european network
of transmission system operators
for gas

TEN-YEAR NETWORK DEVELOPMENT PLAN

2018

ANNEX D – METHODOLOGY

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GENERAL CONSIDERATIONS ON THE METHODOLOGY

The European gas infrastructure supports the completion of the Internal Energy Market and contributes to the achievement of the European climate and energy policies, where sustainability represents one of the major pillars together with security of supply, competition and market integration.

The objective of the CBA methodology is to provide guidelines to be applied for the cost-benefit analysis of projects and more generally of the overall gas infrastructure. This methodology reflects the specific provisions from the Regulation and aims to ensure their consistent application by all parties involved.

The primary field of application of this CBA methodology is within the TYNDP process and the selection of projects of common interest.

The TYNDP comprises of an assessment of the gas system and gas infrastructure projects and subsequently of an assessment of the impact of gas infrastructure projects.

The ENTSOG 2nd CBA Methodology is based on a multi-criteria analysis, combining a monetised CBA with non-monetised elements to measure the level of completion of the pillars of the EU Energy Policy from an infrastructure perspective.

1 ASSESSMENT FRAMEWORK

1.1 SCENARIOS

The assessment framework must be in line with the provision of Annex V(1) of the Regulation, which requires that the input data set represents years "n+5, n+10, n+15, and n+20 where n is the year in which the analysis is performed".

In line with the guidelines included in the 2nd CBA Methodology, in order to be able to evaluate projects impact against the targets set by the European policies while keeping the number of results reasonable, by default the assessment framework is defined for 5-year-rounded years (e. g. 2020, 2025, 2030, 2040).

The TYNDP 2018 contains different demand scenarios, out of which the data for the three scenarios are selected as input data for the assessment (figure 1.1).

For details see the demand chapter of the TYNDP2018 Scenario report[1].

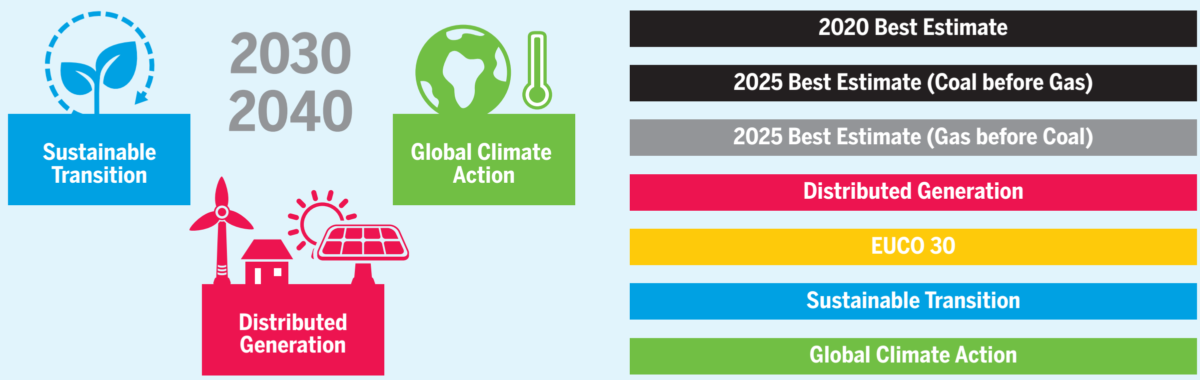

Figure 1.1: Abbreviations and colour code of the different scenarios

1) https://www.entsog.eu/public/uploads/files/publications/TYNDP/2018/entsos_tyndp_2018_Final_Scenario_Report.pdf

1.2 NETWORK AND MARKET MODELLING ASSUMPTIONS

1.2.1 APPROACH TO MODELLING

ENTSOG has developed a modelling approach since 2010, based on a specific structure facing the need to consider simultaneously network and market dimensions. The network model represents the gas market within the geographical scope of the TYNDP. Arcs for the network modelling, including the relevant capacities for each infrastructure level can be found in ANNEX CD.

Entry/Exit model

The geographical scope is the European Union and other countries part of the European Economic Area. In the following, the term "Zone" will be used generally to refer to a country. In some instances, it refers to a balancing zone.

The basic block of the topology is the balancing Zone (or Zone) at which level demand and supply shall be balanced. The Zones are connected through arcs representing the sum of the capacity of all Interconnection Points between two same Zones (after application of the "lesser of" rule). Interconnectors with specific regime (e. g. BBL or Gazelle) are represented by Zones with no attached demand.

Focus on a Zone

The supply and demand balance in a Zone depends on the flow coming from other Zones or direct imports from a supply source. Gas may also come from national production, underground storage and LNG facilities connected to the Zone. The sum of all these entering flows has to match the demand of the Zone, plus the need for injection and the exit flows to adjacent Zones.

In case the balance is not possible, a disruption of demand is used a last resort virtual supply. This approach enables an efficient analysis of the disrupted demand.

Objective function

The primary objective of the modelling is to define a feasible flow pattern to balance supply and demand for every node, using the available system capacities defined by the arcs. In addition, the use of price assumptions in the input data supports the definition of a feasible flow pattern minimising the objective function[2)] representing costs to be borne by the European society.

This optimum differs from national optimums which are potentially not reached through the same flow pattern.

The minimisation of the objective function is based on the concept of marginal price of a node. It is defined as the cost of the last unit of energy used to balance the demand of that node.

1.2.2 NETWORK ASSUMPTION AND DESCRIPTION OF THE GAS INFRASTRUCTURE

The topology of the gas infrastructure as developed and regularly updated by ENTSOG, is used in the TYNDP process. The topology refers both to the existing and planned infrastructure. The corresponding capacities are made publicly available in Annex D.

The EU-level network modelling used for TYNDP 2018 reflects market areas transmission, storage and LNG capacities as well as internal specificities if relevant from an infrastructure assessment perspective. Capacities as provided by network operators and project promoters to ENTSOG for the description of the gas infrastructure are calculated based on hydraulic modelling.

This EU-level topology reflects at least the following European gas infrastructure:

- Transmission Infrastructure
- LNG terminal infrastructure
- Underground storage infrastructure
- Connection to indigenous production infrastructure
- The gas infrastructure in countries adjacent to the EU as much as the infrastructure in these countries contribute to imports to or exports from Europe.

2) Use of the Jensen solver as developed by Paul Jensen for the Texas University in Austin (https://www.me.utexas.edu/~jensen/ORMM/index.html)

Infrastructure levels

The selection of the proper level of development of infrastructure is key for the identification of infrastructure gaps and a reliable system and project assessment. In line with the 2nd CBA Methodology provisions, the following infrastructure levels are considered.

Low infrastructure level, the reference grid

The low infrastructure level is formed by existing infrastructure and projects with FID status representing the minimum level of infrastructure development considered for the identification of infrastructure gaps and against which to assess projects.

TYNDP 2018 assesses what the current infrastructure, complemented with FID projects, already achieves and which are the remaining gaps that may trigger additional investment.

Advanced and PCI infrastructure levels

Once the infrastructure gaps are identified, the assessment of the European gas system is complemented by assessing the overall further impact of additional infrastructure levels:

- the Advanced infrastructure level including existing infrastructure and projects with FID and Advanced status (projects to be commissioned before 2025, which have started the permitting process or their Front-End Engineering Design before the TYNDP 2018 data collection).
- the PCI infrastructure level gathering all the projects from the 3rd PCI list, although it includes projects of very different maturity.

