PROJECT PE2GAS

Benchmarking European Gas Transmission System Operators: A Feasibility Study

FINAL REPORT

Per J. AGRELL
Peter BOGETOFT
Henri BEAUSSANT
Jacques TALARMIN

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Disclaimer

This is the final report of a feasibility study on the development of pan-European efficiency benchmarking models for gas transmission system operations commissioned by the Netherlands Authority for Consumers and Markets (ACM), Den Haag, on behalf of the Council of European Energy Regulators (CEER) under the supervision of the authors: professors Per AGRELL and Peter BOGETOFT as well as experts Henri BEAUSSANT and Jacques TALARMIN for SUMICSID.

The current report is the final report. An earlier version of the report has been discussed with the Commissionaires and with European gas TSOs, but no part of the final report has been formally reviewed by the Commissionaires and expresses only the viewpoint of the authors, who exclusively bear the responsibility for any possible errors.

The project acronym is PE^2GAS (Pre-study for the Economic Efficiency analysis of GAS transmission operators).

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Sumicsid SPRL
Rue Maurice Lietart 56
B-1150 Brussels, BELGIUM
www.sumicsid.com

Executive Summary

This report presents a feasibility analysis for a potential pan-European benchmark of gas transmission system operators on behalf of the Council of European Energy Regulators (CEER). The study goes through the steps of activity analysis to determine a feasible scope, then addresses the necessary data collection, including an approach for addressing heterogeneity in operating conditions, continues by outlining a modeling approach and a process planning, finally to arrive at a feasibility assessment.

The activity analysis distinguishes the specific assets of the gas transmission operators (GTSO), namely the pipeline system with compressors and control systems; the optional storage systems; and the optional LNG terminals. Likewise, a number of core activities are defined; ownership, planning, construction, maintenance, metering, system operations, market facilitation, storage and LNG operations. For various reasons, it is recommended to start the benchmarking process with an initial scope limited to the transport and transit services. This implies focusing on the pipeline system with associated activities. The scope may then be extended in possible successive studies using the same definitions to take profit of collected data and to address a higher share of the overall service provision.

A reliable benchmarking model should contain the major cost drivers and the critical environmental factors affecting the managerial control of the operations. The assessment of the two categories can either be done sequentially or in one step with a minor correction. The first alternative is easy to deploy, using an aggregate model and then soliciting candidates for explanatory control factors to enhance the model. However, the approach may easily be complex if the control factors presented are difficult to collect for all operators, leaving no choice but to use ad hoc adjustments. Given the relatively limited reference set, feasibility is higher using the second alternative where a larger set of asset and environmental variables that are relevant a priori for grid construction and operation cost are collected and processed in the first stage. This means that already in the first run the model would contain a minimal but powerful set of environmental parameters and output parameters that are already meaningful in terms of standardized construction and operating cost.

In order to guarantee sufficient time for data definition and documentation, a pan-European benchmarking is suggested to be a two-phase project, at least initially, where the first phase could be devoted to a thorough and anchored data definition and data collection process. The second phase could concentrate on the actual benchmarking, through a series of interactive workshops for TSOs and NRAs. Provided that the tender specification is complete and that the data definitions are established, a benchmarking project is likely not to be subject to detrimental risks of data errors, delays or model flaws. The risks for the project, primarily data quality and model validation, must be adequately addressed in the process planning stage. Although designed to provide reliable information about cost efficiency performance to regulatory authorities, the benchmark as proposed may also give valuable information to the operators about areas of strengths and weaknesses in capital and operating expenditure.

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1. Benchmarking

Before entering in the analysis, this chapter sets the stage by formulating a series of crucial questions for any benchmarking. Some questions will be answered already in this chapter, but most will find their responses in the actual text. Thus, the questions also serve as a reading map for the document, that otherwise might appear as somewhat technical. At the end of this chapter, we summarize the questions and provide an outline for the document.

1.1 Overview

1.01 This report investigates whether and how a regulatory benchmarking of gas transmission could be done in Europe. It is not presenting a detailed plan for such project, but aims at addressing some principal issues by providing analysis and some feasible solutions to the identified challenges. As such, it is more open-ended and less directive than an actual project plan would be.

On the history of benchmarking

1.02 The concept of "benchmarking" was born with the work of Taiichi Ohno, a quality engineer at Toyota aiming to improve the competitiveness of Japanese manufacturing in the 1950s (Ohno, 1988). Noticing that the final result, the value for money, of the Japanese car manufacturers was lower than that of the competitors at the time, Ohno visited e.g. Ford plants together with industry leaders to observe their practices. However, rather than limiting the observations to *partial productivity measures* (e.g. cars per hours) or *accounting metrics* (e.g. cost of goods sold in USD), Ohno undertook objective and systematic collection of data to compare and simulate the performance of the manufacturing system. The concept of a '*peer*' occurred in the meaning of a competitor that is not only doing something better, but who is also objectively comparable to our own production. The precursory use of benchmarking in Japan developed into the total quality management (TQM) paradigm, based on the foundations of objective data collection, but also involving the utility or value of the product or process.

1.03 In Europe, benchmarking has developed in two different and parallel tracks. In the evolution of political governance in Europe, benchmarking has become a term to describe the exchange of best practice, the analysis of needs and the objective monitoring of [political] effectiveness. 'Benchmarking' is in this connotation an instrument of control, enforcing convergence towards some common goal or outcome (e.g. market opening or a decrease in youth unemployment). Its popularity is partially explained by the alignment to other societal trends, e.g. increased transparency and accountability in public governance.

1.04 A second strand of benchmarking is an evolution of the original approach by Ohno, enhanced by the launch of mathematical methods to calculate comprehensive efficiency metrics in the early 1980s (cf. Chapter 6). Analysts, engineers and civil servants gradually undertake an impressive range of data analyses on many different activities, from schools, subsidies ferries, drug enforcement policies, sales staff performance – and not least – regulated infrastructure providers (energy, water, rail, airports). This report is naturally drawing on this latter stream as the benchmarking here is aiming at objectively measuring the relative performance of a set of operators.

1.05 After this short backdrop, we formulate a number of fundamental questions:

1) Why benchmark?
2) Who should be in the comparison?
3) What could be compared?
4) How can the benchmark be made?
5) When is it a good idea to benchmark?

1.2 Why?

1.06 A benchmarking may serve several goals

1) Learning
2) Forecasting
3) Target setting

1.07 The first type of benchmarking, aiming at identifying and quantifying best practice in order to actually implementing it in operations, prioritizes the *learning* effect. Here, the actual representativeness of the sample, the generality of the results and the scope of evaluation matter less than the level of detail obtained in some selected processes. Naturally, this first objective is strongly represented in *industry benchmarking*, such as those organized by consultants on behalf of some operators interested in a specific issue, e.g. pipeline maintenance.

1.08 Benchmarking data can also be collected in order to anticipate market and supply changes, e.g. the resources consumption needed to perform a task by using best practice is likely to provide a good forecast for future resource allocations. Likewise, firms showing high operating efficiency, perhaps in spite of mediocre financial results, are likely take-over targets. Benchmarking of this type is usually aiming for high statistical explanatory power, but is less interested in understanding the reasons for superior performance.

1.09 Finally, benchmarking has from its outset been a technique to enable robust *target setting*. When the objective is to improve performance, the level of the target to achieve cannot be set arbitrarily. Although this is endeavor is shared among many firms, the attention here is naturally on the role of the regulatory authority to monitor and challenge the operators under tariff regulation to continuously provide money for value. The critical mechanism behind this motivation is the monopoly license or concession granted to the operator, removing the risk of being replaced by a hypothetical competitor in case of inefficient service provision. However, the regulator, acting on behalf and in the interest of the final customer, cannot arbitrarily request reductions in cost or increases in services. The benchmarking here serves the important role of providing objective and attainable targets for the performance of comparable operators. This function can be seen as a sort of accountability that the regulated firm offers the society in return for a certain reduction of the investment and operational risks.

1.10 Benchmarking here is primarily intended to provide information for regulators in performing their statutory tasks, producing information that is ideally both more reliable and less costly than ad hoc reviews of detailed procedures by different methods.

1.11 However, we note that a benchmarking can be designed to provide useful information for identification of strong and weak sides of the operation also for operators. The level of learning attainable depends to some extent on the level of aggregation of the information and the necessary level of confidentiality associated with the data.

1.3 Who?

1.12 At a first glance, the question of composing a relevant reference set of comparators may seem obvious. The set of apples should not contain any oranges, but preferably all apples. Or not? Perhaps only the red apples? Or only *Golden Delicious* from Belgium?

1.13 If structural comparability is the criterion for inclusion, can this information be obtained even before collecting data? Should we first consider the result of a comparison before stating about its legitimacy? Which are the relevant grounds for composing a reference set?

1.14 In Chapter 2 we make an overview over the GTSO sector in Europe, discussing some common challenges and features. We also provide an initial idea about the size of a potential reference set were it is composed of European operators.

1.4 What?

1.15 The scope of a benchmarking is tightly linked to two important objectives that need to be reconciled: the materiality and the representativeness of the measure.

1.16 On the one hand, for a benchmarking to be impactful, the scope should contain the major services and costs that are covered by the tariffs authorized. Mechanically cutting the scope may not only reduce the interest of the final result, but also it perceived fairness, since 'invisible' aspects may affect the dimensions compared.

1.17 On the other hand, the scope is intimately intertwined with the comparability discussed in the previous section. Could not an adjusted scope actually improve comparability by highlighting the similarities and eliminating the differences? What is then the consequence on the question for the relevant reference set?

1.18 Chapter 3 deals with the question of the scope of a GTSO benchmark, it also provides some ideas how comparability can be analyzed and the importance – or not - of having certain dimensions included in the scope.

