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for gas

TEN YEAR NETWORK
DEVELOPMENT PLAN 2015

TYNDP 2015

ANNEX F

METHODOLOGY

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1 General considerations on the ESW-CBA Methodology

Following the requirements of the New TEN-E Regulation, ENTSOG has developed an Energy System-Wide Cost-Benefit Analysis (CBA) methodology supporting the selection of Projects of Common Interest (PCI).

This methodology is composed of a TYNDP-Step, which is a part of this Report, and a Project Specific-Step to be applied by promoters of projects which are candidates for PCI status, the first step being an enabler of the latter. This annex describes the part of the methodology, approved by the European Commission on 4 February 2015, which has been applied in this Report. The following graph illustrates the link between the two steps of the methodology.

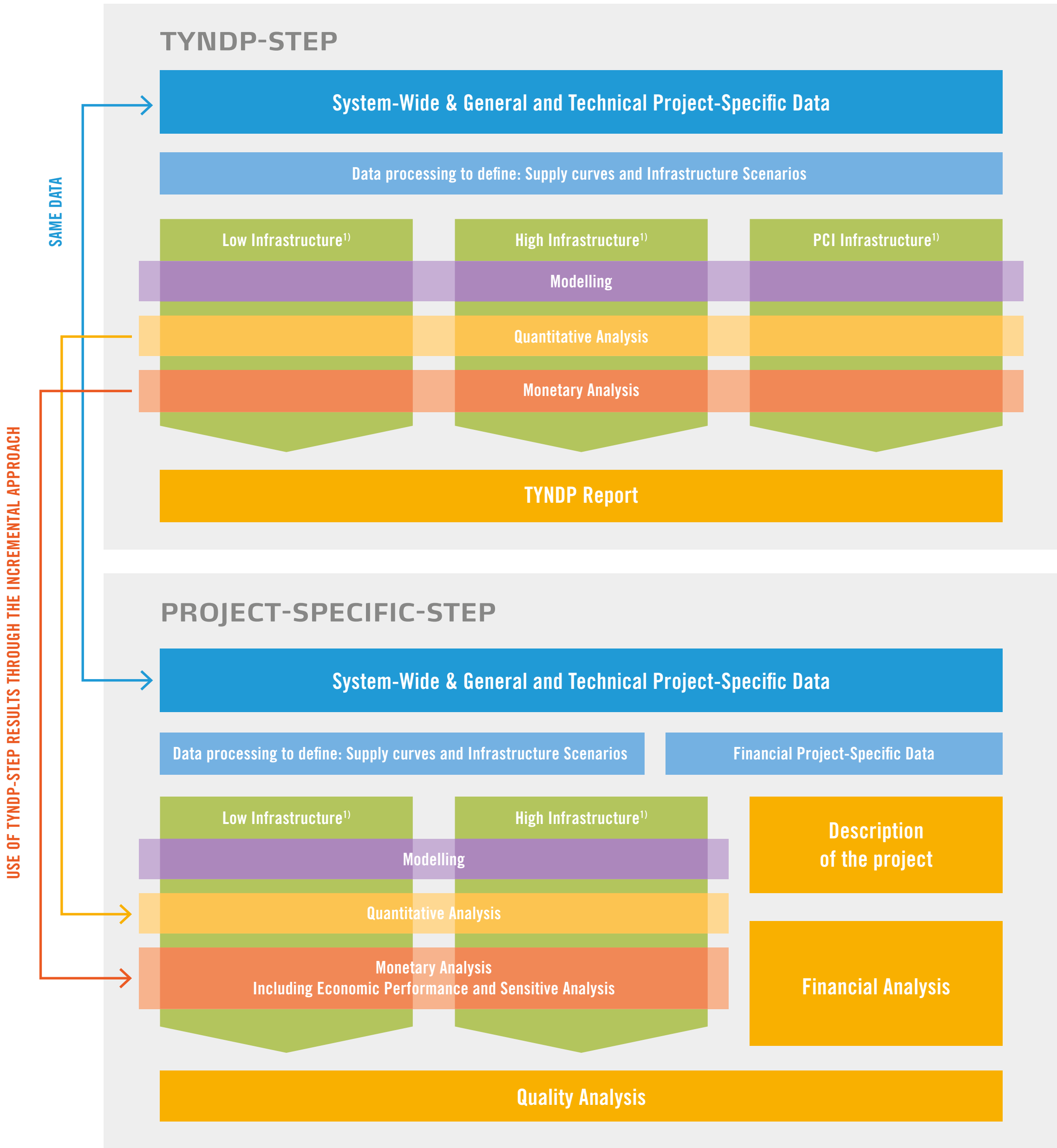

Figure 1.1: Overall ESW-CBA process

1) Level of development of infrastructures as defined under chapter 3.6.2 of the present Annex

2 Common Input data for the ESW-CBA

This chapter identifies the data to be used in the TYNDP-Step for the ESW-CBA methodology. Considering the high dependence of the benefit of infrastructure projects on the long term development of the gas market, the data set considers several scenarios for the relevant data series. This data set results from a market consultation process as most of the data included are beyond ENTSOG / TSO remit.

2.1 TIME HORIZON FOR THE INPUT DATA

The set of input data covers the 2015 – 2035 time horizon.

2.2 LIST OF INPUT DATA

The following table identifies every data item to be used as part of the implementation of the TYNDP-Step of the ESW-CBA methodology. They are structured in two categories:

- System-wide data: related to existing infrastructures, gas demand and supply, power generation and coal.
- General and technical Project-specific data: relating to each project collected as part of the call for infrastructure projects launched by ENTSOG ahead of each TYNDP report.

The following table identifies each input data of the ESW-CBA methodology to be defined on 2015, 2020, 2025, 2030 and 2035:

LIST OF INPUT DATA			
CATEGORY	**TYPE**	**DATA ITEM**	**LEVEL OF DEFINITION**
SYSTEM-WIDE DATA	Gas demand for power generation, residential, commercial and industrial	Yearly	Zone
		Average Summer Day	
		Average Winter Day	
		14-day Uniform Risk	
		1-day Design Case	
	Thermal gap	Average Summer Day	Country
		Average Winter Day	
		14-day Uniform Risk	
		1-day Design Case	
	Global Context	Yearly average import price of gas	Europe
		Yearly average price of coal	
		Yearly average price of oil	
		Yearly average price of CO_2 emission	
	Supply potential from import sources	Maximum historical deliverability on one day	Source
		Maximum historical deliverability on 14 days	
		Minimum	
		Intermediate	
		Maximum	
	Existing Infrastructures (capacity)	Transmission	Zone
		UGS	
		LNG Terminal	
	CO_2 emission factor of primary fuels	Gas	Europe
		Coal	
		Oil	
	Efficiency of power plant	From gas	Country
		From coal	
		From oil	
	Range of use for fuel in power generation	For gas	Country
		For coal	
	Other	Social Discount Rate	Europe
PROJECT-SPECIFIC DATA	General and technical	Capacity increment	Project
		Expected commissioning date	
		FID status	
		PCI status according latest selection	