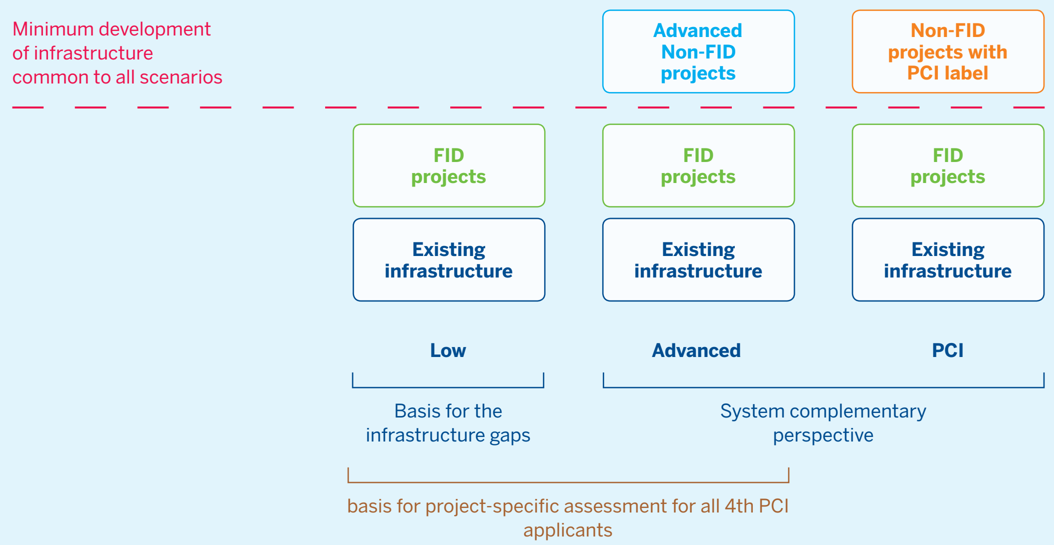

Figure 2.2: Infrastructure Levels

1.2.3 MARKET ASSUMPTION

In the 2nd CBA Methodology, the following elements are recommended to be considered:

- Infrastructure tariffs: transmission system operators, LNG system operators and storage system operators tariffs incurred by gas infrastructures users. Capacity and commodity charges have been considered in view of flow modelling perspective, as well as possibly the share of capacity booked upfront on medium to long-term basis to accurately reflect the impact of tariffs on the use of capacities;
- Information on gas supply prices regarding variability among supply sources or import routes and possibly long-term supply contracts, provided data is available.

2 INPUT DATA ITEMS

2.1 TOTAL GAS DEMAND

The total gas demand is comprised of the final demand (Industrial, Residential & Commercial and Transport) and the gas demand for power generation. The evolution of the total gas demand in areas with existing gas demand only depends on the scenario.

For gas demand in new consumption areas, the gas demand depends on the infrastructure connecting this area to gas supply.

In addition to the demand within the geographical scope of the TYNDP, exports have also been considered.

Details on the gas demand can be found in the demand chapter of the TYNDP report and in Annex C.

2.2 TARIFFS

The TYNDP 2018 assessment, considers at least this minimum set of tariff components:

- **Capacity tariffs:**

  tariffs paid by network users based on the capacity they book during a specific time period. This tariff does not depend on the actual usage. Most TSOs currently apply such capacity tariffs. Typically, a capacity tariff is defined in

  $$\mathrm{EUR/(quantity/period)/runtime_d}$$

  Where:

  $\mathrm{quantity/period}$ is a capacity unit. This should be converted into "energy" units. In some countries, the capacity tariff is defined in "energy per period" while in others it is defined in "volume per period", requiring the use of a specific Calorific Value to move to the same unit.

  $\mathrm{runtime_d}$ is the duration of the capacity product considered.

- **Commodity tariffs:**

  tariffs paid by network users in relation to their actual gas flows during a specific time period. A number of TSOs currently apply such commodity tariffs.

  Commodity tariff is expressed as

  $$\text{Commodity tariff} = \mathrm{EUR/quantity}$$

  Where:

  $\mathrm{quantity}$ is the amount of gas flowed for the assessed period.

  For example, in case of EUR/GWh it refers to the tariff incurred for a flow of 1 GWh.

- **User "load factor":**

  to convert capacity tariffs into tariffs per unit of commodity/gas flowed based a load factor value of 100 % has been used. By considering an open and efficient market, assume that network users use fully the capacity they book and that gas is flowed at a uniform rate throughout the year. ACER uses the same approach for their annual Market Monitoring Report (MMR), where they posit a load factor of 100 % too. This is clearly mentioned in Annex 1 of MMR 2016 published in 2017, and is referred to in the up-to-date MMR 2017 published in 2018 (cf. MMR 2017, page 45/67).

The resulting equivalent commodity tariffs and consequently the flows induced by those are sensitive to the value of the load factor used. In order to guarantee an adequate comparison of the assessment results a unique common load factor has been used among existing infrastructures.

- **Duration of the capacity contract:**

  in relation with the topic of capacity tariffs, the duration of the capacity contract is one of the elements to consider. In TYNDP 2018 it was assumed that yearly products were used. This is for three reasons. First, yearly tariffs at IPs correspond to the so-called 'reference prices' in the Tariff Network Code (TAR NC), and they are the basis on which all short-term tariffs are calculated. Second, the Implementation Monitoring and Baseline for Effect Monitoring of the Tariff Network Code document (cf. page 60/78), which was published by ENTSOG in March 2018, shows that for many TSOs participating in data collection for that report, yearly bookings still represent a significant majority of total bookings at IPs (75 % of total capacity bookings as of 2017), despite a probable and gradual shift to short-term bookings. Third, ACER also considers yearly products in their MMR 2017 as the reference for their tariff simulation at IPs. Therefore, the assumed duration of the capacity contract is one year in TYNDP 2018.

- **Unit of measure to be used:**

  all tariff elements should be converted to a common unit of measure. Such unit should be defined in Euro per volume, expressed in energy unit (EUR/MWh).

- **Exchange rate:**

  for countries using another currency than the Europa common reference to exchange rates provided by the European Central Bank[3] at 1 January 2018 has been used.

For this exercise, the capacity tariff is not used directly, but converted in a commodity cost, and the following formula will be applied (factoring some preliminary unit conversions where needed):[4]

$$\text{Transmission Tariff} = \frac{\text{Capacity Tariff}}{\text{LF}} + \text{Commodity Tariff}$$

Where LF is the user load factor, with a value between 0 and 1, but strictly higher than 0.

In addition, for cases where several IPs exist at a border between two entry-exit systems, it was used the capacity-weighted average of the individual IP tariffs of the points in order to define a single value at the border level. For established Virtual Interconnection Points (VIPs) as per the Capacity Allocation Mechanism Network Code (CAM NC)[5], the tariff published at each VIP was used.

- **LNG terminals tariffs (or charges)**

  GLE kindly provided ENTSOG with two documents to refer to regarding the existing LNG infrastructure tariffs.

  The main document was the CEER report from December 2017.

  As mentioned in this report, the tariff structure of the bundled (unloading + LNG storage + regasification service) varies significantly between terminals. The report tries to have easier to compare values by considering "*the costs derived from the application of the tariff for the bundled (unloading + storage + regasification) service, to a 1,000 GWh LNG cargo, which regasifies the whole LNG amount in a period of 15 days.*".