1.5 Which method?

1.19 When Ohno started his early comparisons, the only techniques that existed were partial productivity measures. Basically, a partial productivity metric is a Key Performance Indicator KPI defined as a ratio between some aggregate of output and an important input; say labor or capital. Of course, this type of calculation is easy to undertake and to present. However, assume that a firm has the highest amount of gas transported per employee hour; does it mean that its cost per nm3 is the lowest? Another firm may have a lower investment cost per pipeline kilometer – can a regulator combine these two observations to set a double target for a firm: labor and capital productivity? How about comparing a small and a large network? How does one include other factors in the analysis – environmental and contextual? Clearly, these simple ratios cannot form a consistent and reliable basis for decisions – but what alternatives are there?

1.20 Frontier analysis techniques rely on the idea that there is not a single best observation but a multi-faceted frontier of best-practice firms with somewhat different strategies and orientation. What methods can we choose from here? How robust are they to outliers? To noise and random influences?

1.21 A firm can be compared against other firms today to get a snapshot of the initial situation, but what about the evolution over time? How can observations over time be combined in a useful and systematic way? Is it a good idea to measure against average performance today? Or over time? What problems could occur if the initial (static) efficiency is measured in a different way than the evolving (dynamic) efficiency?

1.22 The question of whether one can define a feasible and reliable method to benchmark GTSO is addressed in some detail in Chapter 6. The analysis is not exhaustive, but focusing at analyzing whether conceptually sound approach that could work with the type and number of data points obtainable in a GTSO study.

1.6 How?

1.23 Gathering international parties around a common objective is never evident, even less so when the project may involve substantial efforts to deliver good results. Can such a process converge? How to deal with confidentiality? What expertise should be represented in the group? How long time could it take? What type of results could be obtained? What input can TSOs and/or NRAs provide during the process?

1.24 Naturally, the feasibility of multi-stakeholder study depends on the project organization deployed. There are many different ways of running projects, depending on resources, objectives and expectations. In Chapter 7 we outline some critical elements that are based on insights from similar projects in international energy network benchmarking.

1.7 Can it work?

1.25 Ultimately, even under the assumption that some positive answers could be found for the previous questions, the critical point is whether the overall endeavor would be worth the effort. What types of participants are necessary? How many? What are the risks facing such project?

1.26 The comprehensive feasibility analysis is made in Chapter 8. In turn, we assess and summarize the overall feasibility with respect to six criteria and then proceed to a contingency analysis.

1.8 Reading guide

1.27 Chapter 2 gives an overview of the European gas transmission operators, the sector to benchmark. The question of what to benchmark, the relevant scope is treated in Chapter 3. Data collection with parameter definitions is covered in Chapter 4 with details given in Appendix A (CAPEX) and B (OPEX). The question of environmental factors and differences is covered in Chapter 5. The model approaches possible are analyzed in Chapter 6. The process planning requirements are given in Chapter 7. The comprehensive feasibility analysis is found in Chapter 8, followed by a summary in Chapter 9.

2. Gas transmission in Europe

In this Chapter we present the regulated gas transmission sector in Europe, we give an overview of the organizations present and the number of eligible participants in a benchmarking.

2.1 Infrastructure operators in market opening

2.01 The European Union launched in the mid-1990s a profound reform of the gas sector in order to build at a then undefined horizon a single gas market and to develop competition, particularly by promoting networks interoperability and the development of gas trade between Member countries. This approach led to the signing of a EU directive in 1998 (directive 98/30/EC) that introduces a first series of common rules for the organisation of the gas sector to all Member countries. This directive provided for the implementation of free and non-discriminatory access of third parties to the transmission and distribution networks (concept of Third Party Access – TPA) and the opening of competition in the large consumers (industry, power generation) market. It also made mandatory the accounting separation of vertically integrated operators, who had to keep separate accounts for their regulated activities (networks) and deregulated activities (purchase and sale of gas to eligible customers).

2.02 This first directive was followed by a second, adopted in 2003 (2003/55/EC), which accelerated and deepened the opening of the markets. It provided for more stringent restrictions in relation to the separation of transmission and distribution networks: the accounting unbundling gave way to the legal unbundling with the creation of legally well-identified subsidiaries within the integrated groups. It finally gave obligation to Member States to create an independent regulatory authority.

2.03 Finally the adoption of the Third Energy Package in July 2009 created a common market for gas and electricity, including the Commission's proposals to harden the obligations regarding the separation of the networks, ensuring greater transparency in the operation of the markets, clarifying the roles and responsibilities of the national regulators, and creating the Agency for the Cooperation of Energy Regulators (ACER). However the Directive allowed maintaining ownership and control of transport networks within those integrated companies in the Members who so wished, while strengthening the regulation of the subsidiaries to provide guarantees that the groups may not influence the decisions taken.

2.2 A new business model for infrastructure operators

2.04 In a time where the consumption of gas in Europe was growing and gas imports were developing at an even faster pace due to the depletion of European reserves, the role of gas infrastructure, connecting more remote production sources with final consumers, was becoming even more important. In each infrastructure activity (pipeline transmission, LNG trade, storage), diversification of supply and the new fluidity of the gas market were requiring massive investments to modernize or expand the infrastructure.

2.05 While the strong link between these activities and their constituency of origin was fading in the creation of a single gas market in gas operators took advantage of this new environment to spread out of from their former, historical borders towards a scale unprecedented in this area: the European continent. Examples are numerous, including Gasunie (NL) extending into Germany, Fluxys (Belgium) into Germany and Switzerland, or Storengy, the storage subsidiary of the French GDF-Suez developing activities in the UK and Germany – just to name a few.

2.06 In parallel, many State-owned European gas infrastructure operators looked to get progressively free from the 'guardianship' of public funding. The single market prepared the entry of private capital in companies previously owned and operated by public entities. In a context of indebtedness of European States, operators were no longer keen on relying on the public power to fund the maintenance and modernization of transport networks. The profitability of these long-sighted infrastructures, the network logics and economies scale promising players greater profitability serving a greater number of clients, was enough robust and stable to attract private financiers: investment banks, pension funds and sovereign funds thus made their entrance into a market that had for a long time remained strictly industrial.

2.07 The emergence of transmission operators (TSO), LNG terminals operators (LSO) and storage operators (SSO) on a European scale has shaped the future gas market. In the early 2000s, the mergers of European actors give birth to emerging, European-sized groups in several countries. The strength of these giant groups lies, inter alia, in the extent of their networks and their storage facilities, securing recurring revenues, and also in their presence across the gas value chain; often owners of storage infrastructure, these actors are able to manage imbalances and ensure a full service to their customers. They finally have the necessary funds to finance gas large infrastructure, although they often seek financial partners to share the risk and debt. While the cooperation in European infrastructure projects may be required, these actors are still rivals, as shown in the fierce competition in the acquisition of facilities.

2.3 Regulation at European level

2.08 To ensure the technical and economic efficiency of the European gas market, the regulation of the gas sector consolidates also at European level. The creation of a single market in gas is not just for the liberalisation of national markets. The European Commission conducts several projects to improve the functioning of the market.

2.09 With this objective in mind 31 TSOs from 21 European countries created in December 2009 the Network of Transmission System Operators for Gas (ENTSOG). The creation of ENTSOG was initiated by the adoption of the Third Package, aiming at promoting the completion and cross-border trade for gas on the European internal market, and development of the European natural gas transmission network. The network codes developed by ENTSOG under the supervision of ACER is meant to set out the rules for gas market integration and system operation and development, covering subjects such as capacity allocation, network connection and operational security, including common network operation tools to ensure the transparency and coordination of network operations under normal and emergency conditions.

2.10 However, while the harmonisation of the rules through the establishment of common mechanisms is an indispensable prerequisite to ensure the fluidity of the network and therefore of the European market and simplifies the market for gas shippers and traders, it requires infrastructure operators to publish always more reliable information, at ever shorter intervals, and to a growing number of players.

2.4 The Operators

2.11 Infrastructure operators are now about a hundred across Europe, including all three activities (TSO, LSO and SSO). A large majority belongs to at least one of the two institutions: the above mentioned ENTSOG (which gathers only TSOs) and the GIE (Gas Infrastructure Europe) a professional association that represents the whole infrastructure industry in the natural gas business through three components: GTE for the TSOs, GSE for SSOs and GLE for LSOs.

2.12 In total 92 operators belong to either one or both institutions. ENTSOG gathers 44 members, plus 3 Associated Partners and 4 Observers. GIE has currently 68 members in 25 European countries, plus 3 Observers. Some important operators, in particular in the LNG activity (such as SEGGAS, the operator of the Sagunto, Spain LNG terminal, or Dragon LNG, in Milford Haven) do not belong to any of them.

2.13 Table 1 and Table 2 below present the list of the operators who are members of ENTSOG and/or one of the GIE components, along with some basic data on their respective activities.

Table 1 Gas operators in Europe 2014 1(2).

