sees opposition or gives details on their own viewpoint. However, their whole opinion of the report is not negative, as there are many points on which they agree and for which they did not post any comments. Overall, they support many of the recommendations in the document.

The general opinions of [2] on the CBA methodology and recommendations can be divided into two sections:

- First, the modelling tool and assumptions in the methodology are very poor and thus prevent any further refining of indicators, monetisation, etc. In reality, it should even prevent decision-makers from using or considering as realistic the methodology outputs. In particular, the EU bill indicator (the main indicator monetised) is plagued by many difficult assumptions: view on strategic behaviour, relevant scenarios on LNG prices, modelling of market spreads… An yone of these hypotheses or modelling choices can radically change the global picture of market prices across Europe, and even more the impact of each individual project of the PCI list on the EU bill. Therefore, the EU bill indicator will remain fragile, and giving a single EU-bill indicator as a single dimension yardstick to prioritise projects makes absolutely no sense.
- Second, monetisation should not be engaged and a demonetisation should instead be envisaged. This comes partly from the fact that the model is very fragile and will lead to extremely low confidence in any monetisation undertaken. As long as the current ENTSOG model is not fit for purpose, further efforts towards monetisation are worthless. This also stems from the difficulty in translating every indicator into money: weighing and mixing scenarios is a complex task (link with recommendation 2B) and modelling assumptions cannot be purely objective. In particular, many political and behavioural inputs are required. This means that the person in charge of the modelling and monetisation will have to take deeply impacting choices, in an opaque and technocratic way, which they may not even be conscious of. These difficulties may mean that the quality of monetised indicators is extremely poor and could lead to massive mistakes across the whole choices of the PC list.

Therefore, [2] encourages considering “dropping” the monetisation and modelling efforts in favor of a sounder, more transparent and easier-to-grasp multi-criteria analysis. This would be based on a short, qualitative and pedagogic assessment of the benefits of a given project on each country, along with some clear and understandable figures. This would be a simplified scorecard focused on indicators that do not rely on future price spreads. Decision-makers cannot rely on a strictly neutral and automated process and the information, if monetised and aggregated, would rely on too much “hidden” interpretation of political and behavioural inputs. Therefore, the political choices should be sent back to decision-makers in the clearest way possible. Indicators should not take into account the market test (in terms of price spread and price expectations) but the inefficiencies of the market that the PCI could solve: physical gas balance, security of supply issues, physical dependence on a single supplier, etc. The idea would be to see PCI as complementary to the market view on investment and not a replacement.

[2]’s comments show an interest in reshaping and improving the recommendations, focusing on:

- The value of consulting the market to complement ENTSOG’s work on the verification of PCI input data and the identification of clusters and competing projects (R3B & R3C). Concerning the verification of PCI input data in particular, ENTSOG is institutionally not in a position to challenge project promoters
- The difficulty in assessing and monetising market power, pf doing so with a single HHI measure (R1B & R4C)
- The recommendation of year discounting seeming too burdensome compared to the desired benefits (R2C)

6.1.3 Respondent [3]

[3] generally agrees with the recommendations in all four sets.

[3] highlights another major issue with the CBA methodology which would need to be addressed by another recommendation. According to [3], the quantified indicators cannot adequately represent the benefits to be derived from some projects, in particular projects aimed at addressing the thermal gap or diversification and dependence.

6.1.4 Respondent [4]

On recommendation set #1 on monetisation of benefits, [3] fully agrees that ENTSOG should male further efforts to monetise the benefits, and has pushed many times in this direction, but with little success. Thus [3] agrees with most of the recommendations in this regard. On recommendation 1D specifically, regarding monetisation of CO2 benefits, [3] has doubts on the benefits compared to the feasibility of the implementation, as it would require significant changes in ENTSOG's modelling tool.

[3]'s opinion on the second recommendation set is more contrasted. It agrees that efforts should be made to simplify the number of outputs, but only those that are monetised. Furthermore, it points out the actions already undertaken by ENTSOG. At the opposite, [3] rejects the proposal to simplify the number of scenarios, as it is difficult to predict their probability. It however stresses the possibility for Regional Groups to deal with this task.

On recommendation set #3, [3] agrees with the first three recommendations, even though it stresses the need to deal with governance issues. However, it rejects the need for recommendation 3D on indicators at MS level, which are, according to [3], already calculated by ENTSOG.

On recommendation set #4, [3] seems to agree with the need to improve the modelling assumptions, but highlights the risk of such an exercise being too complex. Thus, the first two recommendations should be simplified and the third rejected as not a priority.

[3] finally identifies a complementary recommendation, regarding the fact that the methodology only provides benefits if the project offers firm annual capacities. According to [3], this does not reflect the real capacity situation in Europe, and ENTSOG should not restrict its simulations to firm annual capacities.