  Then, the case study is repeated, "*considering not only the terminal bundled service tariffs (unloading + storage + regasification), but also the entry tariffs from LNG terminals to the transmission network (that is, the tariffs that users have to pay to introduce gas form LNG terminals to the relevant balancing zone.*"

  The results from this case study are used to derived tariffs for LNG infrastructure in the TYNDP2018

3) https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/index.en.html

4) https://transparency.entsog.eu

5) Commission Regulation (EU) 2017/459 establishing a network code on capacity allocation mechanisms in gas transmission systems and repealing Regulation (EU) No 984/2013

Storages tariffs (or charges)

For the SSO tariff, GSE provided ENTSOG with a standard value of 1.5 euro per MWh/d (bundled product for injection and withdrawal charges along with the working volume charge).

In the TYNDP, SSO tariff is assumed equal to 1.5 €/MWh which corresponds to the seasonal gas price spread.

However, GSE highlights that currently the seasonal spread is used as the main driver for the value of storage revealed by the market. In the recent years, the spread has decreased and remain low. As a result, in the upcoming ten years, there is a risk that too much storage may close or close in the wrong locations.

This possible reduction of gas storage capacity has not been projected in the TYNDP as there are only limited data available and SSO do not publish in advance sites that are going to shut down.

Storage facilities provide value to the energy system in four key ways:

The seasonal value

The difference between futures gas price in summer and futures gas price in winter (also known as summer-winter spread or seasonal spread) is the key value which is recognized by the market.

It allows market participants to purchase and store gas in the summer when prices are normally lower and withdraw and deliver it during the winter when the prices are normally higher.

In fact, this value looks at the seasonality of prices and represents the expected premium of the price of gas to be delivered during the winter period with respect to the price of gas to be delivered during the summer period.

The trading value

It allows market participants to exploit the difference between spot and futures gas prices, by assuming an increase of the spot price in a tight situation that can move above the futures price.

In fact, this value looks at volatility of prices (price movements) that can be exploited by traders especially during periods of high volatility or can also be used as a natural hedge to price fluctuations. In the second case, it acts as an insurance against the risk of market price spikes, with a view of containing gas procurement costs.

The insurance value

Gas storage plays a key role in ensuring security of supply by reducing the risk of supply disruptions even in unexpected emergency situations. The market cannot predict unexpected events.

The system value

This means that pipeline systems integrated with gas storage can be sized optimally resulting in lower costs for the end-users and allows pipeline upstream of storage to operate at high load factors year-round, despite wide swings in demand. By providing alternative gas volumes already in place close to demand centres, it can react on very short notice and at a large scale.

The seasonal spread (the metric used by shippers to value gas storage) only reflects the seasonal value, whereas it does not recognize the trading, insurance and the system values. These externalities are not internalised within the market price.

Project tariffs

To ensure a comprehensive and sound assessment of gas infrastructures, tariffs borne by the infrastructure users from the commissioning of an infrastructure project were considered in addition to the tariffs from the already existing infrastructure. This is relevant both

- from a system assessment perspective, as the assessed system includes a number of projects, and serves as counterfactual for the incremental project assessment;
- from a project assessment perspective.

How much of the costs of a project will be reflected on an interconnection point is subject to various uncertainties such as: the share of the project cost that will be directly reflected on the IP tariffs (which will presumably depend on the type of need the project fulfills); whether the project will be subject to Cross-Border Cost Allocation (CBCA) with part of its costs covered in a different country; whether the project will benefit from the European Union's financial assistance. Despite all these uncertainties, accurate system and project assessment impose to make an assumption for all the different projects considered. For this reason, the key element will be to fix a reference to be used consistently across projects, to ensure comparability.

For TYNDP 2018 the 'combined approach' from the 2nd CBA Methodology was applied. It means that, to derive project tariffs, it combines tariff information at neighbouring existing points (IPs, LNG terminals or SSO sites). More precisely, the combined approach allows to infer tariffs, based on a decision tree, depending on the availability of tariff information at neighbouring existing points.

Regarding any existing and future point connecting entry-exit systems A and B, the IP tariff value to exit A and enter B is defined as per the following decision tree:

1. The actual exit tariff from A + the actual entry tariff in B at the corresponding point; if not applicable or available, then
2. The average exit tariff from A + the average entry tariff in B at all existing points connecting A to B, if any; if not applicable or available, then
3. The average exit tariff from A to any system + the average entry tariff in B from any system; if not applicable or available, then
4. The average exit tariff from any system to system B + the average entry tariff in B from any system; if not applicable or available, then
5. The average exit tariff from A to any system + the average entry tariff in any system from system A; if not applicable or available, then
6. In the last resort, the average value of all tariffs calculated following steps 1, 2, 3, 4 or 5.

The figures below give an illustration of step 2 described above regarding IP tariffs.

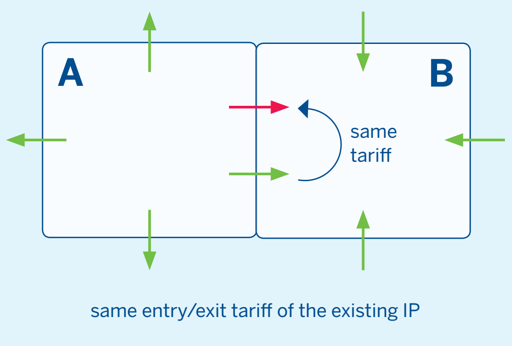

Figure 2.1: Combined approach in case of an existing IP at the considered border

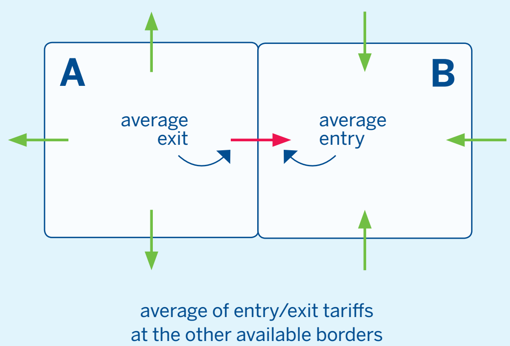

Figure 2.2: Combined approach in case of no existing IP at the considered border

As for LNG tariffs, the tariff value for any LNG terminal corresponds to the following decision tree:

1. The actual LNG regasification tariff at this LNG terminal; if not applicable or available, then
2. The average regasification tariff in the country; if not applicable the average regasification in Europe.

As for SSO tariffs, the tariff value for any SSO point corresponds to the standard SSO tariffs provided by GSE.

Long Term Capacity Booking

For transmission tariffs, as explained above, TYNDP 2018 calculated the commoditised cost of using the TSO capacity, plus the actual commodity tariff if any.

For LNG tariffs, TYNDP 2018 considered the data available on LNG websites, corrected with a coefficient, which takes into account the historical values of the terminal use.

Long Term Supply Contracts

Long-Term Supply Contracts represent commercially sensitive information that are beyond the remit of TSOs, in line with the unbundling principle, and may not be publicly available. Those contracts are subject to renegotiation at or before their term and the outcome of such renegotiation is uncertain. Therefore, Long-Term Supply Contracts are not considered in TYNDP 2018.

2.3 SUPPLY PRICE CURVE

Within the modelling tool, each supply source (for LNG different LNG basins[6] are considered) is described as a supply curve reflecting the supply potential and the gas price in the respective scenario for the given year.