		Main Facilities					Membership				
		Pipelines	Underground Gas Storage		LNG Terminals		TRANSMISSION		STORAGE	LNG	
	Companies	length (km)	Sites	Working Gas Cap. (bcm)	Sites	max phys.cap. (mmcmd)	ENTSOG	GTE	GSE	GLE	GIE
AT	Gas Connect Austria	930									
	ÖMV Gas Storage GmbH		4	2.7							
	RAG Energy Storage GmbH		5	1.3							
	TAG Trans Austria Gasleitung GmbH	1,140									
BE	Fluxys SA	4,100	1	0.7							
	Fluxys SA (LNG)				1	39.6					
BG	Bulgartransgaz EAD	2,650	1	0.6							
KR	PLINACRO d.o.o.										
	PSP Podzemno skladište plina d.o.o.										
CZ	NET4GAS s.r.o.	3,820									
	RWE Gas Storage, s.r.o.		6								
	SPP Storage, s.r.o.		1	0.6							
DK	DONG Storage		1	0.6							
	Energinet.dk	800	1								
EE	AS EG Võrguteenus						*A*				
FI	Gasum OY	1,300									
FR	Dunkerque LNG, SAS (EDF)				1 (u/con	36.0					
	EDF Electricité de France, S.A.										
	Elengy SA (GDF-Suez)				2	67.2					
	Fosmax LNG, SAS				1						
	GRTgaz (GDF-Suez)	32,100									
	Storengy SA (GDF-Suez)		14	12.5							
	TIGF	5,000	2	2.6							
DE	astora GmbH & Co. KG		3	> 4							
	Bayernets	1,330									
	BGW / BDEW										*O*
	E.ON Gas Storage GmbH		16	8.9							
	Fluxys TENP GmbH	500									
	GASCADE Gastransport GmbH	2,400									
	Gazprom Germania GmbH		1	0.6							
	GTG - Gastransport Nord GmbH (EWE AG)	320									
	Gasunie Deutschland Transport Services	3,200									
	GOAL - Gasunie Ostseeanbindungsleitung	sharehldr NEL									
	GRTgaz Deutschland GmbH	1,000									
	jordgas Transport GmbH	340									
	terranets bw GmbH	2,000									
	Thyssengas GmbH										
	NEL Gastransport GmbH	440									
	Nowega GmbH	700									
	Ontras Gastransport GmbH	7,200									
	Open Grid Europe GmbH	12,000									
	RWE Gasspeicher GmbH		6	1.9							
	Storengy Deutschland Leine GmbH		7	2.0							
	VNG Gasspeicher GmbH		5	2.7							
GR	DESFA	990			1	12.5					
HU	FGSZ Földgázszállító Zrt.	5,700									
	Magyar Földgáztároló Zrt.		5	4.4							
	MMBF Földgáztároló		1	0.7							
IRL	Gaslink	2,310									
	Shannon LNG									*O*	
IT	Adriatic LNG				1	26.4					
	Edison Stoccaggio S.p.A.		2								
	GNL Italia S.p.A. (SNAM)				1	11.7					
	Infrastrutture Trasporto Gas SpA	80									

Table 2 Gas operators in Europe 2(2).

		Main Facilities					Membership				
		Pipelines	Underground Gas Storage		LNG Terminals		TRANSMISSION		STORAGE	LNG	
	Companies	length (km)	Sites	Working Gas Cap. (bcm)	Sites	max phys.cap. (mmcmd)	ENTSOG	GTE	GSE	GLE	GIE
	OLT Offshore LNG Toscana S.p.A.				1	15.0					
	Snam Rete Gas S.p.A. (SNAM)	32,000									
	Stogit S.p.a. (SNAM)		8	11.4							
LV	Latvia Gaze Joint Stock Company						*A*				
LT	AB Amber Grid						*A*				
	KN - AB „Klaipėdos nafta”									*O*	
LU	Creos Luxembourg	1,850									
NL	BBL Company V.O.F.	230 (int'l)									
	Gasunie Transport Services	15,500									
	Gate terminal B.V.										
	NAM										
	N.V. Nederlandse Gasunie										
	TAQA Energy B.V.		1	4.1 (op. 2015)							
NO	GASSCO	8 000 (int'l)					*O*				
PL	GAZ-System	10,100									
	Operator Systemu Magazynowania Sp. z o.o.		7	2.5							
PT	REN Armazenagem S.A.		1	0.2							
	REN Atlântico S.A				1	18.2					
	REN Gasodutos S.A.	1,380									
RO	Transgaz SA	13,140									
SL	EUStream										
	NAFTA a.s.		1	2.4							
	Pozagas a.s.		1	0.7							
SI	Plinovodi d.o.o.	1,121									
ES	BBG Bahia de Bizkaia Gas, S.L.				1	19.2					
	ENAGAS SA	10,180	3	2.7	ope	111.5					
	REGANOSA Regasificadora del Noroeste				1	9.9					
SE	Swedegas AB	620									
UK	BGE (UK) Ltd										
	Centrica Storage Limited		1								
	Interconnector UK Ltd	230 (int'l)									
	National Grid Gas plc	7,600									
	National Grid Gas plc (Grain LNG)				1	59.1					
	Premier Transmission Limited	160									
	South Hook LNG Terminal Company Ltd.				1	59.1					
CH	Swissgas AG	2,240					*O*				
UG	Ukrtransgaz						*O*				
FYROM	GA-MA AD						*O*				
ALL 30	Members						44	29	32	16	68
	Associated Partners						*3*				
	Observers						*4*			*2*	*3*

3. Benchmarking scope

In this Chapter the question of what to benchmark, the relevant scope, is discussed. Activity by activity is analysed with respect to homogeneity and data access, resulting in a suggestion for a restricted initial scope that later can be extended.

3.1 General

3.01 The most general objective of a benchmarking study is to determine the managerial performance of a transformation of controllable resources (inputs) into valuable services (outputs), if necessary controlling for exogenous complicating factors (cf. Figure 1). In the case of energy infrastructure, the services are not limited to the mere transport work, but also the provision of capacity for transport and the activities related to customer interaction.

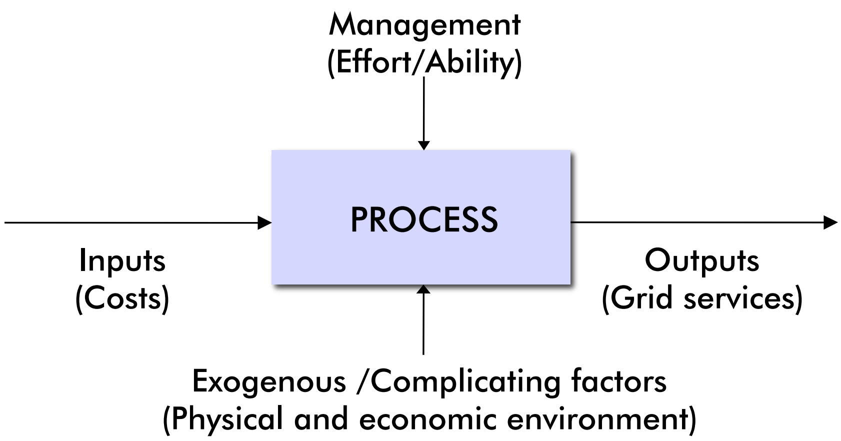

Figure 1 Activity model for benchmarking.

3.02 Below, we distinguish between the (regulated) services provided by gas transmission operators, the (specific) assets used for such services and the (generic) activities performed by an operator on the assets. The motivation for this differentiation is to achieve comparable observations; not all certain services (say, system operations) may be accomplished with different assets (e.g. control or storage systems) and under different regulations. However, an activity such as maintenance of the pipeline system is not directly a service, but necessary to perform any value-added operations on the network (transport, transit, etc.). This approach is common in regulatory benchmarking where the technology is based on fixed assets such as energy transport networks.

Services

3.03 For gas transmission, some or all of the following services are represented among the TSOs:

1) Transport services to downstream exit
2) Transit to a cross-border point
3) System services

4) Storage services
5) LNG services

3.04 As depicted in Figure 2 below, an initial approach to activity analysis would aim at finding direct observations or proxies for the five services above under the prerequisite that there were no joint costs, assets or products. As we will see below, this is not the case and some delimitations will have to be made.

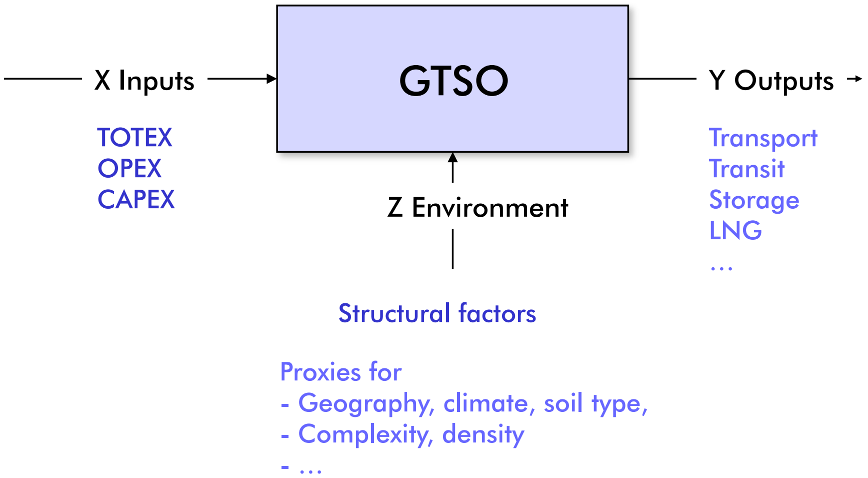

Figure 2 Principal process model for gas transmission.

Assets

3.05 A typical European gas transmission system can be subdivided as follows:

1) A pipeline network with its control system (SCADA, telecommunications and control centers)
2) Optional underground storages;
3) Optional LNG re-gasification terminals and/or LNG peak-shaving plants.

3.06 Below the pipeline network includes associated stations (in-line stations, compressor stations and pressure reducing and metering stations) necessary for accomplishing the primary task, transport of high-pressured gas.

3.2 Pipeline network

Pipeline

3.07 The pipeline network transmits gas from the receiving points located at the borders of neighboring TSOs and/or from LNG either to customers directly or through DSOs or for gas transit purposes to or from neighboring TSO.

3.08 The network parts used for transport to (domestic) customers versus transit offtake often have different dimensioning.

3.09 The pipeline is protected against external corrosion by an external coating and a cathodic protection system, alternatively through the use of other materials.

3.10 In-line stations (block valves and pig traps) are installed at regular intervals along the pipelines for safety and operational purposes.

3.11 The overall length of the pipeline by pressure level, material and cross-section are normally easily obtainable data from the TSO, whereof normally the first is regularly collected by NRAs. The exact location of the pipelines, the underground/land position, the type of soil cover and the maintenance state of the pipeline system may be obtainable through proprietary systems at the TSO.

Compressor stations

3.12 Compressor stations are erected along the pipeline route in order to compensate pressure drops as the network develops.

3.13 The number of compressor stations, their location as well as the types of drivers, compressors, installed ISO power fuel, annual gas compressed and fuel gas quantities are normally easily obtainable data from the TSO, but rarely collected by NRAs.

Metering station

3.14 Metering stations are of two types:

1) Border metering stations used for commercial and fiscal purposes;
2) Internal delivery stations located at the output of the transport system to measure the gas delivered and reduce its pressure to the needs of the downstream distribution system.