Table 2.1: List of input data

2.3 SCENARIOS FOR GLOBAL CONTEXT

Certain input data are dependent from each other and at the same time they are beyond the direct control of Europe. That has been defined as global context and applies to:

- Yearly average price of imported gas
- Yearly average price of coal and oil
- Yearly average price of CO_2 emission quotas

These above prices have a direct influence over:

- The balance between the use of gas and coal in power generation
- The monetization of project benefits

Two different settings of the global context have been defined for the ESW-CBA in order to cover opposite coal versus gas balance in power generation:

- Green: the price scenarios correspond to the »Gone Green« projection in the UK Future Energy Scenarios[1)] document which is consistent with:
  - a high price of CO_2 emissions due to the introduction of a carbon tax
  - a continuous reduction in the oil-price linkage mitigating the increase of gas price
- Grey: the price scenarios correspond to the Current Polices Scenario from the IEA WEO 2013[2)] which is consistent with:
  - lower price of CO_2 emissions as no new environmental political commitments are taken
  - high energy prices following higher energy demand in absence of new efficiency policies but with prices still too low to trigger the development of renewables

2.4 DEMAND SCENARIOS AND CLIMATIC CASES

2.4.1 Demand scenarios

The level of demand in each Member State is the main driver of gas market development and flow patterns between balancing zones. The uncertainty about the gas demand evolution is captured through two demand scenarios for residential, commercial and industrial sectors. The two scenarios are defined for opposite general circumstances and macro-economic parameters:

- Scenario A covers favourable economic and financial conditions, with higher CO_2 emission prices and lower energy prices than in Scenario B. This results in higher electricity demand and lower carbon heating solutions than in scenario B.
- Scenario B covers non-favourable economic and financial conditions, with lower CO_2 emission prices and higher energy prices than in Scenario A. This results in a lower electricity demand and higher carbon heating solutions than in scenario A.

The inclusion of the price data for gas, coal and CO_2 emissions in the modelling approach enables the calculation of the gas demand for power-generation as the main source of short term price elasticity. The associated input data for the modelling are defined by ENTSOG's elaboration on the basis of the installed capacities and electricity consumption in ENTSO-E visions 1 (Slow progress) and 3 (Green transition) from ENTSO-E TYNDP 2014, and includes the country detail of:

1) nationalgrid – July 2014
2) International Energy Agency – World Energy Outlook 2013

- The thermal gap (part of electricity demand to be covered by gas- and coal power generation)
- The power generation capacities from gas and coal
- The ranges of use and the average efficiencies of the above capacities.

In order to strike the right balance between the number of cases and the robustness of the assessment, the Table 2 defines two combinations of Gas Demand scenario, Global Context and ENTSO-E Visions are considered in the ESW-CBA:

COMBINATION OF GAS DEMAND, GLOBAL CONTEXT AND ENTSO-E VISIONS			
COMBINATION	**GLOBAL CONTEXT**	**GAS DEMAND**	**ENTSO-E VISION**
1	Green	A	Green transition
2	Grey	B	Slow progress

Table 2.2: Combination of Gas Demand, Global Context and ENTSO-E Visions

The main features of selected ENTSO-E visions are defined in following table:

MAIN FEATURES OF ENTSO-E VISIONS		
	VISION 1 (SLOW PROGRESS)	**VISION 3 (GREEN TRANSITION)**
ECONOMIC AND FINANCIAL CONDITIONS	Poor	Favourable
ENERGY POLICIES AND R&D PLANS	National focus	
NUCLEAR DECISION	National decision	
CO_2 PRICES	Low	High
PRIMARY ENERGY PRICES	High	Low
ELECTRICITY DEMAND	Low	High
DEMAND-RESPONSE	As today	Potential partially used
ELECTRICITY PLUG-IN VEHICLES	No commercial breakthrough	Commercial breakthrough with flexible charging
HEAT-PUMPS	Not even spread across Europe	Not even spread across Europe
LEVEL OF BACK-UP GENERATION	Low	High
CCS	Not commercially implemented	
STORAGE	As planned today	Decentralised and in limited amount
SMART GRID SOLUTIONS	Partially implemented	

Table 2.3: Main features of ENTSO-E Visions

2.4.2 Climatic cases

In order to capture the seasonality of the gas market different levels of gas demand and thermal gaps are considered along the year. These climatic cases and the associated levels of demand are defined as following:

- **Average Summer day:** Total demand of an average summer divided by 183 as a proxy for the season
- **Average Winter day:** Total demand of an average winter divided by 182 as a proxy for the season
- **14-day Uniform Risk (14-UR):** aggregation of the level of demand reached on 14 consecutive days once every twenty years in each country to capture the influence of a long cold spell on supply and especially storages
- **1-day Design Case (1-DC):** aggregation of the level of demand used for the design of the network in each country to capture maximum transported energy and ensure consistency with national regulatory frameworks.

2.5 SUPPLY, FROM SCENARIOS TO CURVES

2.5.1 Supply scenarios

For a given level of demand, the use of gas infrastructures will depend on the share of each supply source and the import routes selected by the network users. In that respect the availability of each supply source is an important element. At the same time Europe is an importing market in a global environment which introduces a significant uncertainty on the supply side. The definition of three Supply Potential scenarios per source can be found in the Supply Chapter of this Report.

2.5.2 Supply ranges

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

Average Summer day:

- **Minimum:** the minimum between the Minimum Supply Potential scenario and 60 % of the Intermediate Supply Potential scenario
- **Maximum:** the Maximum Supply Potential scenario

Average Winter day:

- **Minimum:** the minimum between the Minimum Supply Potential scenario and 60 % of the Intermediate Supply Potential scenario
- **Maximum:** 110 % of the Maximum Supply Potential scenario

14-day Uniform-Risk for each import source:

- **Minimum:** the minimum between the Minimum Supply Potential scenario and 60 % of the Intermediate Supply Potential scenario
- **Maximum for each pipe import source:** the highest delivery of the source on 14 consecutive days as observed from 2011 to 2013, multiplied by the ratio between the average yearly delivery of the source and the Intermediate Supply Potential scenario. For these sources without historical records, it will be applied the average ratio between maximum delivery and capacity for the remaining sources.
- **Maximum for LNG for each terminal:** the highest level of send-out that could be sustained on the period assuming:
  - LNG tanks are 50 % full at the beginning of the period
  - LNG tank levels cannot go below 15 %
  - Cargo delivery rate equivalent to 110 % of the Maximum Supply Potential scenario

1-day Design Case for each import source:

- **Minimum:** the minimum between the Minimum Supply Potential scenario and 60 % of the Intermediate Supply Potential scenario
- **Maximum for pipe imports:** the highest delivery of the source on a single day as observed from 2011 to 2013 multiplied by the ratio between the average yearly delivery of the source and the Intermediate Supply Potential scenario. For these sources without historical records, it will be applied the average ratio between maximum delivery and capacity for the remaining sources.
- **Maximum for LNG for each terminal:** 100 % of send-out capacity

2.5.3 Definition of the supply curves

Within the modelling tool, each supply source is described as a supply curve based on the Supply Potential and Global Context scenarios. It represents the increasing supply cost on the long run when demand is increasing (to be distinguished from the constant price compared to volume once gas has been contracted). The curve is built on:

- The yearly average import price of gas as defined in the Global Context Scenario (P_{GC})
- The Supply Potential Scenarios of each source

Figure 2.1 illustrates the construction of the curve of given source on a given year:

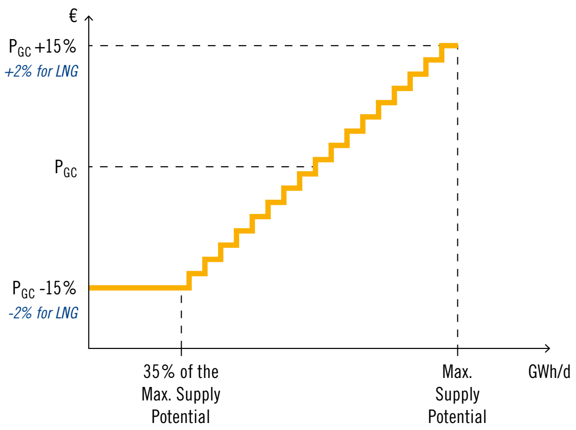

Figure 2.1: Supply curve

Compared to the CBA methodology published on ENTSOG website a ±15% range has been used for pipe gas sources and ±2% for LNG instead of a uniform ±10%. Such changes were necessary to:

- Ensure the necessary overlap of the curves when one source becomes cheaper or more expensive than the other ones
- Reflect the small influence of Europe on the global LNG market

In addition the low point of the curve of each supply source is now based on a constant 35% of the Maximum Supply scenario (which is the average of the ratio between the Maximum and Minimum Potential scenario of each source). This modification ensures a more even split of the sources in the EU gas supply mix.

A specific curve has been defined for the European indigenous production (conventional, shale gas and biogas). The curve is set flat at the level of the average import gas price as defined by the Global Context with a thirty percent discount. Such rebate derives from the fact that the considered price information for indigenous production is rather the production cost than the wholesale price. It enables to include the producer surplus on EU territory within the EU social welfare assessed by the methodology as requested by the New TEN-E Regulation.

2.6 INFRASTRUCTURE SCENARIOS

2.6.1 Definition of criteria for the infrastructure scenarios

The FID status has been identified as the most robust criteria for aggregation of planned infrastructure projects. FID is defined according to Regulation (EC) 256/2014[1]; Art. 2.3 as follows:

» ›final investment decision‹ means the decision taken at the level of an undertaking to definitively earmark funds for the investment phase of a project;«

In order to be considered as FID status, the promoter shall have taken the Final Investment Decision of its project by the last day of the infrastructure project collection launched by ENTSOG ahead of each TYNDP.

By comparison, all those projects for which the FID has not been taken are considered to have a non-FID status. The PCI label granted during the latest selection is used as additional criteria for aggregation.

2.6.2 Infrastructure scenarios

Based on the above criteria, three infrastructure scenarios have been defined representing different levels of project implementation. This will support a robust assessment as project impact depends on the level of development of infrastructures.

- **Low Infrastructure Scenario (LI):** Existing Infrastructures + Infrastructure projects having a FID status (whatever their PCI status is)
- **PCI Infrastructure Scenario:** Existing Infrastructures + Infrastructure projects having a FID status (whatever their PCI status is) + labelled PCIs according to the previous selection (not having their FID taken)
- **High Infrastructure Scenario (HI):** Existing Infrastructures + Infrastructure projects having a FID status (whatever their PCI status is) + Infrastructure projects not having a FID status (whatever their PCI status is)

The Existing Infrastructures are defined as the firm capacity available on yearly basis as of 1st January 2015.

Figure 2.2 illustrates the difference in the level of infrastructure development of each scenario.[2]

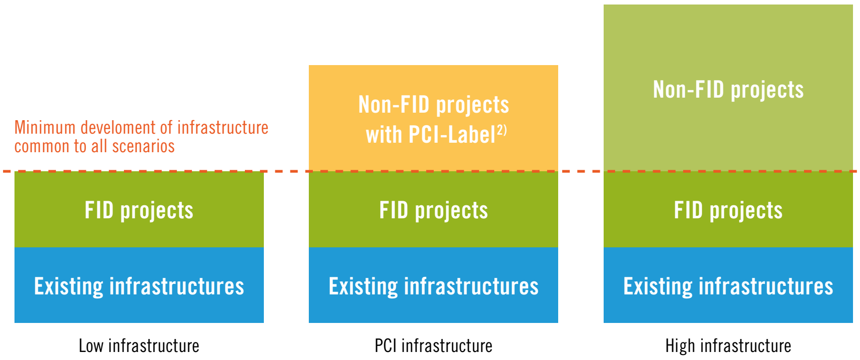

Figure 2.2: Infrastructure Scenarios

1) Regulation (EU) 256/2014 of the European Parliament and of the Council of 26 February 2014 concerning the notification to the Commission of investment projects in energy infrastructure within the European Union, replacing Council Regulation (EU, Euratom) 617/2010 and repealing Council Regulation (EC) 736/96

2) As labelled in the previous list selected before the current TYNDP step for ESW-CBA Supply curve

The assessment of the European gas system under Low and High Infrastructure Scenarios will show different levels of project interaction according to the degree of development of infrastructure. The assessment of the European gas system under the PCI Infrastructure Scenario is used separately only within the TYNDP Step to measure the benefits from a full implementation of the latest PCI list. Its role is to provide a feedback loop to Regional Groups.