Reference Price

Supply "Central" price derived

- LNG: price is based on the Netback Asia approach (Japan). For Qatar LNG we consider Japan LNG price plus correction to keep plausible exports compared to historical flows
- Norway pipe: Norway pipe price is competitive with LNG in Atlantic countries
- Algerian pipe: Based on LNG Africa North prices
- Libyan Price: based on Algerian Pipe price in Italy
- Azeri gas: as expensive as Algerian gas and Libyan gas in Italy while factoring Long Term Contract Booking's (LTCBs)
- Russian Gas for North West: Russian Pipe and Norway pipe are competitive in Germany
- Russian Gas for East: Russian Pipe plus spread from EC average of the last four Quarterly Report
- Turkey: price is competitive with Algerian LNG price in Greece

An Example of the merit order of the supply sources in the Reference case is shown in figure 2.3 (for the purpose of this example the Japan reference price here shown is purely indicative). The range of each supply is defined by the consideration entry cost to deliver the supply to EU as well as the shipping cost for LNG.

The above assumptions include the feedback received from the participant of the 13 February working session on modelling and market related assumptions[7].

This represents a significant improvement compared to TYNDP 2017 where all supply sources were based on the same reference price. The new approach allows for a better reflection of supply prices differences.

However, since the uncertainty related to the supply price is high, especially in the long-term, the projects assessment is complemented by the analysis of different supply price situation (called supply configuration) where one specific source is considered being more expensive or cheaper than the others. More details on the different supply price configuration considered for TYNDP 2018 are available below.

In order to adjust prices as closely as possible to reality winter supply curves are shifted upward with a summer-winter spread consistent with the storage tariffs.

In order to analyse the sensitivity of countries to changes in gas prices TYNDP2018 considers the following supply configuration

- LNG MIN/MAX where LNG minimisation corresponds to high LNG price and LNG maximisation corresponds to low LNG price
- RU MIN/MAX where Russia Minimisation corresponds to high Russian Price and Russia maximisation corresponds to low Russian Price
- SOUTH MAX (DZ, LY, AZ, NA LNG) where South maximisation corresponds to low South gas supply price. In TYNDP2018, we do not consider SOUTH Minimisation.

6) Australia, Peru, North-Amercia, Sub-Sahara, Middle-East, Trinidad and Tobago

7) https://www.entsog.eu/events/tyndp-2018-2nd-cba-methodology-working-session-entsog-consult-stakeholders-on-modelling-and-market-related-assumptions

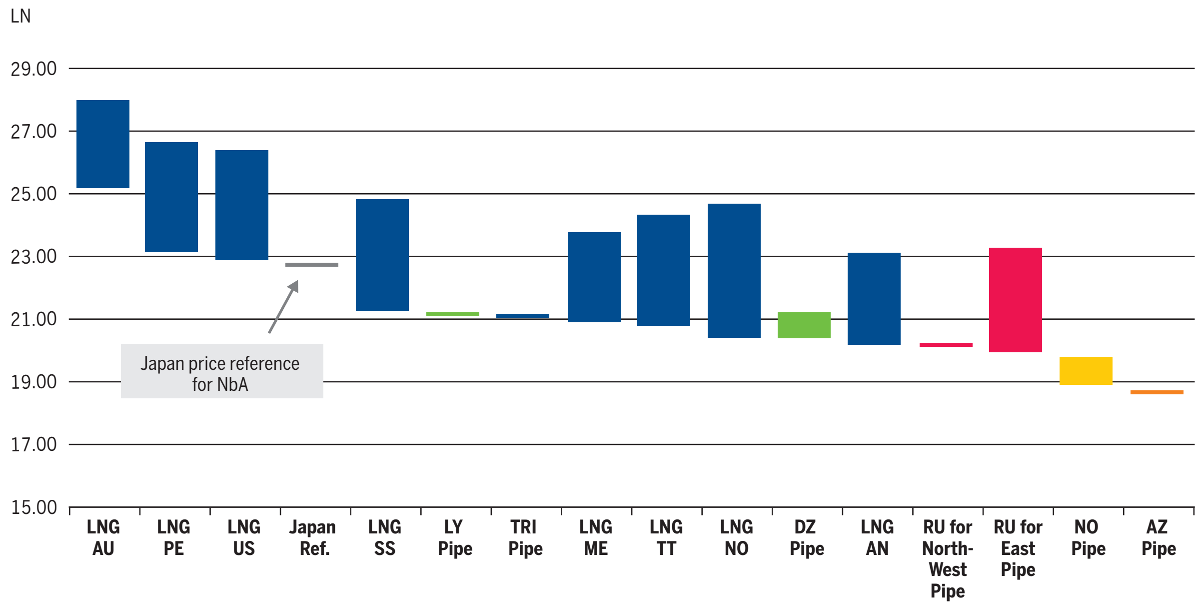

Figure 2.3: Example of the merit order of the supply sources in the Reference case (for the purpose of this example the Japan reference price here shoed is purely indicative). The range of each supply is defined by the consideration entry cost to deliver the supply to EU as well as the shipping cost for LNG.

2.4 GAS SUPPLY POTENTIAL FROM IMPORT SOURCES

For each climatic case and each import supply sources, a range is defined as:

- **Minimum:**

  The Minimum Supply Potential as defined in the TYNDP 2018 scenario report.

- **Maximum:**

  The Maximum Supply Potential as defined in the TYNDP 2018 scenario report.

- **Maximum for LNG:**

  – Flexibility from the LNG tanks was used as additional LNG supply for Peak day and 2-week cold spell in both weeks.

  – In the first week, the global LNG flows are limited to the level observed in Average Winter from the previous modelling of the whole year.

  – In the second week, additional cargos can arrive allowing supply to reach the daily maximum supply potential of Average Winter.

The actual use of supply is a result of the model taking into account the minimum and maximum constraints.

The working gas volume of the storages starts and ends with the same level (30 %) for the whole year. The modelled storage fill rate at the beginning of winter is determined by the whole year simulation. The working gas level, the withdrawal capacities and the withdrawal curves define the constraints for the storage use during high demand situations. The actual use of storages is a result of the model taking into account these constraints.

2.5 EXISTING INFRASTRUCTURE (CAPACITY, STORAGE VOLUMES)

The existing transmission infrastructure is defined as the firm capacities available on a yearly basis as of 1st January 2018. In addition to the existing transmission infrastructure, the existing LNG and storage infrastructure is considered (chapter 2.7).

The transmission infrastructure is defined by the technical capacities between countries. For this, the technical capacities at interconnection points between these countries are aggregated after the application of the lesser-of-rule[8].

LNG infrastructure is defined by the regasification capacity along the average year and during high demand situations. The LNG tank volumes have characteristics; a flexibility factor defines the share of the tank volume that can be expected to be available during high demand situations. This flexibility has been defined by GLE.

In addition to the working gas volumes and the withdrawal and injection capacities, withdrawal and injection curves for storages are taken into account. These curves define the abilities of storages to withdraw or inject gas depending on the fill level. The curves for the TYNDP 2018 have been defined in cooperation with GIE.

2.6 ROUTE DISRUPTION

Most of the gas consumed in Europe is imported through pipelines and LNG cargos. The disruption of a supply route can have a significant impact on the infrastructure and its ability to satisfy demand.

The assessment focuses on the disruptions listed in the Union-wide simulation of gas supply and infrastructure scenarios carried out for the risk assessment defined in Article 7, Regulation (EU) 2017/1938 (hereafter SOS Regulation) concerning security of gas supply. More specifically, those disruption cases expected to show a risk of demand curtailment in the Union-wide simulation are assessed in this section:

1. Ukraine route
2. Belarus route
3. Imports to Baltic states and Finland
4. Algerian import pipelines

Note: the assessment is limited to the impact of a supply disruption occurring during a peak day and a 2-week cold spell. The SOS Regulation considers also disruption with a longer duration as assessed in the Union-wide SoS simulation report.