3.15 Data concerning the location, activity (either inlet or outlet transit or transport), technical design characteristics and share for gas transit and internal delivery of border metering stations are often readily obtainable by TSOs.

3.16 The location, technical design characteristics of internal delivery stations, including pressure reducing facilities and odorization devices, are typically TSO-specific data not collected by NRAs.

3.3 Underground storage

3.17 Installations for underground gas storage (UGS) may be used for gas modulation and storage purposes, mainly intended for grid users redelivering gas internally to distribution operators. Only a minority of the storage facilities are owned and operated by TSOs.

3.18 The data for the underground storages connected to the European gas network can be obtained also from public sources, including type, location, utilization, capacity for storage, withdrawal and injection (www.gie.eu)

3.4 LNG terminals

3.19 The Liquefied Natural Gas (LNG) terminals allow import of gas from producers by maritime transport to the gas transmission system. Currently (GLE, 2014) there are 22 existing LNG terminals in operation, offering a total capacity of 196 bcm per year. Prompted by the European energy supply security policy an expansion of an additional

6 (GLE, 2014) terminals is already underway and some 32 port locations are subject of feasibility studies for LNG installations. However, the overall LNG import to Europe has fallen considerably since 2011 and the overall utilization of the LNG facilities is down to above 20% (GLE, 2014).

3.20 Data for the LNG terminals is available from TSO and some public sources such as EUROSTAT and GLE, not only location and capacity, but also actual storage inventory, exact usage, services for reloading, transshipment, loading operations off grid. The transparency policy of GIE (Gas infrastructure Europe) also entails the provision of investment data for the LNG installations, including projects under study.

3.21 LNG peak shaving facilities, such as those operated by Fluxys at Zeebrugge, are also used for LNG storage purposes. Technical data for such facilities are likely at TSO level, when applicable.

3.5 Activities

3.22 After having reviewed the types of assets, we continue with an analysis of the core activities of the TSOs, following the definitions below into

1) Grid planning
2) Grid ownership/financing
3) Grid construction
4) Grid maintenance
5) Grid metering
6) Gas storage operations
7) LNG terminal operations
8) System operations
9) Market facilitation
10) Administration

3.23 In an NRA survey (cf. Appendix C) with 10 responding countries, the distribution of regulated activities among the TSOs is given in Figure 1 below.

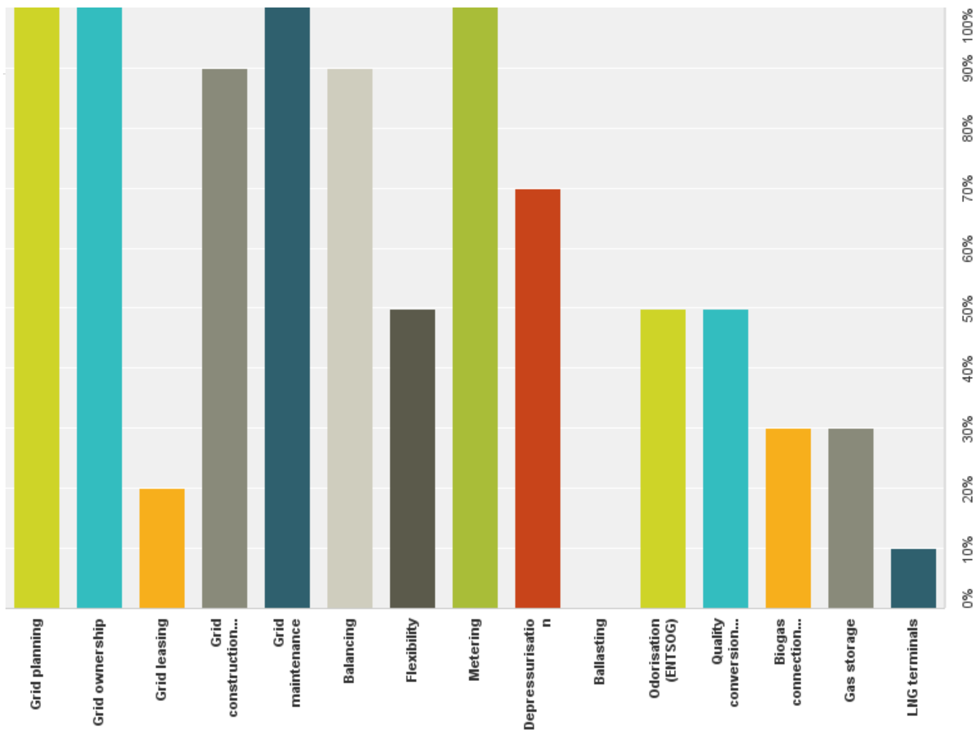

Figure 3 Activities of GTSO in Europe (Survey PE2GAS, 2014)

3.6 Grid planning

3.24 The analysis, planning and drafting of gas network expansion and network installations involve the internal and /or external human and technical resources, including access to technical consultants, legal advice, communication advisors and possible interaction with European, governmental and regional agencies for preapproval granting.

3.25 Grid planning also covers the general competence acquisition by the TSO to perform system-wide coordination, in line with the IEM directive, the TEN corridors and the associated ENTSOG tasks. Consequently, costs for research, development and testing, both performed in-house and subcontracted, related to functioning of the transmission system, coordination with other grids and stakeholders are reported specified under grid planning P.

3.7 Grid financing/ownership

3.26 The grid owner is the function that ensures the long-term minimal cost financing of the network assets and its cash flows, including debt financing, floating bonds, equity management, general and centralized procurement policies, leasing arrangements for grid and non-grid assets, management of receivables and adequate provision for liabilities (suppliers, pensions, etc.). Naturally, the major part of the capital costs for the transmission system is proportional to the investments made: the timing, currencies and conditions negotiated with suppliers to deliver and install the network assets. However, the gross financial costs depend on national fiscal rules for depreciation of assets, the leverage used in the financing, the yield requested by the markets for equity and debts for the country, currency and operator concerned.

3.8 Grid construction

3.27 The grid constructor implements the plans from the grid planning once all necessary authorizations have been granted. Construction involves tendering for construction and procurement of material, interactions, monitoring and coordination of contractors or own staff performing ground preparation, disassembly of potential incumbent installations, temporary site constructions and installations, installation of equipment and infrastructure, recovery of land and material, test, certification and closure of the construction site.

3.28 In particular, all expenses related to site selection and environmental impact analyses are classified as grid construction since this cost normally is activated with the investment.

3.29 As for electricity transmission operators, that costs related to the expropriation of land for construction, remodeling or dismantling of grid assets, including direct legal costs for the process and costs potentially paid to claimants as consequences of legal proceedings are to be excluded as country-specific costs out of scope. Attempts to use gross unit costs including land value may lead to distortions of the results.

3.9 Grid maintenance

3.30 The maintenance of a given grid involves the preventive and reactive service of assets, the staffing of facilities and the incremental replacement of degraded or faulty equipment. Both planned and prompted maintenance are included, as well as the direct costs of time, material and other resources to maintain the grid installations. It includes routine planned and scheduled work to maintain the equipment operating qualities to avoid failures, field assessment and reporting of actual condition of equipment, planning and reporting of work and eventual observations, supervision on equipment condition, planning of operations and data-collection/evaluation, and emergency action.

3.10 Grid metering

3.31 The TSO operates metering of the flow of gas in segments of the pipelines, at stations and at interconnections to other grids or terminals, including the IT-systems and administrative resources necessary for such services.

3.32 As noted in Figure 4 below, almost half of the TSO perform maintenance activities on behalf of third parties (normally DSOs or external storage and terminal operators).

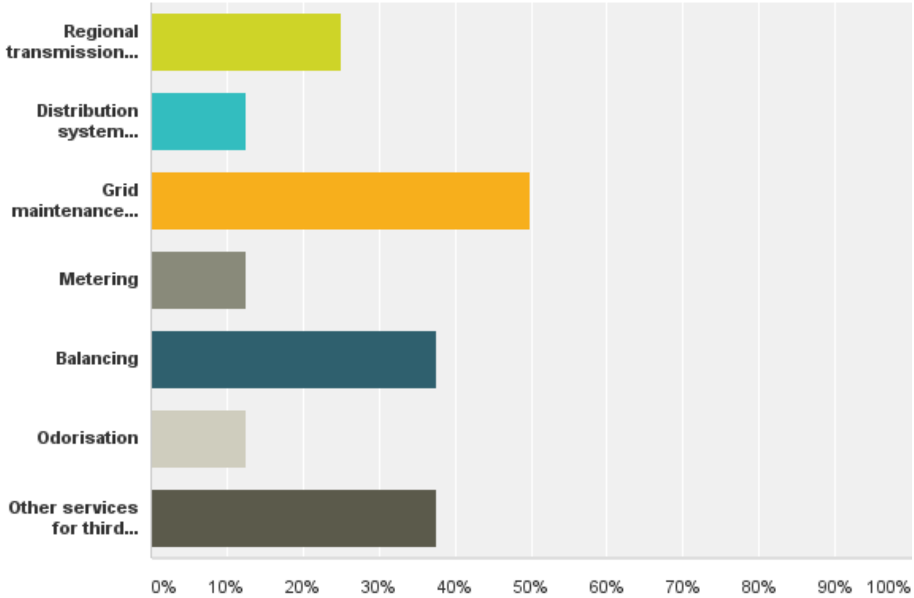

Figure 4 GTSO activities for third parties (PE2GAS Survey, 2014)

3.11 Gas storage operations

3.33 The operation of gas storage facilities (see assets above), including their maintenance and internal energy consumption, can be considered as separate service of gas storage, analogous to that of non-TSOs.

3.34 Costs concerning gas storage are separable according to the Directive 2009/73/EC Art 23 §1 (principle), Art 30§3 (obligation) and Art 41 §1(f), 6(a) (NRA authority to request data), both in terms of ownership of assets and their operation.