2.6.3 Capacity increment considered in the Economic Analysis

The incremental approach is at the core of the cost-benefit analysis. It is based on the differences of indicators and monetary values between the scenario »with the project« and the scenario »without the project«. The inclusion of a capacity increment associated to an infrastructure project depends on the status of infrastructure on both sides of a flange. The next table indicates which increment is used in the Economic Analysis:

CONSIDERED CAPACITY INCREMENT PER SCENARIO

FLANGE A	FLANGE B	INFRASTRUCTURE SCENARIO IN WHICH THE CAPACITY INCREMENT IS CONSIDERED
EXISTING OR FID	FID	Low and High
	Non-FID	High
	None	None
NON-FID	Non-FID	High
NON-FID	None	None

Table 2.4: Considered capacity increment per scenario

3 Approach of network / market modelling

3.1 INFRASTRUCTURE-RELATED MARKET INTEGRATION

Within TYNDP 2013–2022, ENTSOG has defined the infrastructure-related market integration as a physical situation of the interconnected network which, under optimum operation of the system, provides sufficient flexibility to accommodate variable flow patterns that result from varying market situations. In addition to its embedded value, market integration sustains the pillars of the European energy policy (Security of Supply, Competition and Sustainability). These four aspects define the specific criteria under this Regulation. A thorough assessment of these criteria shall be based on modelling in order to capture the network and market dimensions of the European gas system. These dimensions are not limited to capacity and demand but are strongly influenced by supply availability, the location of the source and gas price.

3.2 RATIONALES FOR THE PERFECT MARKET APPROACH

When assessing the physical layer of market integration it is important to assume a well-functioning commercial layer (e.g. full implementation of Network Codes). The consideration of market constraints (e.g. a minimum flow between 2 zones deriving from commercial arrangements) within the EU would lead to investment signals that bear the risk of future stranded assets under the situation that the market constrains are alleviated. Therefore the model follows a single–user perspective, shipping gas within a multi-TSO European gas system.

3.3 TOPOLOGY

ENTSOG has developed since 2010 a modelling approach based on a specific structure facing the need to consider simultaneously network and market dimensions.

ENTSOG model applies the methodology of »Network Flow Programming[1)]« to:

- the capacity figures obtained through hydraulic simulations performed by TSOs
- the power-generation capacity figures derived from ENTSO-E visions
- the demand and supply approach defined in the input data section of the current methodology.

Considering the seasonal aspect of the gas market and in particular the seasonality of some gas storages, it is necessary to proceed to yearly modelling considering simultaneously the summer, winter and peaks constraints.

The following graphs illustrate the main features of the topology used in the modelling approach supporting the present methodology:

1) Network Flow Programming is a methodology used in the Operational Research (study of logistic networks to provide for decision support at all levels). The term network flow program includes such problems as the transportation problem, the assignment problem, the shortest path problem, the maximum flow problem.

Yearly structure

The modelling of a year is composed of the simultaneous simulation of four climatic cases each one represented with the topology of the European gas system. The main difference between each layer is the level of gas demand and thermal gap. This structure (illustrated in Figure 3.2) enables the model to take into consideration annual constraints such like the minimum and maximum import from a supply source or then working gas volume of storages.

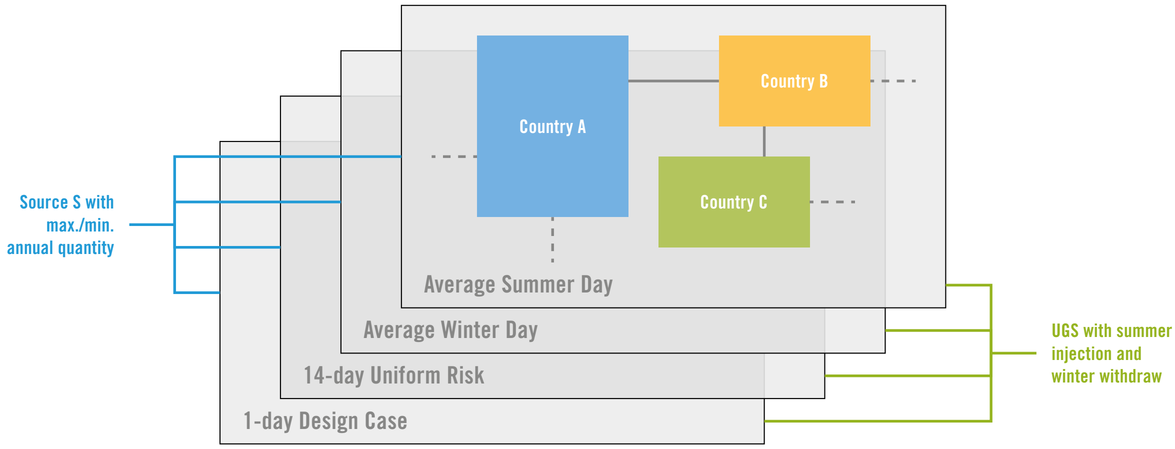

Figure 3.1: Yearly structure of the topology

The considered supply sources in the modelling approach are:

- gas (whatever the use) from Algeria, Azerbaijan, Libya, LNG, Norway, Russia and Turkmenistan (if import route projects submitted)
- coal (only for power generation) from global market

Entry/Exit model

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.

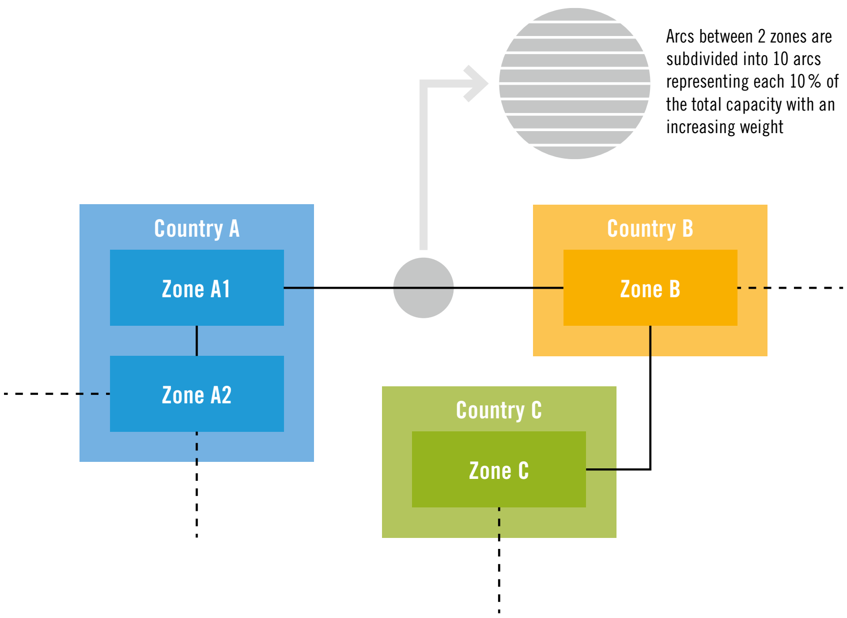

Figure 3.2: Links between adjacent Zones

In order to avoid extreme flow patterns (e.g. most of the arcs empty or fully used) where it is not necessary to balance demand and supply, each arc is subdivided into ten arcs each one representing ten percent of the total capacity between the two Zones with an increasing weight. The more sub-arcs are used between two Zones, the higher is the resulting value of the objective function.