For disruption simulations, demand curtailment follows the logic of unified allocation. In unified allocation, all member States within the risk group cooperate by avoiding a demand curtailment to the extent possible by transporting other supply and furthermore by sharing the curtailment equally in such a way that they try to reach the same curtailment rate.

Figures 2.4 – 2.7 show the risk groups.

2.7 DATA COLLECTION

Project data has been collected from promoters between 31 January 2018 and 28 February 2018. For each TYNDP ENTSOG collects information on existing infrastructure capacities directly from TSOs (for transmission infrastructures) as well as from GIE[9] (for LNG regasification terminal and storage facilities). For TYNDP 2018 the existing capacity was collected as of 1 January 2018.

8) The lesser-of-rule applied by ENTSOG aggregates available capacities on the two sides of a point to generate consistent capacity for modelling purposes. In case operator A submits an exit capacity with the value of 100 and operator B submits at the same point but in entry a capacity with value of 50, the latter will be considered as final value.

9) Gas Infrastructure Europe.

Figure 2.4: Risk group for Ukraine transit disruption (Austria, Bulgaria, Croatia, Czech Republic, Germany, Greece, Hungary, Italy, Luxembourg, Poland, Romania, Slovenia and Slovakia)

Figure 2.5: Risk group for Belarus disruption (Czech Republic, Belgium, Finland, Estonia, Germany, Latvia, Lithuania, Luxembourg, Netherlands, Poland and Slovakia)

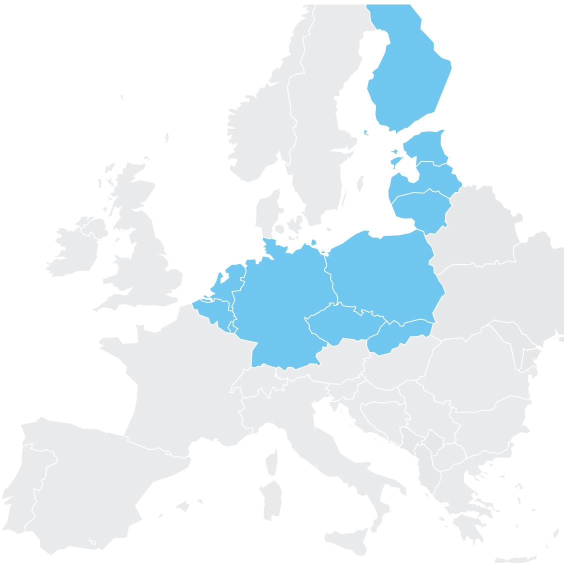

Figure 2.6: Risk group for Baltic states and Finland disruption (Estonia, Finland, Latvia, Lithuania and Czech Republic, Belgium, Germany, Luxembourg, Netherlands, Poland and Slovakia*)

Figure 2.7: Risk group for Algerian pipes and LNG disruption (Austria, Croatia, France, Greece, Italy, Malta, Portugal, Slovenia and Spain)

* Compared to ENTSOG EU-wide SoS simulation, the risk group for Baltic States and Finland considered in TYNDP 2018 has been extended to other countries belonging to the Belarus risk group. The FID project GIPL is part of the low infrastructure level and connects the group made up of the Baltic states plus Finland to Poland and therefore allows for cooperation between all concerned countries.

2.8 GENERAL AND TECHNICAL INFORMATION

The general and technical information covers the price information for gas depending on the year and scenario as well as project-specific data like the capacity increment, the expected commissioning date, the FID status, the advanced status and the PCI status according to the 2017 selection (the 3rd PCI List). This information was submitted by the project promoters during the project data collection and is used to aggregate the different infrastructure levels based on the individual projects.

3 INDICATORS

The Regulation has identified four main criteria: market integration, security of supply, competition and sustainability. The European system and projects are assessed against those criteria.

As part of the PCI selection process, this will allow to check if a project significantly contributes to at least one of four criteria[10)].

In line with those criteria, the 2nd CBA Methodology recommends considering the following potential benefits of gas infrastructure projects:

- Reduction of the cost of gas supply and price convergence between markets;
- Reduction in supply dependence and increase of the number of supply sources that a country has access to;
- Enhancement of market integration;
- Contribution to security of supply;
- savings in CO_2 emissions, related to
  - integration of renewable energy (including biomethane and other synthetic gases)
  - and/or substitution of higher-carbon energy sources (like coal in power generation) by gas;
- Replacement of more expensive fuels in new or existing markets.

The above-mentioned benefits can be:

- Quantified, measured through specific indicators;
- Quantified and monetised, assigning a specific monetary value;
- Qualitative, when benefits cannot be quantified.

The 2nd CBA Methodology is based on a multi-criteria analysis, combining a monetised CBA with non-monetised elements. In line with this concept, the above benefits are taken into account along with cost information, allowing for a level-playing field and comprehensive assessment of the European gas system and of projects on all criteria.

This can be summarised in figure 3.1 below.

Some indicators are used only for the project-specific cost-benefit analysis (PS-CBA) while others are used for both the system assessment and the PS-CBA.

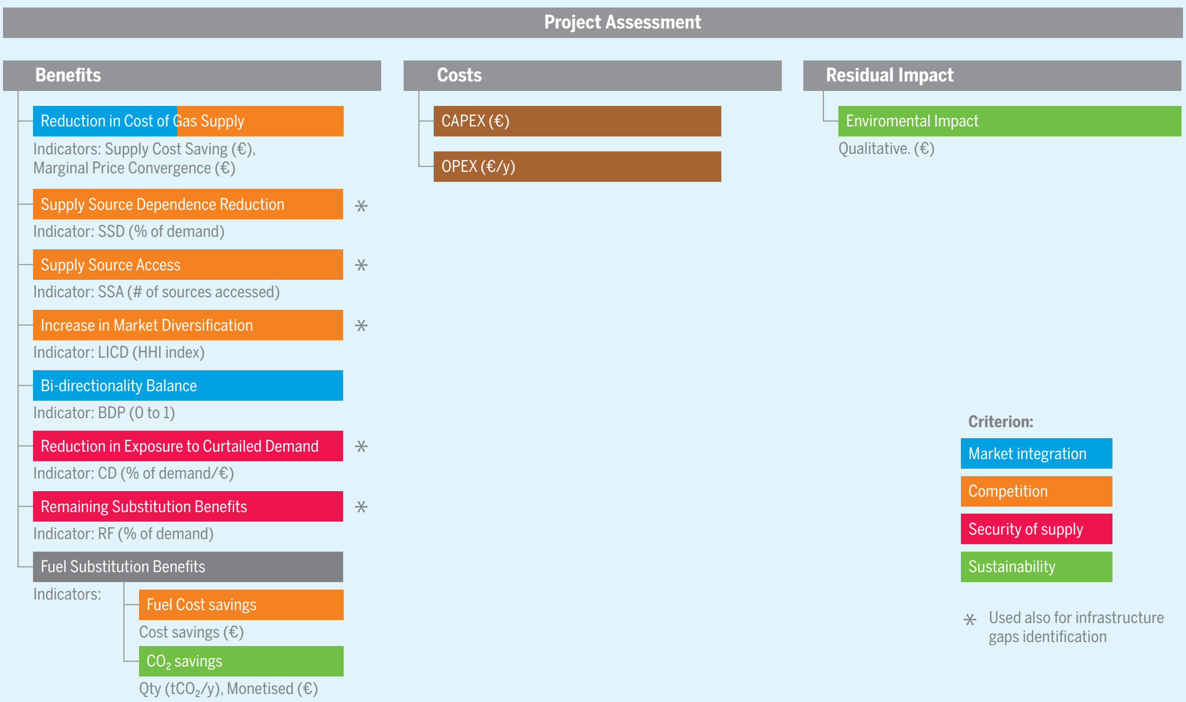

Figure 3.1: CBA metrics and Regulation criteria

10) Art. 4 of Regulation (EU) 347/2013.