6.1.5 Respondent [5]

[5]'s comments encompass all fifteen recommendations. They are very precise and technical, and thus deal mainly with how to reinforce the recommendations and implement them technically and practically. For example:

- R1B on market power (monetised) indicator: such an indicator should cover global correlations as suppliers aim for "security of demand" and Gazprom has only begun to develop new markets way from Europe. Additionally, it needs to secure how LNG is covered (despite multi-source).
- R2B on the relevant future cases: practicability should be a long-term aim. Firstly, transparency of the relevant scenarios should be increased by explicit indication and implementation in the project fiches which will be included in the TYNDP
- R3A on the formalisation of a project fiche: underlying requirements from the Regional Groups which are significant for the ranking of the project, added to the profile would form another important component of the analysis of the. Feasibility would be increased as these would be published data, strengthening the TYNDP in its relevance as a sort of "single source of truth"
- R3B on the verification of input data: NRAs could be responsible, in conjunction with national development plans. Any project not included could be examined by an independent third party.

[5] also highlights the recommendations for which feasibility would be quite low and/or the complexity would be too high, for example:

- R1B on market power (monetised) indicator: the implementation is technically difficult and may lead to distortions of decisions against the Russian source of supply.

Only a few comments seem to show whether [5] globally agrees with the recommendations being implemented:

- R1C on monetisation of disrupted demand: the current assumption for VoLL is set very high and leads to a risk of increased expansion for SoS reasons
- R2C on aggregation of yearly results: the implementation of a discount of indicators is very helpful and should also be easily applicable. This suggestion is worthy of support and helps to display reality more precisely.
- R4D on the use of common models: after amendments within the ENTSOG model this should apply immediately in order to compare the results of the calculations by TSOs with those from ENTSOG. Additionally, the comparability that would be enabled by using the same model would simplify the work of the Regional Groups and would strengthen the statement of the results in general

As a general comment, [5] suggests that ENTSOG members participate in the implementation of the methodology update both technically and financially. ENTSOG would thus gain more flexibility in its work as it would be able to hire more staff or hire a consultant in addition to ENTSOG members.

6.1.6 Respondent [6]

[6] appears to mostly agree with the analysis and proposals of the consultation report.

Regarding recommendation set #1 on monetisation of benefits, [6] agrees with monetising what is relevant but issues two safeguards (which are relevant to the analysis developed in the rest of the recommendation set): first, monetisation of benefits should be based on robust economic inputs to avoid a distorted vision of reality. Second, the improvements should be treated in parallel with improving market-modelling assumptions (recommendation set #4).

On recommendation set #2 on the outputs of the methodology, [6] agrees with the first two recommendations. For the first (reduce the number of indicators), they indicate that the simplification should imply keeping only those indicators that are strictly necessary, but that it should not impair an in-depth analysis of the impact of a given project. For the second recommendation (simplify the treatment of cases/scenarios), [6] agrees with a probability analysis of scenarios.

On recommendation set #3, [6] agrees with the analysis developed regarding the treatment of clusters and competing projects. [6] points out that for both a group of and single projects, all the investment costs necessary to obtain the benefits should be taken into account, e.g. the costs enabling transportation of gas by the adjacent TSO. One should also ensure that the periods when the capacity is interrupted do not coincide with the periods when the benefits of the project are expected. Note that these specifications also involve recommendation set #4, as they stress the need to consider the commercial and transportation constraints in the system more closely.

On recommendation set #4, as with the above indications, [6] points out that market modelling assumptions should be greatly improved for the monetisation of indicators to better reflect and improve the European gas market's functioning. For example, it is necessary to introduce transportation costs into the model, particularly as those costs may have the same order of magnitude as the spreads between competing gas sources.

Finally, [6] also identifies another recommendation not mentioned in the consultation report, for the indicator regarding LNG's role as a multisource. [6] justifies its stance with the support of the GLE position paper 'LNG as a multisource', in which GLE proposes improvements. In ENTSOG's methodology, LNG is considered as a single source, thus representing a global liquid market. This means that the current methodology does not fully capture the supply diversification and the security of supply advantages that LNG provides. Because of this wrong representation, the indicators regarding of Import Route Diversification, Supply Source Dependence and Supply Source Price Diversification give a distorted version of reality.

6.1.7 Respondent [7]

The methodology behind the gas PCI cost benefit analysis does not work at all and does not justify the work that has to be done by project promoters, Regional Groups and institutions.

In particular, the demand scenarios developed are neither useful nor realistic. If one applies all EU 20/20/20 policies and the recent winter package correctly, it is quite unlikely that demand will grow that much in the coming 20 years.

Instead of looking at demand forecasts, there should be more focus on identifying bottlenecks, existing and future, and in particular those generated by overcapacity (little bottlenecks, maybe some reverse in Eastern Europe flows since LNG can be easily transferred and therefore in other countries there will not be any real need).

Another issue: this winter has shown a lack of LNG availability despite plenty of capacity being available. Nobody has nominated the gas needed to meet demand without increasing market prices.

The recommendations would thus be:

- Greater effort in forecasting expected demand, including energy efficiency, declining HDD and renewables/distributed generation deployment
- See how natural gas is going to flow around the network and if a price differential could arise
- Rethink the need for more PCI from a cost versus benefits view point

7 Appendix D – ENTSOG's project fiche for the third PCI selection process

ENTSOG introduced a template for reporting the most important outputs of the CBA assessment. The reported project specific effects will be included in an annex to the TYNDP.