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, the missing gas comes from the disruption arc (3) used as a last resort virtual supply. This approach enables an efficient analysis of the disrupted demand.

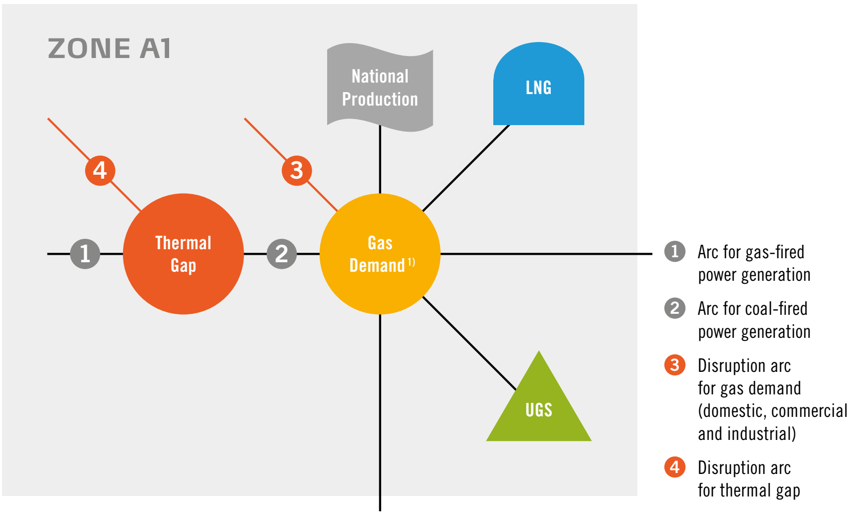

Figure 3.3: Content of a Zone

1) except for power generation

The gas demand of a give Zone is split between one node for the domestic, commercial and industrial sectors and another node for the thermal gap defined as the electricity demand to be covered by coal or gas.

Therefore the arc (1) between the two nodes represents the gas-fired power generation capacity of the Zone. Another arc (2) represents the coal-fired power generation capacity. These two arcs are characterized by the range of use of the power-generation capacity, the efficiency of the electricity production and the CO_2 emission factor. In order to model the range of efficiency of the generation units of each fuel, the arcs are subdivided into arcs of different efficiency.

In case the balance of the thermal gap is not possible, an additional disruption arc (4) has been introduced.

3.4 MARGINAL PRICE AND OBJECTIVE FUNCTION

The primary objective of the modelling is to define a feasible flow pattern to balance for every node supply and demand using the available system capacities defined by the arcs. In addition the use of price assumptions relative to gas and coal supply together with CO_2 emissions supports the definition of a feasible flow pattern minimizing the objective function[1] 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 minimization 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.

The overall objective function used in the methodology is the following:

$$Commodity\ Cost\ + Weight\ of\ infrastructure\ use$$

The optimization is done »first« on the commodity cost then on the weight of infrastructure use (as of second order) to define a realistic flow pattern.

$$Commodity\ Cost =$$
$$Cost\ of\ gas\ supply + Cost\ of\ Coal\ supply + Cost\ of\ CO_2\ emissions$$

$$Weight\ of\ infrastructure\ use =$$
$$Weight\ of\ transmission + Weight\ of\ storage + Weight\ of\ regasification$$

Each component is defined as the sum for each arc of the flow through the arc multiplied by its unitary cost or weight.

Each commodity item is defined as below:

$$Cost\ of\ gas\ supply = \sum_{S}^{Gas\ sources} \sum_{n}^{Arc\ from\ source\ S} Flow_n \times Cost_n$$

$$Cost\ of\ Coal\ supply = \sum_{j}^{Arc\ from\ Coal\ source} Flow_j \times Cost_j$$

$$Cost\ of\ CO_2\ emissions = \sum_{k}^{Arc\ to\ Thermal\ gap} Flow_k \times Cost_k$$

Where:

- $Cost_n$ is the cost per unit of gas supply as resulting from the supply curves defined under chapter 3.5.3
- $Cost_j$ is the cost per unit of coal as defined under chapter 3.3
- $Cost_k$ is the cost per unit of CO_2 emission as defined under chapter 3.3

1) 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)

Each infrastructure item is defined as (the weight of each arc is in monetary unit for addition reason of the overall objective function but does not represent any kind of proxy of the infrastructure fee):

$$Weight\ \ of\ transmission = \sum_{t}^{Arc\ between\ Zones} Flow_t \times Weight_{\ t}$$

$$Weight\ \ of\ storage = \sum_{w}^{Arc\ from\ storage} Flow_w \times Weight_{\ w} + \sum_{i}^{Arc\ to\ storage} Flow_i \times Weight_{\ i}$$

$$Weight\ \ of\ regasification = \sum_{l}^{Arc\ from\ LNG\ terminal} Flow_l \times Weight_{\ l}$$

If all above cost and weight items are used to define the flow pattern through modelling only part of them are used for the monetization of project benefits. Table 3.1 defines the role of each item:

USE OF COSTS AND WEIGHT IN MODELLING		
Type of costs and weights	Costs or weight used in the definition of flow pattern	Costs considered for the Monetization of project benefits
COMMODITY COSTS		
Gas supply	X	X
Coal supply for power generation	X	X
CO_2 emissions from power generation	X	X
INFRASTRUCTURE WEIGHTS		
Transmission	X	
UGS	X	
LNG	X	

Table 3.1: Use of costs and weight in modelling

The infrastructure weights are used to model market behaviour when defining flow pattern (e.g. ensuring a reasonable use of storage to cover winter demand). Nevertheless the high- or low use of gas infrastructures influences only slightly the cost for society (it is mostly an internal transfer between users and operators). Therefore these weights are ignored when monetizing Project benefits.

3.5 EVALUATION OF THE SOCIAL WELFARE

Within the ESW-CBA the social welfare has to be understood within the framework of the Regulation. Its geographical scope is the European Union and other countries part of the European Economic Area. It includes all benefits coming along the gas chain including suppliers, infrastructure operators and end-consumers. For example it does not include items such as the shadow value of the work necessary to build and operate an infrastructure.