3.12 LNG terminal operations

3.35 The operation and maintenance of LNG terminals and peak-shaving plants, the interfaces with ports and other infrastructure, the administration and specific actions necessary to enable such operations are considered part of a specific service.

3.36 Costs concerning LNG terminals are in principle separable according to the Directive 2009/73/EC Art 23 §1 (principle), Art 30§3 (obligation) and Art 41 §1(f), 6(a) (NRA authority to request data), both in terms of ownership of assets and their operation.

3.13 System operations

3.37 Within system operations for gas transmission, we retain ancillary services (as defined in 2009/73/EC and congestion management (compliant with the ENTSO-G classification)

3.38 Ancillary services include all services related to access to and operation of gas networks, gas storage and LNG installations, including local balancing, blending and injection of inert gases, but exclude “facilities reserved exclusively for transmission system operators carrying out their functions”, 2009/73/EC Art 2(14).

3.39 The purpose of system operations is to ensure the real-time energy balance, to manage congestion, to perform failure analysis and detection, to manage the availability and coordination for preventive and reactive reparations, maintaining technical quality and balance within the coherent gas transport system, also ensuring that the necessary supply capacity for physical regulation of the system is available. It also deals with the day-to-day management of the network functionality, including personnel safety (instructions, training), equipment security including relay protection, operation security, coordination with operations management of the interconnected grids, coupling and decoupling in the network and allowances to contractors acting on the live grid.

3.40 System operations may entail delegating operational balance services to subordinate (regional) gas transmission coordinators with limited decision rights. If this delegation entails a contractual relationship with another grid, these costs are included in system operations to the extent that the services correspond to the services defined in 3.37.

3.41 ENTSO-G further considers the transparency in data exchange with the purpose of interoperability as a specific point in system operations. In consequence, costs related to this activity per se are to be considered as system operations for this project.

3.14 Market facilitation

3.42 The classification of ENTSO-G for market facilitation services includes capacity allocation mechanisms, congestion management, incremental capacity auctioning mechanisms, balancing and tariff structure. We note that this definition partially overlaps with the 'ancillary services' definition in the Directive. However, for the purposes of this benchmarking, it suffices to restrict the focus to the resources allocated to and the direct costs incurred by the design, operation and monitoring of the market access services mentioned. In the PE2GAS survey (Appendix C and D), the primary market facilitation service was in fact data provision, almost 70% of the GTSO engage in this.

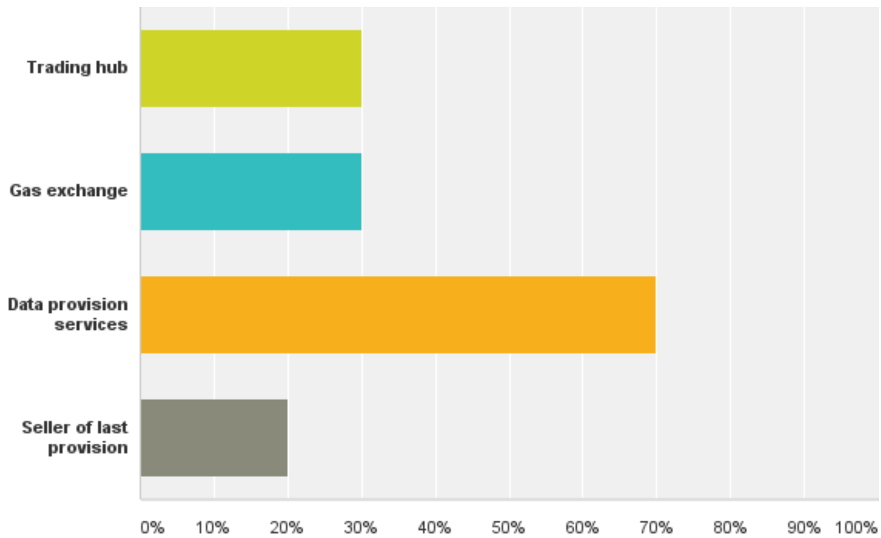

Figure 5 GTSO market facilitation processes (PE2GAS Survey, 2014).

3.43 We note that the national regulations, TSO rules and market procedures for capacity allocation and congestion are still under development and harmonization in Europe (ENTSO-G, 2014). Indeed, some of the definitions themselves for these services are yet to be fully determined and accepted.

3.15 Administration

3.44 With administration, we refer all costs related to the general management of the undertaking, the support functions (legal, human resources, IT, facilities services etc.) that are not directly assigned to an activity above. Administration can here be seen as a residual activity with respect to direct costs.

3.45 In principle, the residual assets for a gas transmission system operator (e.g. office buildings, general infrastructure) could be considered as assets for Administration. However, to the extent that this entails the incorporation of land, land installations and non-grid buildings in the analysis, all of which are susceptible to be country specific investments, such elements are normally listed and excluded from the benchmarking.

3.16 Definition of relevant scope

3.46 To be relevant and informative for the NRA, a benchmarking should compass as many activities of the regulated firm as possible. In theory, all regulated services are included in either a market-based (tendering) or inductive (econometric benchmarking) review. However, in the latter approach, the informativeness of the exercise relies upon the comparability of the data obtained for the activities in the scope. In international regulatory benchmarking (cf. ECOM+, e^{3}GRID) an indicator used for the determination of relevant scope is whether the inclusion of a specific activity leads to an increase in the fit of an average cost function. At this stage, in absence of actual data and considering that a GTSO benchmarking project would be a precursor in the sector, the reasoning must be based on logical arguments.

3.47 Thus, observing that the cost separation between activities System Operation (S) and Market facilitation (X) is weak, that the definitions of the services are evolving and the importance of launching a benchmarking with a cautious and reliable focus, we consider S and X as out of the primary scope.

3.48 Although the services of gas storage facilities and LNG terminals are subject to high cost separability and good data access, we also consider these services out of scope to focus on the core services of gas TSOs that is generally provided. The high cost separability makes it safe to make these exclusions.

3.49 The core services in planning, maintenance, and grid ownership are well in focus, with the caveat that planning activities must be examined after the collection of data. A priori there is no reason to exclude administration from the relevant scope, which also limits the difficulty in data collection and cost allocation for the operators.

4. Data collection

In this chapter a set of definitions for the data is suggested that ultimately would need to be collected to perform a comprehensive benchmarking of all services and functions, including e.g. storage and LNG operations. Certain subsection may not be applicable in the case the first benchmarking is limited to the scope of transport and transit (pipeline system). Specific analyses for CAPEX and OPEX elements are given in two Appendixes (A and B).

4.1 Overview

4.01 A survey was conducted among the NRAs on the availability of data for gas transmission at the authorities. The questions form Appendix C. The survey collected responses from ten regulators, the results are provided as Appendix D. Besides the specific insights given in Chapter 3, particular focus was put on the information acquisition ability of the NRAs concerning gas transmission data. The general findings from the survey in this regard are very positive: 90% of the respondents reported available or NRA-obtainable data for the various aspects (output data, asset data, investment data, cost data). Furthermore, the potential problem of incommensurate opening balances for the TSOs is apparently not serious (10%).

4.02 The organization of the Chapter is follows as

1) Pipeline system
2) Compressor stations (transmission)
3) Metering stations
4) Delivery stations
5) Gas storage
6) Compressor stations (storage)
7) LNG peak shaving
8) LNG terminal
9) SCADA and control equipment

4.03 Suggestions for data collection definitions for CAPEX elements in general are given in Appendix A. Analogously, a suggested set of data collection items for OPEX by function are given in Appendix B. The Chapter can be read independently of the Appendix that should be seen as a constructive proof of feasibility in itself with regards to data collection.

4.04 The data collection proposed in the project goes beyond that of comparable projects for electricity transmission or gas distribution. The reason for this is the ambition to provide stronger engineering construction cost estimates than in the more output-oriented models. The results are then closer to the observed values, which lowers the burden in the second round of data collection for operator-specific conditions and exceptions. We also believe that the data collection of technical engineering cost estimates enables value-added analyses *per se* for both NRAs and TSOs.

4.05 Nevertheless, the reporting burden may be higher than acceptable for some, in particular smaller TSOs. The idea, as we shall explain more carefully below, is therefore to split the benchmarking into two (sub)projects, where the first data collection project precedes the full project. The phased approach is a useful instrument to assess which data can be obtained relatively easily from the TSOs, and based on the outcome of this phase, the benchmarking phase can be adjusted to take into account the data availability. The data details suggested below might therefore not be data details that are ultimately requested in benchmarking phase. The data details below do however indicate what we consider to be ideal data and therefore also the data details that one should strive for.

4.2 Pipeline System

4.06 Information and data shall be tabulated as indicated in the following Table 3 and Table 4 relevant respectively to pipelines used for internal transmission and used for international transit.

Table 3 Pipeline information (internal transmission).

Pipelines used for Internal Transmission		
Pipeline Parameters	**Units**	**Pipeline Data and Informations**
Outside Diameter	DN	
	"	
Max Operating Pressure	bar	
Wall Thickness	mm	
Length	km	
Linepipe Manufacturing Specification (EN, API, ISO, DNV, etc.)	-	
Linepipe Steel Grade	-	
Linepipe Manufacturing Process	-	Seamless, ERW/HFI, SAWL/H, etc.
Pipeline Design and Construction Governing Codes	-	Indicate, if applicable, the reglementation evolution over time
Average Pipeline Location Classes Distribution	-	Indicate, if applicable, the safety factor modifications over time
(indicate Corresponding Safety Factors)	-	
Date of Commissioning	mm/yyyy	
Internal Coating [yes/no]	-	
External coating (CTE, AE, FBE, 2/3LPE, 3LPP, etc.)	-	
Cathodic Protection [yes/no]	-	
Planned Network Extensions	-	To be listed
Planned Network Decommissioning	-	To be listed

Table 4 Pipeline Information (International Transit Transmission).