3.1 INDICATORS USED FOR ASSESSMENT IN TYNDP

In the definition of the indicators, the term capacity corresponds to the technical firm capacity.

3.1.1 SINGLE LARGEST INFRASTRUCTURE DISRUPTION (SLID)

This section investigates the impact of the disruption of the single largest infrastructure of a country during a Peak day.

The SLID computation can be presented as an indicator or a disruption configuration. Either way, the result is the disrupted quantity measured following the disruption of the single largest infrastructure entering a given country (excluding storage and national production).

The SLID is computed in a peak day situation, with the associated supply and national production in this configuration.

This computation allows to identify potential bottlenecks for the considered country and the other European countries.

The simulation of the single largest infrastructure of the different countries look at the impact of such disruptions at a European level and replaces while improving the former N-1 indicator of TYNDP 2017 that was a pure capacity-based indicator limited at country level.

3.1.2 LNG AND INTERCONNECTION CAPACITY DIVERSIFICATION (LICD)

This indicator intends to look at the diversification from the perspective of market integration. It measures the diversification of paths that gas can flow through to reach a market area. Import routes are not considered and capacities are capped by the country demand.

The LICD is an HHI indicator[11)] and ranges from 0 to 10,000. The lower the value, the better the diversification is. Where a market would have two borders the LICD cannot be lower than 5,000. For a market having three borders the LICD cannot be lower than 3,333.

The indicator is calculated following the below formula.

$$\mathrm{LICD} = \left(\frac{\text{LNG border}}{\text{Total Capa border}} * 100\right)^2 + \sum_{1}^{\text{N borders}} \left(\frac{\text{Capa border}_1}{\text{Total Capa border}} * 100\right)^2$$

Where

$$\text{Capa border}_i = \min\left[\sum_{k}^{\mathrm{IP}} \mathrm{IP}_k\text{border}_i\,, \text{Dyearly}\right]$$

DYearly is the gas demand (GWh/d) of the area in average year conditions. This is considered in order to avoid that capacities exceeding the area demand (such as in transit routes) would distort the indicator output showing an unduly high level of the indicator.

$\mathrm{IP}_k\,\text{border}_i$ is the capacity at the interconnection point IP_k at the border_i with the neighbouring area i.

And where

$$\boldsymbol{LNG\ border = min\left[\sum_{m} LNG\ terminal_m, Dyearly\right]}$$

LNG terminal_m is the send-out capacity of the LNG terminal m.

$$\text{Total capa border} = \text{LNG border} + \sum_{i=1}^{\text{N borders}} \text{Capa border}_i$$

All capacities should be considered after application of the lesser-of-rule.

11) Herfindahl-Hirschman index.

3.1.3 REMAINING FLEXIBILITY (RF)

In addition to assessing demand curtailment risks, the remaining flexibility assesses how resilient to climatic stress a country is. The remaining flexibility aims at capturing the extra supply flexibility a country can access through its infrastructure.

This flexibility is measured by the increase of demand an area can accommodate before an infrastructure or supply limitation is reached somewhere in the European gas system. This indicator is to be calculated independently area-by-area under stressful situations (such as climatic and supply or infrastructure stress).

The value is expressed as a percentage of the demand for a given area. The higher the value, the better the resilience.

A zero value would indicate that the country is not able to fulfil any additional demand without perturbating other countries and a 100 % value would indicate that it is possible to supply twice the level of the demand.

3.1.4 DEMAND CURTAILMENT AND CURTAILMENT RATE (CR)

To achieve the energy pillar of Security of Supply it is important to identify whether there are countries in Europe that risk to face any demand curtailment (i.e. to be not fully supplied). The analysis should allow to identify where projects provide benefits coming from mitigating possible demand curtailment.

This indicator has been calculated considering cooperation among countries: under such cooperative approach, areas within a given region will share the same level of curtailment (if any) unless an infrastructure-related limitation prevents them to do so. This cooperative approach is in line with Regulation (EU) 2017/1938 on Security of Supply.

Identification of demand curtailment risk should be performed individually for:

- Normal (climatic) conditions
- Climatic stress conditions, in case of extreme temperatures with lower probability of occurrence than normal conditions (e. g. occurring with a statistical probability of once in 20 years, 1/20);
- Supply stress conditions, in case of supply stress due to specific route disruptions (e. g. Russian transit trough Ukraine);
- Infrastructure stress conditions, in case of disruption of the single largest infrastructure of a country. Curtailment Rate (CR) is the ratio of demand curtailment by the demand.

A value of 600 EUR/MWh has been used in TYNDP 2018 as Cost of Disruption of Gas (CoDG) to quantify the monetary impact of any avoided demand curtailment. This value was derived as:

$$\text{CoDG} = \text{Total EU28 GDP/Gross Inland Consumption}$$

In the simulations to determine the amount of possible curtailed demand a uniform CoDG value ensure that countries will act in a cooperative way significantly reducing the impact of very sever disruptions in the most vulnerable countries.

Additionally, using a uniform value of CoDG across the countries ensures comparability and harmonised assessment of projects.

When applying the 600 EUR/MWh value to the avoided curtailed demand, ENTSOG has considered a 5 % probability (1-in-20 years) in order to take into account the lower probability of occurrence of peak and stressful situations.

3.1.5 SUPPLY SOURCE DEPENDENCE (SSD)

The SSD indicator aims at identifying countries showing a strong dependence to a specific supply source and allows to identify cases where this dependence is related to an infrastructure bottleneck (physical dependence).

It should be calculated vis-à-vis each source under a whole year.

The lower the value of SSD, the lower the dependence.

As for the curtailed demand and rate, this indicator has been calculated considering cooperation within relevant regions: under such cooperative approach, areas within a given region will share the same level of dependence unless an infrastructure-related limitation prevents them to align their dependence.

The Supply Source Dependence to source S is calculated as follows (steps 1 to 4 are repeated for each source):

1. The availability of source S is set down to zero
2. The availability of the other sources remains in line with the defined supply assumptions
3. Modelling of the European gas system under the whole year

The Supply Source Dependence of the Area Z to the source S is defined as:

$$SSD_{Z,S} = \frac{DC_{Z,S}}{Demand_Z}$$

Where:

$DC_{Z,S}$ is the demand curtailment (in GWh) in Z when S is not available

$Demand_Z$ is the demand of Z (in GWh)

For each source S, TYNDP 2018 assesses the dependence of those countries that are part of at least one of the respective supply risk group as defined by Annex I of Regulation (EU) 2017/1938 regarding Security of Supply. For instance, when assessing the dependence of Europe towards Russian supply, the Iberian Peninsula – which is not part of any of the Eastern supply risk groups – can fully cooperate with the rest of Europe to the extent it is not exposed to demand curtailment. With regards to LNG, the approach has been chosen for calculating SSD (Figure 3.2 & 3.3).