Based on the economic theory the European social welfare is defined as the yellow area between the supply and demand curves. The change in social welfare induced by a project is then additional red area resulting from the change of the supply curve where there is a better access to cheap source (additional purple part at the bottom of the curve) as shown in following figures (also defining the marginal price as the intersection of the two curves):

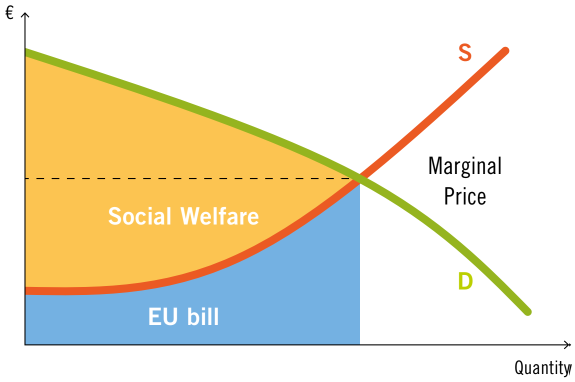

Figure 3.4a: Social Welfare before the project

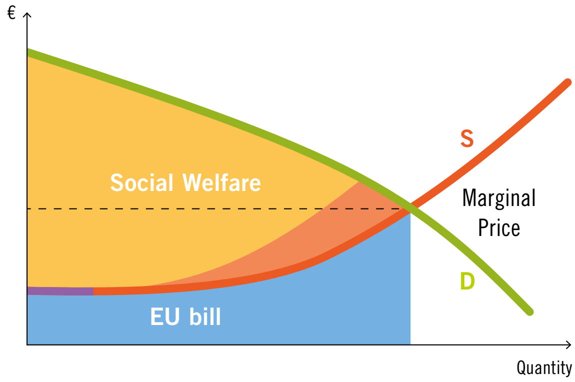

Figure 3.4b: Social Welfare after the project

Applying this approach to the ESW-CBA modelling approach with an inelastic, the change in Social Welfare is equivalent to the change in gas, coal and CO_2 bill as shown in the following figures:

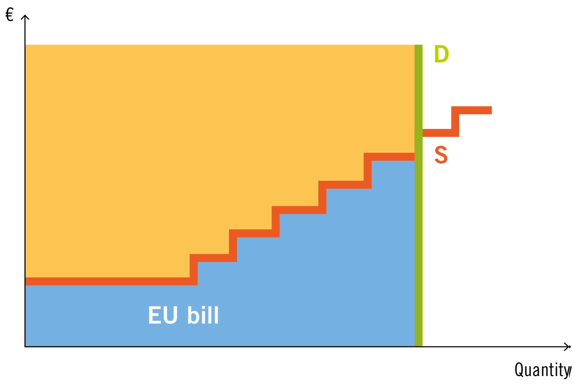

Figure 3.5a: Social Welfare with inelastic demand before the project

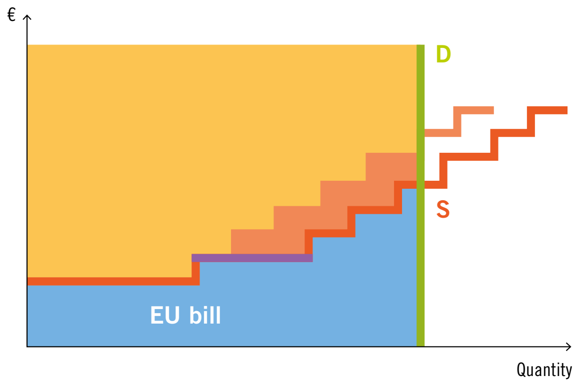

Figure 3.4b: Social Welfare with inelastic demand after the project

3.6 BILL AT EUROPEAN AGGREGATED LEVEL

The gas, coal and CO_2 bill at European level is the main component of the objective function used to define flow patterns.

For the purpose of mitigating demand curtailment in the maximum possible extent a fictive weight of disruption higher than any commodity cost has been introduced.

3.7 GAS PRICE INDEX (PROXY FOR THE BILL AT MEMBER STATE LEVEL)

While implementing the ESW-CBA in TYNDP 2015, ENTSOG noticed that the reaction of the country bill under different price configurations was impacted by many parameters reducing its interpretability (e.g. size of the gas demand, share of coal in the power generation mix, …).

Therefore the bill calculation was replaced by the Gas Price Index (GPI) calculated at Zone level per unit of gas demand.

This process requires the definition of the supply and demand curves of each Zone. The demand curve is an input of the methodology through the definition of the gas demand for domestic, commercial and industrial sectors and the thermal gap. Apart from National Production, the supply curves are defined by source and not at Zone level. The supply curve of each Zone is through successive modelling as below:

1. Modelling of the European gas system with gas demand and thermal gap at 10 %[1] of the normal level
2. Identification of the resulting marginal price of each Zone
3. Repetition of the steps 1 and 2 increasing the gas demand and the thermal gap by 10 % until they reach the normal levels
4. Weighted average of the marginal price based on the size of each demand step

This definition of the Social Welfare per Member State is dependent on the way the supply curve is built at country level. Therefore another approach (e.g. the demand and thermal gap could be increased by constant steps and not relative ones) would result in another split between Member States.

3.8 LIST OF CASES TO BE MODELLED

The modelling approach previously described is to be applied to all the cases supporting the calculation of indicators and monetization of gas supply, coal consumption and CO_2 emissions.

The following table defines the cases to be modelled and their purposes. They have to be modelled for each Infrastructure Scenario, Global Context and Demand Scenario on the years 2015, 2020, 2025, 2030 and 2035.

LIST OF CASES TO BE MODELLED

CLIMATIC CASE	PRICE CONFIGURATION	SUPPLY STRESS	PURPOSE
WHOLE YEAR* TOGETHER	Neutral	No	Monetization
	Each source cheaper one-by-one	No	Monetization
	Each source more expensive one-by-one	No	Monetization
	Defined under each indicator	No	Indicators
DESIGN CASE & 14-DAY UNIFORM RISK	Neutral	No	Remaining Flexibility Disrupted Demand
		Disruptions	Remaining Flexibility Disrupted Demand
WHOLE YEAR* WITH RESULTS PER CLIMATIC CASE	Neutral	No	Price convergence
	Each source cheaper one-by-one	No	Price convergence
	Each source more expensive one-by-one	No	Price convergence

* as the temporal optimization of the succession of one Average Summer Day, one Average Winter Day, 1-day Design Case and 14-day Uniform Risk

Table 3.2: List of cases to be modelled

In the previous table different possible supply mixes have been considered through 13 price configurations where each source price is changed in both directions, source by source. This approach does not cover all possible configurations but helps to identify the link between a project and each source.

1) In order to capture the effect of small sources the first and last 10% of demand are subdivided into smaller steps

The supply curves of the different price configurations are built as following:

- **Neutral:** the supply curve of each source is based on the same average import price of the selected Global Context scenario.
- **Source S cheap:** the supply curve of the source S is move downward along the price axis by 20 % of the Yearly average gas import price
- **Source S expensive:** the supply curve of the source S is move upward along the price axis by 20 % of the Yearly average gas import price

As in previous TYNDP reports the methodology considers some major supply stress against which the European gas system should be assessed. Depending on the source one or two potential complete disruption events have been defined:

- Russian transit through Ukraine
- Russian transit through Belarus
- Langeled pipeline between Norway and UK
- Franpipe pipeline between Norway and France
- Transmed pipeline between Algeria and Italy
- MEG pipeline between Algeria and Spain (including supply to Portugal)
- TANAP pipeline between Azerbaijan and Greece

No specific disruption event is considered for LNG given the global dimension of the market preventing large scale effect of a political or technical disruption along the gas chain.