Pipelines used for Transit Transmission		
Pipeline Parameters	**Units**	**Pipeline Data and Informations**
Outside Diameter	DN	
	"	
Max Operating Pressure	bar	
Wall Thickness	mm	
Length	km	
Linepipe Manufacturing Specification (EN, API, ISO, DNV, etc.)	-	
Linepipe Steel Grade	-	
Linepipe Manufacturing Process	-	Seamless, ERW/HFI, SAWL/H, etc.
Pipeline Design and Construction Governing Codes	-	Indicate, if applicable, the reglementation evolution over time
Average Pipeline Location Classes Distribution	-	Indicate, if applicable, the safety factor modifications over time
(indicate Corresponding Safety Factors)	-	
Date of Commissioning	mm/yyyy	
Internal Coating [yes/no]	-	
External coating (CTE, AE, FBE, 2/3LPE, 3LPP, etc.)	-	
Cathodic Protection [yes/no]	-	
Planned Network Extensions	-	To be listed
Planned Network Decommissioning	-	To be listed

4.3 Compressor Stations (Transmission)

4.07 For each compressor station installed on the gas transmission network, data and information shall be tabulated as indicated in Table 5.

Table 5 Compressor Stations Information (Transmission)

Compressor Station Location		**Units**	**Station**			
Compressor Line Identification			K1	K2	-	Kn
Commissioning Date		mm/yyyy				
Compressor	**Make**					
	Type					
Compression Technology (Centrifugal or Reciprocating)						
Station Arrangement (parallel, series, series/parallel)						
Compressor Lines in Operation		Nb				
Compressor Lines in Stand-by		Nb				
Driver	**Make**					
	Type					
DriverTechnology (Gas turbine, Gas Engine, Electrical Motor)						
Manifold Diameter		ND				
		"				
Compression capacity		Sm^3 or Nm^3/h				
	Reference Pressure	bar				
Pressure	MAOP	bar				
	Suction	bar				
	Discharge	bar				
	Compression Ratio	-				
	ΔP mini	bar				
Voltage		V	-	-		-
Max rotation speed		rpm				
Mechanical power	Per Line	kW (ISO)				
	Total					
Thermal power if applicable	Per Line	kW (ISO)				
	Total					
Mechanical Efficiency		%				
Thermal Efficiency if applicable		%				
Max. Temperature	Suction	°C				
	Discharge	°C				
Process control system (PCS) Station or Site						
Safety system (SSS) Station or Site						
Process control system (PCS) Machines						
CO2 Emission Reduction Policy						
Number of operating hours cumulated		hours				
Number of starts cumulated		Nb				
Compressor stations with recirculation						
Avearge Yearly Availability		%				
Last Overhaul Date		yyyy				

4.4 Metering Stations

4.08 Metering stations are installed on TSO borders and if applicable at the connection of the transmission network with UGS sites and LNG terminals.

4.09 For each metering station, data and information shall be tabulated as indicated in the following table.

Table 6 Metering Stations Information (Transmission)

Parameters		Units	Data & Information			
Metering Station Location		-	Location - Station Name			
Metering Line Identification			Line 1	Line 2	-	Line N
Commissioning Date		mm/yyyy				
Metering	Make					
	Type (US, turbine, etc.)					
	Size	DN				
		"				
	Nominal Capacity	Sm^3 or Nm^3/h				
Calculator	Make					
Chromatograph	Make					
Metering Lines in Operation		Nb				
Metering Lines in Stand-by		Nb				
Station Maximum Capacity		Sm^3 or $Nm^3/year$				
Minimum Pressure	Received	bar				
	Delivered					
Annual Gas	Received	Sm^3 or $Nm^3/year$				
	Delivered					
Max Gas	Received	Sm^3 or Nm^3/day				
	Delivered					
Fuel Consumption		Sm^3 or $Nm^3/year$				
Electricity Consumption		kWh/year				
Planned Extensions			To be listed			
Planned Decommissioning			To be listed			

4.5 Delivery Stations

4.10 It shall be observed that there are two sorts of delivery stations [also called city gate stations or PRMS (Pressure Reducing and Metering Stations)]:

1) Delivery to local distributors at low pressure
2) Direct delivery to industrials consumers at medium pressure.

4.11 It would be difficult to get the information mentioned below for each delivery station, given the very large number of stations even for a smaller TSO. As a consequence, the following information is only requested in aggregate for the whole set of stations:

1) Max capacity
2) Annual gas delivered
3) Max daily gas delivered
4) Fuel consumption
5) Electricity consumption
6) Consumable goods (THT).

4.12 Information shall be also provided about installed gas heating systems (at least the number of stations equipped with an gas heating system).

Table 7 Delivery Stations Information.

Parameters		Units	Data & Information
Delivery Stations connected to Local Gas Distributors	Number	Nb	
	Inlet Pressure	bar	
	Delivery Pressure	bar	
	Gas Heating System (yes/no)	-	
	Total Maximum Capacity	Sm^3 or Nm^3/day	
	Total Annual Gas Delivery	Sm^3 or Nm^3/year	
	Total Maximum Gas Delivery	Sm^3 or Nm^3/day	
	Fuel consumption	Sm^3 or Nm^3/year	
	Electricity consumption	kWh/year	
	Consumable Goods (THT)	Euro/year	
	Planned Extensions		To be listed
	Planned Decommissioning		To be listed
Delivery Stations connected to Industrial Consumers	Number	Nb	
	Inlet Pressure	bar	
	Delivery Pressure	bar	
	Gas Heating System (yes/no)	-	
	Total Maximum Capacity	Sm^3 or Nm^3/day	
	Total Annual Gas Delivery	Sm^3 or Nm^3/year	
	Total Maximum Gas Delivery	Sm^3 or Nm^3/day	
	Fuel consumption	Sm^3 or Nm^3/year	
	Electricity consumption	kWh/year	
	Consumable Goods (THT)	Euro/year	
	Planned Extensions		To be listed
	Planned Decommissioning		To be listed

4.6 Gas Storage

4.13 For each Underground Gas Storage, data and information shall be tabulated as indicated in Table 8.

Table 8 UGS Information

Parameters		Units	Data & Information
UGS Location			UGS Name
Type of Gas Storage			Aquifer, salt caverns, mines, depleted reservoirs, etc.
Commissioning Date		mm/yyyy	
Annual Gas Injection	Volume	Sm^3 or Nm^3/year	
	Injection Pressure	bar	
Annual Gas Withdrawal	Volume	Sm^3 or Nm^3/year	
	Withdrawal Pressure	bar	
Cushion Gas Volume		Sm^3 or Nm^3	
Useful Gas Volume		Sm^3 or Nm^3	
Dehydration System	TEG Consumption	Euro	
	Electricity Consumption	kWh/year	
	Gas consumption	Sm^3 or Nm^3/year	
Desulfuration System	MEA Consumption / Active Coal	Euro	
	Electricity Consumption	kWh/year	
	Gas consumption	Sm^3 or Nm^3/year	
Planned Extensions			To be listed
Planned Decommissioning			To be listed

4.7 Compressor Stations (Storage)

4.14 For each compressor station installed on underground gas storage facilities, data and information shall be tabulated as indicated in Table 9.

Table 9 Compressor Stations Information (UGS)

Compressor Station Location		Units	Station			
Compressor Line Identification			K1	K2	-	Kn
Commissioning Date		mm/yyyy				
Compressor	Make					
Compressor	Type					
Compression Technology (Centrifugal or Reciprocating)						
Station Arrangement (parallel, series, series/parallel)						
Compressor Lines in Operation		Nb				
Compressor Lines in Stand-by		Nb				
Driver	Make					
Driver	Type					
DriverTechnology (Gas turbine, Gas Engine, Electrical Motor)						
Manifold Diameter		ND				
Manifold Diameter		"				
Compression capacity		Sm^3 or Nm^3/h				
Compression capacity	Reference Pressure	bar				
Pressure	MAOP	bar				
Pressure	Suction	bar				
Pressure	Discharge	bar				
Pressure	Compression Ratio	-				
	ΔP mini	bar				
Voltage		V	-	-		-
Max rotation speed		rpm				
Mechanical power	Per Line	kW (ISO)				
Mechanical power	Total	kW (ISO)				
Thermal power if applicable	Per Line	kW (ISO)				
Thermal power if applicable	Total	kW (ISO)				
Mechanical Efficiency		%				
Thermal Efficiency if applicable		%				
Max. Temperature	Suction	°C				
Max. Temperature	Discharge	°C				
Process control system (PCS) Station or Site						
Safety system (SSS) Station or Site						
Process control system (PCS) Machines						
CO2 Emission Reduction Policy						
Number of operating hours cumulated		hours				
Number of starts cumulated		Nb				
Compressor stations with recirculation						
Avearge Yearly Availability		%				
Last Overhaul Date		yyyy				

4.8 LNG Peak Shaving

4.15 Requested information are as follows:

1) Location
2) LNG Capacity [m^3]
3) Annual gas injection [Sm^3 or Nm^3/year]
4) Pressure injection [bar]
5) Annual gas withdrawing [Sm^3 or Nm^3/year]
6) Pressure withdrawing [bar]
7) Daily gas withdrawing (peak) [Sm^3 or Nm^3/day]
8) Gas consumption [Sm^3 or Nm^3/year]
9) Annual gas flare [Sm^3 or Nm^3/year]
10) Electricity consumption [MWh]
11) Calorific water used [Euro]
12) Commissioning date.

4.9 LNG Terminal

4.16 Requested information are as follows:

1) Location
2) LNG Capacity [m^3/
3) Annual gas received [Sm^3 or Nm^3/year]
4) Pressure inlet [bar]
5) Annual gas delivered [Sm^3 or Nm^3/year]
6) Gas pressure delivered [bar]
7) Daily peak gas delivered [Sm^3 or Nm^3/day]
8) Internal gas consumption [Sm^3 or Nm^3/year]
9) Annual gas flare [Sm^3 or Nm^3/year]
10) Electricity consumption [MWh]
11) Calorific water used [Euro]
12) Commissioning date.

4.10 SCADA & Telecommunications

4.17 The way in which the transmission pipeline system is controlled and supervised can have a significant impact on the efficiency and safety of TSOs' services. In this regard, the information in Table 10 shall be provided about the SCADA and telecommunication facilities and corresponding operations.