For SSD LNG, all the European countries can fully cooperate in case of demand curtailment.

TYNDP 2018 considered all LNG sources as one global source on the basis that LNG is a global market and prices are set worldwide. From a competition perspective, and SSD being calculated on a whole year, this may be considered as the most sensible approach; we consider the dependence on the overall LNG as there is no dependence on single basin (global energy market).

Figure 3.2: Risk group for SSD Norway

Figure 3.3: Risk group for SSD Russia

3.1.6 SUPPLY SOURCE ACCESS (SSA) AND SUPPLY SOURCE DIVERSIFICATION INDICATOR (SSDI)

The Supply Source Access indicator (SSA) measures the number of supply sources an area can access.

The ability of an area to access a given source is measured through a supply source diversification metric. SSA provides the aggregate view across all supply sources.

This supply source diversification ability is calculated from a market perspective, as the ability of each area to benefit from a decrease in the price of the considered supply source (such ability does not always mean that the area has a physical access to the source).

It is calculated for each area under a whole year.

This indicator measures the ability of each Zone to take benefits from an alternative decrease of the price of each supply source (such ability does not always mean that the Zone has a physical access to the source).

For the calculation of this indicator:

- the minimum supply constraint is removed for each supply source
- the maximum supply constraint is removed for the studied supply source

It is calculated for each Zone under a whole year as the succession of an Average Summer and Average Winter.

The Supply Source Price Diversification of all Zones to source S is calculated as follows:

Step 1: The maximum supply constraint for source S is removed.

Step 2: All sources have their price curves set flat at the same price (including national production).

Step 3: The price level of source S is decreased by 20 % ensuring that source S is maximised.

Step 4: The marginal price curves are computed for each Zone (see description below).

Step 5: The price level of source S is further decreased by 10 % (from 80 % to 72 %).

Step 6: The marginal price curves are computed again for each Zone (see description below).

Marginal price curve

For a given Zone, the marginal price curve mentioned in step 4 and step 6 is a set of marginal prices (MP_k) that are determined for successive simulations with different percentage of demands.

The process for the k^{th} simulation is the following:

- Consider the original demand for the given scenario
- For each Zone, take x_k % of the demand, where the x_k values are ranging from 0.1 % to 99.9 %.
- Reduce the lower constraints (minimum supply constraints) to x_k % of their original values.
- Run a simulation, and for each Zone retrieve the resulting marginal price MP_k .

SSDi formula

For each demand range *[k,k+1]*, an average drop of marginal price is computed (except for the two extreme ranges, the first and last 0.1 %, where only one marginal price is used):

- $$\text{MP change}_{[k,k+1]} = \frac{1}{2} * [\text{Abs}\left(\frac{\text{MP}_{k+1\ \text{Step6}}}{\text{MP}_{k+1\ \text{Step4}}} - 1\right) + \text{Abs}\left(\frac{\text{MP}_{k\ \text{Step6}}}{\text{MP}_{k\ \text{Step4}}} - 1\right)]$$
- $$Demand\ range\ percentage_{[k,k+1]} = x_{k+1} - x_k$$

$$\boldsymbol{SSDi = \frac{1}{10\%} * \sum_k \left(MP\ change_{[k,k+1]}\right) * \left(Demand\ range\ percentage_{[k,k+1]}\right)}$$

The larger the SSDi, the better the access from a price perspective.

Finally, the diversification of a Zone is characterised by both:

- the number of sources for which the SSDi is high
- the magnitude of a given SSDi.

SSDi should be calculated independently for the different supply sources (SSDi_S1, SSDi_S2,...), and simultaneously for all areas.

The SSA indicates the number of sources for which the SSDi exceeds 20 %, which means that a decrease in the price of this supply source would impact at least 20 % of the country supply bill.

$$SSA = \text{number of sources for which } SSDi \geq SSAthreshold$$

Concerning LNG, TYNDP considers LNG as one global and competitive market. Local LNG price difference being generally related to specific supply contracts.

3.1.7 MARGINAL PRICE

For each climatic case, the marginal price of gas supply of a Zone is a direct output of the optimisation.

It is calculated for each Zone under a whole year as the succession of an Average Summer and an Average Winter, resulting potentially in two different marginal prices (one for summer and one for winter).

The lower the difference between the marginal prices of two Zones, the better the Price Convergence.

Marginal Price is monetised in the Supply Cost Savings.

3.2 INDICATORS USED ONLY IN THE PS-CBA

3.2.1 SUPPLY COST SAVINGS

This indicator is meant to capture the benefits stemming from projects reducing the overall European cost of gas supply.

The monetary analysis of the cost of gas supply is based on the calculation of the gas bill in the situations with and without the project. The benefits are calculated at the European level and according to the following formula:

$$\text{supply cost saving} = \sum_{1}^{n} (S_1^n * C_1^n) \text{ with project} - \sum_{1}^{n} (S_1^n * C_1^n) \text{ without project}$$

Where:

S_1^n represents the supply

C_1^n represents the cost of the gas supply, including the price of the gas delivered at the Europe borders and the tariffs (the latter when considered in the assessment)

In order to consider potential temporary price situations characterising a supply source, a sensitivity on the price associated to that specific source was considered. This sensitivity is represented by the supply price configuration expalined above.

3.2.2 BI-DIRECTIONALITY

Measuring the bi-directionality of capacities is an indication of the physical integration of markets.

The indicator is only to be calculated as part of project assessment and can by nature only be calculated for transmission projects.

The indicator measures the balance between the capacities in each direction of an interconnection. It should be recommended to calculate it at the Interconnection Point (IP) level.

The indicator is calculated according to the following formula:

$$BDP = \text{Min}\left(1; \frac{\text{Added capacity at IP to other direction}}{\text{Existing capacity in prevailing direction}}\right)$$

Where:

Denominator: Existing capacity in prevailing direction (GWh/d);

Numerator: Added capacity at IP to other direction (GWh/d):
capacity of the project against the prevailing direction;

In case of a project creating a new bi-directional IP, the numerator shall be the smaller added capacity. In case the project changes the prevailing direction, the capacity in the new prevailing direction shall be the denominator.

The maximum value of the indicator is one (1). In case the project is a Reverse Flow, it will score above zero (0).

3.2.3 SUBSTITUTION EFFECT (FUEL SWITCHING AND CO_2 IMPACTS)

The benefits stemming from the implementation of a project enabling the substitution of other fuels with gas (including renewable gas) can mainly be of two types:

- Reduction of CO_2 emissions due to the replacement of higher carbon content fuels
- Fuel cost saving in terms of replacement of more expensive alternative fuels.

This indicator is not calculated for the system assessment and infrastructure gap identification but only for the project-specific assessment since any decrease in CO_2 emissions or fuels cost always represent an improvement of the situation.

Benefits related to reduction of CO_2 emissions or fuels cost might be related to local specificities (such as local prices of fuels, national or regional carbon tax, etc.) that cannot be always included in an EU-wide assessment. Therefore, for TYNDP 2018 the final calculation of those benefits has been left under the responsibility of promoters and it will be published in the Project Fiche together with all the others results.

To facilitate promoters, based on TYNDP 2018 scenarios, ENTSOG has estimated some indicative figures in terms of CO_2 emissions and fuels cost savings that could stem from the implementation of projects. Those figures have been provided to promoters as possible input. Promoters however must justify how their project(s) triggers such reduction in CO_2 emissions and fuels cost.