3.9 OUTPUT OF THE MODELLING

As output, modelling enables for each case the identification of a feasible flow pattern minimizing the objective function. Such flow pattern then supports the calculation of modelling-based indicators and monetary analysis.


Image courtesy of Enagás

4 Indicators

A set of indicators has been defined in order to cover all specific criteria of the Regulation and to ensure comparability of project assessments.

According to the way the indicators are calculated, two types can be distinguished:

- Capacity-based indicators which reflect the direct impact of infrastructures on a given country as their formulas are limited to capacity and demand of a country
- Modelling-based indicators which reflect in addition the indirect cross-border impact of infrastructure as their formulas also consider the availability and nature of flows resulting from the modelling of the European gas system.

The next table defines the list of indicators to be calculated per zone or country as part of the TYNDP for each Infrastructure (Low, High and PCI), Global Context and Gas Demand Scenarios on the year 2015, 2020, 2025, 2030 and 2035:

LIST OF INDICATORS

	INDICATOR	CLIMATIC CASE	WITHOUT SUPPLY STRESS	WITH SUPPLY STRESS
CAPACITY-BASED	N-1	1-DC	N/A	N/A
	Import Route Div.	N/A	N/A	N/A
MODELLED-BASED	Remaining Flex.	1-DC & 14-UR	×	×
	Disrupted Demand	1-DC & 14-UR	×	×
	Cooperative Supply Source Dependence	Whole year*	×	
	Uncooperative Supply Source Dependence	Whole year*	×	
	Supply Source Price Diversification	Whole year*	×	
	Supply Source Price Dependence	Whole year*	×	
	Price Convergence	Whole year	×	

* as the temporal optimization of the succession of one Average Summer Day, one Average Winter Day, 1-day Design Case and 14-day Uniform Risk

Table 4.1: List of indicators

4.1 CAPACITY-BASED INDICATORS

4.4.4 Import Route Diversification (IRD)

This indicator measures the diversification of paths that gas can flow through to reach a zone. Together with the Supply Source Price Diversification, it provides a proxy to the assessment of counterparty diversification.

IRD =

$$\sum_{l}^{X\,border}\left(\sum_{k}^{IP}\%\,IP_k Xborder_l\right)^2 + \sum_{j}^{source}\left(\sum_{i}^{IP}\%\,IP_i from\ source_j\right)^2 + \sum_{m}(\%\,LNG\ terminal_m)^2$$

Where the below shares are calculated in comparison with the total entry firm technical capacity into the Zone from each adjacent EU zone, import source and LNG terminal:

- **IP_k $Xborder_l$:** the share of the firm technical capacity of the interconnection point IP_k belonging to the cross border with the zone *l* (or country in the case of transit through Belarus, Ukraine and Turkey)
- **IP_i from $source_j$:** the share of the firm technical capacity of the import point IPi coming directly from the source *j* (e.g.: offshore pipeline).
- **LNG $terminal_m$:** the share of the firm technical send-out capacity of the LNG terminal *m*

For Interconnection Points between European Zones or a same transiting country, capacity is first aggregated at zone level as those physical points are likely to largely depend on common infrastructures. LNG terminals are considered as completely independent infrastructures.

The lower the value, the better the diversification is.

4.1.2 N-1 for ESW-CBA (N-1)

Under REG (EC) 994/2010, this indicator is calculated by the Competent Authority on a two year range. The use of such an indicator within the ESW-CBA on country level will be based on the same formula, using the ESW-CBA data set:

$$\boldsymbol{N-1=\frac{IP+NP+UGS+LNG-I_m}{Dmax}*100}$$

Where:

- **IP:** technical capacity of entry points *(GWh/d),* other than production, storage and LNG facilities covered by NP_m, UGS_m and LNG_m, means the sum of technical capacity of all border entry points capable of supplying gas to the calculated area.
- **NP:** maximal technical production capability *(GWh/d)* means the sum of the maximal technical daily production capability of all gas production facilities which can be delivered to the entry points in the calculated area; taking into account their respective physical characteristics.
- **UGS:** maximal storage technical deliverability *(GWh/d)* means the sum of the maximal technical daily withdrawal capacity of all storage facilities connected to the transmission system which can be delivered to the entry points in the calculated area, taking into account their respective physical characteristics.

- **LNG:** maximal technical LNG facility capacity *(GWh/d)* means the sum of the maximal technical send-out capacities at all LNG facilities in the calculated area, taking into account critical elements like offloading, ancillary services, temporary storage and re-gasification of LNG as well as technical send-out capacity to the system.
- I_m means the technical capacity of the single largest gas infrastructure *(GWh/d)*. The single largest gas infrastructure is the largest gas infrastructure that directly or indirectly contributes to the supply of gas to the calculated area. The application of the »lesser of« rule and the analysis on a 21-year time horizon may result in a different infrastructure than the one identified by Competent Authorities as part of the Risk Assessment under Regulation (EC) 994/2010.
- D_{max} means the total daily gas demand *(GWh/d)* of the calculated area during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years.

Only in case that a regional formula has been defined and agreed by the Competent Authorities of the corresponding region, the calculation shall be adjusted using the same ESW-CBA data set.

The higher the indicator is, the better the resilience.

4.2 MODELLING-BASED INDICATORS

4.2.1 REMAINING FLEXIBILITY (RF)

This indicator measures the resilience of a Zone as the room before being no longer able to fulfil its demand and the exiting flows to adjacent systems. The value of the indicator is set as the possible increase in demand of the Zone before an infrastructure or supply limitation is reached somewhere in the European gas system. This indicator will be calculated under 1-day Design Case and 14-day Uniform Risk situations with and without supply stress.

The Remaining Flexibility of the Zone Z is calculated as follows (steps 2 and 3 are repeated independently for each Zone):

1. Modelling of the European gas system under a given climatic case
2. Increase of the demand of the Zone Z by 100 %
3. Modelling of the European gas system in this new case

The Remaining Flexibility of the considered Zone is defined as 100 % minus the percentage of disruption of the additional demand.

The higher the value, the better the resilience is. A zero value would indicate that the Zone is not able to fulfil its demand and a 100 % value will indicate it is possible to supply a demand multiplied by a factor two.

4.2.2 Disrupted Demand (DD)

In case the Remaining Flexibility of a Zone is zero, the amount of disrupted demand for a given Zone is provided as:

- The unserved demand in energy
- The relative share of unserved demand

This amount is calculated under the flow pattern maximising the spread of the non-fulfilled demand in order to reduce the relative impact on each country.