Table 10 SCADA and Telecommunication (UGS)

Parameters		Units	Data & Information
Commissioning Date		mm/yyyy	
Control / Command and Degree of Automation	Pipelines & Related Appurtunances		
	Compressor Stations		
	Metering Stations		
	Delivery Stations		
	UGS if any		
	LNG Peak Shaving & Terminals if any		
SCADA General Architectture			
Telecommunication Media	Leased telecommunication services		
	Fiber Optical cable laid in the pipeline trench		
	Radio		
	Satellite		
	GSM		
	Others		
Back-up of telecommmunication media in case of failure (yes/no) and type of telecom. media			
Real Time management	Flow measurement & Quality Control		
	Gas movements follow-up		
	Line pack monitoring		
	Storage injections and withdrawals monitoring		
	Compressor performing monitoring		
	Leak detection [yes/no] and if applicable leak detection technology		
Integrated Pipeline simulation software (mention the selected software)			
Commercial operations principles (gas measurement and accounting)			
Location of main control center			
Availability [yes/no] and, if applicable location of a backup control center in case of main control center failure			
Other secondary control centers (if any) and location if applicable			
Planned Extensions			To be listed
Planned Decommissioning			To be listed

5. Heterogeneity

In this Chapter the problem of comparability is discussed, an approach based on environmental cost factors for pipeline construction is proposed.

5.1 Specific assets and costs

Assets

5.01 Whereas the default approach for benchmarking is output-oriented, i.e. the assets deployed are endogenous to the operator as to achieve some service objective, there may be instances where the type or configuration of the assets are imposed by a regulator. In such cases, these differences should be identified and quantified.

5.02 Assets that differ substantially from the assumptions in the data collection, e.g. in their functioning and dimensions, may also lead to adjustments of the reporting formats or the reported values.

Complicating factors and properties

5.03 To allow fair comparisons and relevant modeling, we need to account for a range of complicating factors, i.e. factors that the TSOs do not control and which may have significant impact on their ability to perform cost-efficient services. The complicating factors could for example reflect:

1) the climate, geographical and other operating conditions which might render the construction, operation and maintenance more difficult and costly
2) the environmental restrictions which may severely limit the firms' choice of technical solutions
3) the interconnectedness of the country, which could have a considerable impact on network configuration and operating practice.
4) the universal service obligations that are imposed on the different companies
5) the operator specific and market structures in entry and exit patterns that affect the company and on which it has limited control
6) public safety and operational security standards that are imposed on the company and which could have a considerable impact on network configuration and operating practice

5.04 To allow fair comparisons and relevant modeling, one also needs to account for a range of complicating properties, i.e. properties that the companies may affect but which are neither inputs nor outputs in the usual sense. Rather, the complicating properties capture different properties of the inputs or outputs. The complicating properties for a gas TSO may for example include:

1) Differences in the service restoration (leakage detection and correction) levels
2) Differences in customer satisfaction
3) Differences in the gas quality

How to handle complicating factors and properties

5.05 There are different ways to address such heterogeneity. Simply put, the most common approach is to make the corrections in a second stage. In the first stage parameters (such as network length) are constructed strictly on 'base-level' assumptions, e.g. dimensions and construction material, to create standardized parameters (e.g. equivalent network length). After statistical validation of the first-level parameters, the average cost model (or the benchmarking results) are tested for possible bias using separate environmental variables (e.g. dominating soil type, population density) to see whether the inclusion of such is statistically justified. This approach is effective for larger data series and environmental conditions that apply similarly across operators. An alternative approach, here called the engineering cost approach, involves the collection of asset data and environmental data in one stage. Here the collected data is used to calculate cost progression factors as function of the environmental factors, e.g. the relative cost increase due to rocky soil. Then, a 'normalized' set of parameters is constructed (e.g. network length) that already take into account the relevant parameters for grid construction. A subsequent second stage testing for bias will normally not yield any new parameters, since the important ones are already integrated in the analysis. Below, we comment upon the alternatives in some more detail.

5.06 Some projects have used second-stage statistical analyses of a few indicators (Jamasb et al., 2007). Here, a 'general' model with no environmental characteristics is developed using aggregated data and scores (cost estimates) are calculated using the model after regression validation. The final results are then tested for bias due to omitted variables by regression of the efficiency estimates against proxies for environmental difficulty (e.g. population density by country). We do not consider this approach ideal, in particular since the dataset will be small and the statistical analysis therefore will only be weak. Also, even the construction of proxy variables for test may be difficult if no structure has been foreseen (e.g. conditions by asset type or activity).

5.07 Other projects have used very detailed cost-submission scheme with deductions from benchmarked cost (e^3GRID, 2009, 2012). The idea here is to develop a somewhat more detailed cost model, but still through aggregation of asset types and activities (if applicable). The model provides correction for 'common' environmental conditions (e.g. routing complexity and density in e^3GRID). The TSOs may then provide additional detailed information about conditions that are not included in the correction factors, both OPEX and CAPEX factors. The submitted material may be validated by technical consultants and/or NRAs, potentially leading to direct deductions from the benchmarked cost base. Although this approach solves many of the difficulties of having a small data sample, it has the drawback of potentially being dependent on consultants' judgments, leading to heavy resource needs and strains on the process transparency.

5.08 A third approach is to make a more direct assessment of pipeline cost differences via the engineering cost norms, i.e. to let the weights depend on the environmental severity. Assuming linearity in the cost structure, the validation of these norms could be done with regression if data are available. The idea is closer to that of an engineering construction cost analysis, where the environmental factors are included in an integrated assessment already at the investment analysis, rather than as an ex post correction. The approach does not necessarily lead to overparametrized models (too many variables) since the weighting of the factors may be used to develop 'normalized' asset intensities of the type discussed above (pipelines, compressors, etc.). Considering the small data sample and the need to establish a new data standard for upcoming analyses, we consider this latter approach as the most interesting from a feasibility viewpoint. However, we note that the three approaches are not mutually exclusive and the final consideration must take into account the actual data access provided.

5.09 Nevertheless, in order to provide some more structured support for our analysis of the feasibility of performing an analysis of the heterogeneity of gas transmission networks, the following chapter outlines the criteria and parameters that could be collected for an approach corresponding to that in art 5.08. Below, the major asset category pipelines is chosen as base for the analysis, but analogous work could be done for other assets if shown to be relevant.

Criteria

5.10 Given the limited number of TSOs in any detailed study and the informational asymmetry inherent in the benchmarking of national monopolies, all individual conditions that are, or have been, applicable to the service cannot be covered. Instead, TSOs in international studies submit a statement of alleged complicating factors. To qualify for inclusion in the study as an operator-specific allowance, the cost driver has to have exogenous, durable and sizeable impact on benchmarked cost. In addition, factors that are indeed valid in terms of the relevance criterion, but shared among all TSOs, are excluded.

5.11 Analogously, specific assets or assets not conforming to the definitions in the reporting guidelines should be reported separately and submitted for review. In the PE2GAS survey in Figure 6 the majority of GTSO were indicated as operating under semi-urban, agricultural and urban conditions, having river crossings as common complication.

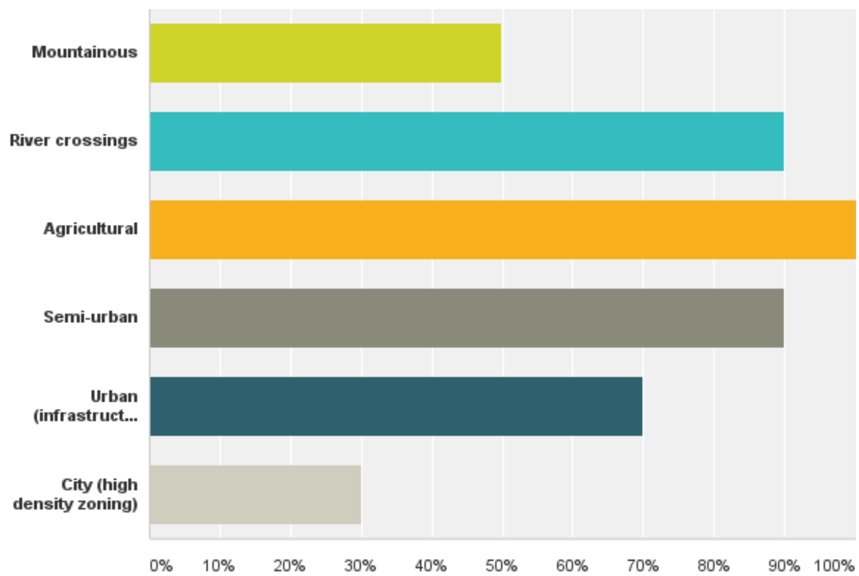

Figure 6 TSO specific network construction conditions (PE2GAS Survey, 2014).

5.2 Pipeline cost factors

5.12 Although the technical regulations to design, build and operate a gas network are increasingly harmonized in Europe, there may still be differences that must be documented according to the various countries involved in the benchmarking analysis. This observation may also relate to the environmental protection and land rehabilitation constraints after pipeline construction.

5.13 It is conceivable that two transport pipelines, with almost similar dimensions, can have very different CAPEXs as a result of construction difficulties related, for example, to the nature of obstacles to cross, the nature of sub-soils conditions, etc. It is evident, for example, that laying a pipeline is more costly in rocky terrain that in soft ground. Likewise the crossing of a mountainous area requires resources in equipment and personnel that cannot be compared with the related expenses for pipeline installation in a flat area without any particular subjection.

5.14 Similarly OPEX may be affected by changes related to external elements that must be identified and taken into account to make an objective comparative analysis of TSOs.

5.15 This section relates to the study of variables Z (Complicating factors) and parameters that may explain the variability observed in CAPEX and OPEX of transmission pipeline network and associated facilities.