The main building blocks of the proposed template are as follows:

- Project description – technical and locational details of the investment item, other investment items belonging to the same project, and potential complementarities with other projects
- Benefits description – list of impacted countries, monetised benefits, non-monetised indicators
- CAPEX costs – to be reported by the promoter

The benefits are reported considering two reference networks called "low" and "advanced". The non-monetised indicators are reported for the short-term horizon assuming inputs that are consistent with the green evolution scenario. For the mid-term and long-term horizons the indicators are reported assuming different inputs that are consistent with the TYNDP scenarios. The project promoter can also add comments for clarification or to report specific benefits not already captured by the template.

The simulation-based outputs will be reported and compared against a threshold value defined by the Regional Groups. The threshold values are based on the identified infrastructure needs.

- Access to supply sources: the number of sourcing countries
- Dependence on LNG: the share of LNG in the sourcing mix
- Dependence on the main supply source (e.g. Russia): the share of a supply source in the total mix
- Disruption rate – route A: the share of demand that cannot be supplied in case of disruption of a transmission path
- Disruption rate – route B: the share of demand that cannot be supplied in case of disruption of a transmission path
- Disruption rate – without any supply disruption
- Import route diversification: HHI index for the diversification of paths that gas can flow through to reach a zone
- N-1

ENTSOG project fiche outputs are based on reported benefits in the economic template

- EU bill improvement
- Mitigation in disrupted demand
- Mitigation in N-1
- Gasification

Figure 2. First page of the project fiche for the 3rd PCI selection process

Group Fiche

Group reference	Group name - To be filled in by promoters
	CAPEX [Million EUR 2017] — To be filled in by promoters

Description - To be filled in by promoters

<please provide the necessary description>
<Should you have any change in the schedule compared to project submission in TYNDP please report it here>

Projects Constituting the Group

Project Code	Project Name	Promoter	Applied for 3rd PCI list	2nd PCI List No.

Complementarity - based on PCI call information

Project Code	Project Name	Promoter	Complementarity	Comments

Project Overview - based on TYNDP project data

Transmission Projects

Project Code	Country	Operator	Interconnection Point	Entry Capacity Increment	Exit Capacity Increment	Commissioning Year	Diameter (weighted average) [mm]	Length [km]	Compressor Power [MW]	Last Completed Stage	Enabler	Commissioning Year in TYNDP 2015

LNG Projects

Project Code	Country	Operator	Interconnection Point	Increment Capacity [GWh/d]	Commissioning Year	Expected Yearly Volume	Storage Increment	Last Completed Stage	Enabler	Commissioning Year in TYNDP 2015

Underground Storage Projects

Project Code	Country	Operator	Interconnection Point	Injection Capacity Increment [mcm]	Withdrawal Capacity Increment [mcm]	Commissioning Year	WGV Increment [mcm]	Last Completed Stage	Enabler	Commissioning Year in TYNDP 2015

Group Benefits - Pre-filled by ENTSOG based on selected needs by promoters as part of PCI call

Comments on benefits - To be filled in by promoters

<please provide the necessary information>

Impacted Countries - Pre-filled by ENTSOG based on Simulation results (below)

Economic Results in Million EUR/year [2017] - Pre-filled by ENTSOG based on monetised benefits from Economic template

	LOW			ADVANCED		
	Blue Transition	Green Evolution	EU Green Revolution	Blue Transition	Green Evolution	EU Green Revolution
EU Bill improvement						
Mitigation in Disrupted Demand						
Mitigation in N-1						
Gasification (by promoter)						

Figure 3. Second page of the project fiche for the 3rd PCI selection process

Simulation Results - *based on PS-CBA results*

Delta values are the incremental impact of the group up to (resp. down to) the threshold defined by Regional Groups

	LOW													
	2020		2025						2030					
	Green Evolution		Blue Transition		Green Evolution		EU Green Revolution		Blue Transition		Green Evolution		EU Green Revolution	
	Value	Delta	Value	Delta	Value	Delta	Value	Delta	Value	Delta	Value	Delta	Value	Delta
Access to supply sources (nb of sources)														
-														
Dependence to LNG (%)														
-														
Dependence to Russia (%)														
-														
Disruption Rate (%) - Ukraine route disruption														
-														
Disruption Rate (%) - Belarus route disruption														
-														
Disruption Rate (%) - Without any supply disruption														
-														
IRD														
-														
N-1 for ESW CBA (%)														
-														

	ADVANCED													
	2020		2025						2030					
	Green Evolution		Blue Transition		Green Evolution		EU Green Revolution		Blue Transition		Green Evolution		EU Green Revolution	
	Value	Delta	Value	Delta	Value	Delta	Value	Delta	Value	Delta	Value	Delta	Value	Delta
Access to supply sources (nb of sources)														
-														
Dependence to LNG (%)														
-														
Dependence to Russia (%)														
-														
Disruption Rate (%) - Ukraine route disruption														
-														
Disruption Rate (%) - Belarus route disruption														
-														
Disruption Rate (%) - Without any supply disruption														
-														
IRD														
-														
N-1 for ESW CBA (%)														
-														

8 Appendix E – Bibliography

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