The figures estimated by ENTSOG and provided to promoters as indicative input have been calculated based on the following approach:

1. Based on TYNDP 2018 scenarios and Eurostat energy balance the share of each fuel in the energy mix for each TYNDP assessment year has been derived;
2. For all TYNDP 2018 scenarios assessment year only the share of demand not covered by national production has been considered (i. e. conventional production and biomethane CO_2 saving are not attributed to any projects unless the project is needed to enable such production and/or enable country gasification);
3. For each sector, gas has been assumed to replace other fuels (mainly coal and oil) only when gas demand is increasing[12)] and fuel switch calculated accordingly as difference between two assessment years;
4. Fuel cost savings monetised using natural gas and coal prices from TYNDP 2018 Scenario Report while oil price considered 40 % more expensive than gas since most of the oil is replaced in the transport sector[13)]. The formula used is the following:

$$\text{Fuel cost saving} = Q_{fuel1} * P_{fuel1} + \ldots + Q_{fueln} * P_{fueln} - Q_{gas} * P_{gas}$$

where

Q is the quantity of fuel in energy terms (GWh);

$fuel\ i=1\ to\ n$ is any alternative fuel replaced by the increased gas driven by the new project;

P_{fuel} is the price of the specific replaced fuel (in EUR/GWh).

12) In case of gas demand is flat or decreasing it can be assumed that gas is in fact replaced by other fuels or impacted by energy efficiency.

13) Based on available literature such as CREG or NGVA publications. Please note that the oil price in the TYNDP 2018 Scenario Report is in fact more than double than the natural gas price.

5. Amount of CO_2 reduction is calculated considering carbon intensity[14] and monetised using CO_2 prices from TYNDP 2018 Scenario Report[15] according to the following formula

$$CO_2 \text{ saving} = (Q_{fuel1}*factor_{fuel1} + ... + Q_{fueln}*factor_{fueln} - Q_{gas}*factor_{gas}) * CO_2 \text{ value}$$

where

Q is the quantity of fuel in energy terms (GWh);

fuel i=1 to n is any alternative fuel replacement by gas driven by the project;

$Factor_{fuel}$ is the CO_2 emission factor of the specific replaced fuel;

$Factor_{gas}$ is the CO_2 emission factor of gas;

CO_2 value value (such as EUR/ton).

6. The fuel switch savings as calculated in point 4) and 5) have been split pro-quota between existing capacity and new capacity brought by the project based on the idea that the more capacity already exists the lower will be the benefit of each GWh/d of increment brought by the project in terms of fuel switch savings.
7. When attributing those benefits to the existing and new infrastructure only the savings observed in the countries actually impacted by the project have been considered (e. g. for an interconnector A – B only savings calculated for countries A and B have to be considered but not the ones observed in country C).

Environmental Impact

Any gas infrastructure has an impact on its surroundings. This impact is of particular relevance when crossing some environmentally sensitive areas. Mitigation measures are taken by the promoters to reduce this impact and comply with the EU Environmental acquis[16].

More details are available in the 2nd CBA Methodology in chapter 3.2.2 Indicators.

3.2.4 CAPEX/OPEX

Costs represent an inherent element of a CBA analysis. According to Annex V(5) of the Regulation, "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 following cost information were collected for TYNDP 2018::

- Capital expenditure (CAPEX), including initial investment costs and replacement costs (if any)
- Operational and maintenance expenditure (OPEX)

More information is available in the guidelines described in the 2nd CBA Methodology.

All cost data is considered at constant (real) prices.

As part of the TYNDP and PCI processes, constant prices refer to the year of the TYNDP project collection.

14) Natural gas (0.2 kg CO_2/kWh); Oil (0.26 kg CO_2/kWh); Coal (0.35 kg CO_2/kWh).

15) The ENTSOG 2nd CBA Methodology indicates that the Social Cost of Carbon (SCC) value can be used to monetised CO_2 savings instead of CO_2 market prices. For this TYNDP ENTSOG did not investigate and consulted such option. Future TYNDPs may therefore consider to use the SCC.

16) Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment.

LIST OF **ABBREVIATIONS**

ACER	Agency for the Cooperation of Energy Regulators
Bcm/Bcma	Billion cubic meters/Billion cubic meters per annum
CAM NC	Capacity Allocation Mechanism Network Code
CAPEX	Capital expenditure
CBA	Cost-Benefit Analysis
CIS	Commonwealth of Independent States
DIR-73	Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC.
EBP	European Border Price
EC	European Commission
EIA	Energy Information Administration
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
ETS	European Trading Scheme
EU	European Union
FEED	Front End Engineering Design
FID	Final Investment Decision
GCV	Gross Calorific Value
GIE	Gas Infrastructure Europe
GHG	Greenhouse Gases
GLE	Gas LNG Europe
GRIP	Gas Regional Investment Plan
GSE	Gas Storage Europe
GWh	Gigawatt hour
e-GWh	Gigawatt hour electrical
GQO	Gas Quality Outlook
HHI	Herfindahl-Hirschman-Index
H-gas	High calorific gas
HDV	Heavy duty vehicles
HGV	Heavy goods vehicles
IEA	International Energy Agency
IP	Interconnection Point
ktoe	A thousand tonnes of oil equivalent. Where gas demand figures have been calculated in TWh (based on GCV) from gas data expressed in ktoe, this was done on the basis of NCV and it was assumed that the NCV is 10 % less than GCV.
L-gas	Low calorific gas
LDV	Light Duty Vehicles
LNG	Liquefied Natural Gas

mcm	Million cubic meters
MMBTU	Million British Thermal Unit
MS	Member State
MTPA	Million Tonnes Per Annum
mtoe	A million tonnes of oil equivalents. Where gas demand figures have been calculated in TWh (based on GCV) from gas data expressed in mtoe, this was done on the basis of NCV and it was assumed that the NCV is 10 % less than GCV.
MWh	Megawatt hour
e-MWh	Megawatt hour electrical
NCV	Net Calorific Value
NERAP	National Energy Renewable Action Plans
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
OPEX	Operational expenditure
PCI	Project of Common Interest
P2G	Power-to-Gas
REG-703	REGULATION (EU) 2015/703 of 30 April 2015 establishing a network code on interoperability and data exchange rules
REG-347	Regulation (EU) No 347/2013 of the European Parliament and of the council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009
REG-715	Regulation (EC) No 715/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the natural gas transmission networks.
REG-SoS	Regulation (EU) No 994/2010 of the European Parliament and of the Council of 20 October 2010 concerning measures to safeguard security of gas supply and repealing Council Directive 2004/67/EC.
RES	Renewable Energy Sources
SIF/SWF	Seasonal Injection Factor/Seasonal Withdrawal Factor
SoS	Security of Supply
Tcm	Tera cubic meter
TSO	Transmission System Operator
TWh	Terawatt hour
e-TWh	Terawatt hour electrical
TYNDP	Ten-Year Network Development Plan
UGS	Underground Gas Storage (facility)
WI	Wobbe Index

COUNTRY CODES (ISO)

AL	Albania
AT	Austria
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BE	Belgium
BG	Bulgaria
BY	Belarus
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
DZ	Algeria
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
LY	Libya
MA	Morocco
ME	Montenegro
MK	FYROM
MT	Malta
NL	Netherlands, the
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
RU	Russia
SE	Sweden
SI	Slovenia
SK	Slovakia
TM	Turkmenistan
TN	Tunisia
TR	Turkey
UA	Ukraine
UK	United Kingdom

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