4.2.3 Uncooperative Supply Source Dependence (USSD)

This indicator identifies Zones whose physical supply and demand balance depends strongly on a single supply source when each Zone tries to minimize its own dependence (the Zones closest to the considered source are likely to be the more dependent). It is calculated for each Zone vis-à-vis each source under a whole year as the succession of an Average Summer, Average Winter, 1-day Design Case and 14-day Uniform Risk. Results are aggregated on a yearly basis.

The Supply Source Dependence of all Zones 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 is not changed
3. The cost of disruption is set flat and at the same level for each Zone
4. Modelling of the European gas system under the whole year

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

$$USSD = \frac{DD^{Z}_{Adjusted}}{Demand^{Z}_{Adjusted}}$$

Where:

$DD^{Z}_{Adjusted}$ is the disrupted gas demand for residential, commercial and industry plus the disrupted share of the thermal gap divided by the gas-fired power generation efficiency

$Demand^{Z}_{Adjusted}$ is the gas demand for residential, commercial and industry plus the share of the thermal gap which cannot be covered by coal and divided by the gas-fired power generation efficiency

The lower the value of USSD is, the lower the dependence.

4.2.4 Cooperative Supply Source Dependence (CSSD)

This indicator identifies Zones whose physical supply and demand balance depends strongly on a single supply source when all Zones together try to minimize the relative impact (the flow pattern resulting from modelling will spread the dependence as wide as possible in order to mitigate as far as possible the dependence of the most dependent Zones).

It is calculated for each Zone vis-à-vis each source under a whole year as the succession of an Average Summer, Average Winter, 1-day Design Case and 14-day Uniform Risk. Results are aggregated on a yearly basis.

The Supply Source Dependence of all Zones to source S is calculated as follow (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 is not changed
3. The cost of disruption is escalating by step of 10% of demand with the same price steps for each Zone
4. Modelling of the European gas system under the whole year

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

$$CSSD = \frac{DD^{Z}_{Adjusted}}{Demand^{Z}_{Adjusted}}$$

Where:

$DD^{Z}_{Adjusted}$ is the disrupted gas demand for residential, commercial and industry plus the disrupted share of the thermal gap divided by the gas-fired power generation efficiency

$Demand^{Z}_{Adjusted}$ is the gas demand for residential, commercial and industry plus the share of the thermal gap which cannot be covered by coal and divided by the gas-fired power generation efficiency

The lower the value of CSSD is, the lower the dependence.

4.2.5 Supply Source Price Diversification (SSPDi)

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).

It is calculated for each Zone under a whole year as the succession of an Average Summer, Average Winter, 1-day Design Case and 14-day Uniform Risk. Results are aggregated on a yearly basis.

The Supply Source Price Diversification of all Zones to source S is calculated as follow (steps 2 to 5 are repeated for each source):

1. All sources have their price curves set flat at the considered Global Context level
2. The price level of the curve of the source S is decreased by 20 % ensuring that the source S is maximised
3. The residential, commercial and industrial gas bill of each Zone is measured ($\boldsymbol{Gas\ Bill_{Step3}}$)
4. The curve of the source S is further decreased by 10 %
5. The updated residential, commercial and industrial gas bill of each Zone is measured ($\boldsymbol{Gas\ Bill_{Step5}}$)

The ability of a Zone to access the source S is defined as the difference of the gas bills measured in steps 3 and 5 through the following formula:

$$\boldsymbol{SSPDi} = \left(\frac{\boldsymbol{Gas\ Bill_{Step3} - Gas\ Bill_{Step5}}}{\boldsymbol{Gas\ Bill_{Step3}}}\right) \times \frac{\mathbf{1}}{\mathbf{10\%}}$$

The bigger the difference is, the better the access from a price perspective.

Finally the diversification of a Zone is characterized by both:

- the number of sources resulting in a price decrease in the considered zone
- the magnitude of this decrease

4.2.6 Supply Source Price Dependence (SSPDe)

This indicator measures the price exposure of each Zone to the alternative increase of the price of each supply source. It is calculated for each Zone under a whole year as the succession of an Average Summer, Average Winter, 1-day Design Case and 14-day Uniform Risk. Results are aggregated on a yearly basis.

The Supply Source Price Dependence of all Zones to source S is calculated as follow (steps 2 to 5 are repeated for each source):

1. All sources have their price curves set flat at the considered Global Context level
2. The price level of the curve of the source S is increased by 20 % ensuring that the source S is minimized
3. The residential, commercial and industrial gas bill of each Zone is measured ($\boldsymbol{Gas\ Bill_{Step3}}$)
4. The curve of the source S is further increased by 10 %
5. The updated residential, commercial and industrial gas bill of each Zone is measured ($\boldsymbol{Gas\ Bill_{Step5}}$)

The price exposure of a Zone to the source S is defined as the difference of the gas bills measured in steps 3 and 5 through the following formula:

$$\boldsymbol{SSPDe} = \left(\frac{\boldsymbol{Gas\ Bill_{Step5}} - \boldsymbol{Gas\ Bill_{Step3}}}{\boldsymbol{Gas\ Bill_{Step3}}}\right) \times \frac{\mathbf{1}}{\mathbf{10\%}}$$

The bigger the difference is, the higher is the exposure from a price perspective.

Finally the dependence of a Zone is characterized by both:

- the number of sources resulting in a price increase in the considered zone
- the magnitude of the bill increase

4.2.7 Price Convergence (PC)

This indicator measures the difference between the marginal prices of gas supply of each Zone. For each climatic case, the marginal price of gas supply of a Zone is a direct output of the optimization used in modelling. It is calculated for each Zone under a whole year as the succession of an Average Summer, Average Winter, 1-day Design Case and 14-day Uniform Risk. Results are provided for each climatic case.

The lower the difference between the marginal prices of two Zones is, the better the convergence.

5 Monetization

The monetary analysis is based on the calculation of costs for Europe measuring the completion of the Specific Criteria defined by Regulation.

The following table defines the cost items to be calculated per country as part of the TYNDP for each Infrastructure (Low, High and PCI), Global Context and Gas Demand Scenario on the year 2015, 2020, 2025, 2030 and 2035:

COST ITEMS MONETIZED AS PART OF THE TYNDP-STEP			
COST ITEM	CLIMATIC CASE	WITHOUT SUPPLY STRESS	WITH SUPPLY STRESS
GAS SUPPLY	Whole Year*	×	
COAL FOR POWER GENERATION	Whole Year*	×	
CO_2 EMISSION FROM POWER GENERATION*	Whole Year*	×	
* as the temporal optimization of the succession of one Average Summer Day, one Average Winter Day, 1-day Design Case and 14-day Uniform Risk			

Table 5.1: Cost items monetized as part of the TYNDP-Step

In TYNDP, results of the monetization illustrate the potential evolution of the gas, coal and CO_2 bill from one scenario to the others. They should not be interpreted as any form of forecast.

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