5.16 These parameters are related primarily to the following factors

1) Climatology
2) Codes, standards, specifications used for transmission pipeline system sizing and construction
3) Land use
4) Soil subsurface features
5) Topographical, geomorphological and geological features
6) Wetlands
7) Anticipated pipe laying difficulties
8) Minor crossings
9) Major crossings

5.17 It is therefore important to determine the influence of Z variables (complicating factors) in order to make the adjustments necessary to establish an objective comparison of CAPEX and OPEX of various TSOs involved in a study.

5.18 A preliminary analysis of CAPEX for gas transmission pipelines and associated facilities shows that the price for pipe laying is the most dependent on external factors. The TSOs will have consequently to document, in particular, the cost of pipeline construction in order to establish the necessary adjustments.

5.19 As a general rule, TSOs shall provide, during data collection exercise, the technical information required about their transmission pipeline system. It is essential that all TSOs provide their information in the same (or as similar as possible) format in order to make easier (and less time consuming) the technical analysis of their data. It could therefore be advantageous to define this format and the tools necessary for easy control prior to the start of the actual benchmarking project (tables mentioned above can used as a basis of discussion with TSOs).

5.20 For the same reasons, the TSOs shall also provide their data costs (CAPEX and OPEX) according to a format which should be defined in advance.

5.21 Note that the collection of standardized and validated data on unit investment costs is beneficial irrespective of whether a benchmarking is undertaken, in line with recent initiatives by ACER, CEER and e.g. ENTSO-E for electricity.

5.22 Table 11 below shows a breakdown list (not limited) of previous items that could be taken into account in the cost estimation of a pipeline. The exact list and their definitions should be determined in consultation with the TSOs prior to a benchmarking.

5.23 Combined with the earlier asset data for the base case, the additional parameters in Table 11 are to be used statistically to estimate a robust set of complexity coefficients that can be applied to the network asset data for all operators. The dependent variables would be capital cost (investments) and/or operating expenditure, depending on the type of parameter. Engineering expertise intervenes here to limit the set of parameters in the estimations, as opposed to a pure second-stage approach where no hypothesis is made a priori for the cost impact of a parameter, say density.

5.24 Provided data is obtained, it is then possible to determine an overall coefficient of difficulty of pipe laying, which would represent the ratio of the total cost of construction (known) to the construction price of the same pipeline (same route and size) that could be built without any special constraints (i.e.: flat area, easily trenched, and without any surface and subsurface features). This leads to the establishment of normalized grid asset variables that need fewer or no environmental correction, while still being based on TSO-data.

5.25 Local regulations and possibly TSOs' specifications may result in additional constraints compared to European requirements in this field. Then, as we have already pointed out, some TSOs may decide for safety reasons to go beyond the requirements of the applicable regulations, e.g. specifying larger pipeline wall thicknesses. Similarly, some TSOs may, again for security reasons, specify:

1) deeper depths of cover for their pipes;
2) installation of a warning tape over the entire pipeline route;
3) etc.

Table 11 Environmental factors for pipeline cost estimation

ZONE		Additional Characteristics & Information
Base Cost (1)		
Land use	Urban (2)	
	Suburban	
	Industrial (2)	
	Rural	Land fragmentation
		Cultivated areas (2)
		Breeding areas
		Unproductive areas
	Desert	
	Wood	
	Forest	
	Roads (2)	
	River (2)	
	Environmental Protected Area (2)	
Soil Subsurface Features	Stony	
	Rocky	Soft
		Average
		Hard (2)
	Permafrost (2)	
	Unstable	
Topographical, Geomorphological & Geological Features	Undulating	Longitudinal Slope < 5 %
	Hilly	5 % < Longitudinal Slope < 10 %
		10 % < Longitudinal Slope < 15 %
	Mountainous (2)	15 % < Longitudinal Slope < 30 %
		Longitudinal Slope > 30 %
		10 % < Tranverse Slope < 25 %
		25 % < Tranverse Slope < 45 %
		Wide Ridge with transverse slope from 10 to 25 %
		Medium Ridge with transverse slope from 25 to 45 %
		Narrow Ridge with transverse slope over 45 %
	Seismic Sensitive Area (2)	
Wetlands	Occasionally Wet and/or Floodable	
	Permanently Wet or Flooded (2)	
	Swampy (2)	
	Peaty (2)	
Anticipated Pipelaying Difficulties	Pipelaying Spread Disruption	
	Tie-in	
	Temporary Fencing	
	Reduced Pipelaying Track	
	Access to Pipelaying Track	
Minor Crossings	Roads	Minor crossings (or singular points) corresponds to common obstacles which do not require the intervention of a specialised construction spread and the use of special construction procedures. Otherwise the crossing is classified as a major crossing (or special point or area).
	Railways	
	Small Wetlands	
	Water Courses	
	Ponds	
Major Crossings	Highways (2)	Major crossings (or special points or areas) corrresponds to important obstacles crossing requiring special construction procedures and the intervention of specialized contractors
	Important Railways (2)	
	Important Wetlands (2)	
	Rivers (2)	
	Lakes (2)	
	Subsea Areas (3)	

Notes

(1) Correspond to a flat area, easily excavable and without any subsurface and surface obstacle.
(2) Specific studies generally required
(3) Subsea pipeline sections shall be considered separately from land pipeline sections

6. Model approaches

This Chapter is devoted to the discussion of methodological approaches for TSO benchmarking in a regulatory context. The discussion is not focused at a discussion between specific methods, but outlines the necessary links between the stages of model specification, model validation, estimation method and sensitivity analysis to noise and outliers. The purpose is not to provide a unique and complete description, but to produce a substantiated and credible motivation for why – or why not – benchmarking could be possible in this context.

6.1 Background

6.01 The benchmarking model is pivotal in incentive based regulation of natural monopolies. By essence, benchmarking is a relative performance evaluation. The performance of a TSO is compared against the actual performance of other TSOs rather than against what is theoretically possible. In this way, benchmarking substitutes for real market competition.

6.02 Of course, the extent to which a regulator can rely on such pseudo competition depends on the quality of the benchmarking model. This means that there is no simple and mechanical formula translating the benchmarking results into for example revenue caps. Rather, regulatory discretion – or explicit or implicit negotiations between the regulator, the industry and other interest groups – is called for.

6.03 Different regulatory conditions in different jurisdictions means that the benchmarking approach should ideally support a multiplicity of potential applications. To facilitate this while at the same time creating a coherent benchmarking approach, we suggest starting the analysis from a unit cost approach before extending it to the use of more advanced benchmarking methods like Data Envelopment Approach (DEA). The unit cost approach is informative, intuitive and can provide useful information for more process oriented analyses while the use of DEA allows us to do a comprehensive evaluation with less stringent a priori assumptions than a unit cost approach. The use of asset data and assets weights in the unit cost approach is also necessary to cope with the problems of estimating in a small data set.

6.2 Model specification and validation methods

6.04 It is important to understand that there is no mechanical or linear procedure to develop an optimal benchmarking model. Good benchmarking models are typically developed by combining conceptual ideas, analytical results and empirical findings. This entails a process that develops interactively and which requires a good knowledge and understanding of the data available and the pros and cons of the possible estimation techniques.

Conceptual approach

6.05 Conceptually, it is useful to think of the benchmarking model as in Figure 2 above. A gas TSO transforms resources X into services Y. This transformation is affected by the environment Z. The aim of the benchmarking is to evaluate the efficiency of this transformation. The more efficient TSOs are able to provide more services using less resources and in environments that are more difficult.

6.06 The inputs X are typically thought of as Opex, Capex, or Totex. In any benchmarking study and in an international benchmarking study in particular, it requires a considerable effort to make costs comparable. We have found in previous studies that a careful cost reporting guide is of outmost importance to make sure that out-of-scope is interpreted uniformly, and that differences in depreciation practices, that taxes, land prices, labor prices etc. are neutralized. We have also found that it is useful to do process oriented models of Opex and Capex efficiency in addition to the theoretical ideal of Totex benchmarking.

6.07 The outputs Y are made of exogenous indicators for the results of the regulated task, such as typically variables related to the transportation work (volume of gas delivered etc.), capacity provision (storage volume, peak load, coverage in area etc.) and service provision (number of connections, customers etc.). Ideally, the output measures the services directly. In practice, however, outputs are often substituted by proxies constructed as functions of the assets base, like km of pipes, number of meters, number of compressors etc. One hereby runs the risk that a TSO could play the benchmarking based regulation by installing unnecessary assets. In practice, however, we have found that this is not a major risk in the early stages of the regulation and that the advantages of using such output indicators outweigh the risk. We shall therefore think more generally of the outputs as the cost drivers.

6.08 The class of structural variables Z contains parameters that may have a non-controllable influence on operating or capital costs without being differentiated as a client output. In this class we may often find indicators of geography (topology, obstacles), climate (temperature, humidity, salinity), soil (type, slope, zoning) and density (sprawl, imposed feed-in locations). One challenge with this class of parameters is that they may be difficult to validate statistically in a small data sample. They role of potential complicating factors will therefore have to be validated by other studies or in a process of individual claims from the TSOs. Another challenge is that in a small dataset, the explicit inclusion of many complicating factors will put pressure on the degrees of freedom in a statistical sense. In small data samples, therefore, we have normally found that individual adjustment of costs or weights to reflect for example difficult terrains is more useful.

Statistical tests and robustness

6.09 In addition to conceptual reasoning, statistical tests can be used to derive the model specification and to validate the resulting model.

6.10 In a larger data sample, we can rely on iterative regression model analysis to find the cost drivers that best explain the cost variation. In a small data set, the use of this is approach is more limited. Again, however, other studies even if the original purpose of these may be different, may have documented the statistical relevance of certain cost drivers.

6.11 In a similar way, a proposed model can be statistically validated by investigating if the cost drivers are significant, the signs are correct, the statistical properties (like homoscedasticity) is met etc. Again, however, limitations on the data set will restrain the possibilities of such formal second stage analysis.

6.12 To cope with the limitations of a small dataset while carefully investigating a set of alternative specifications, we have found that simple measures of goodness of fit may be useful. The general structure of these measures are based on the idea that a change in the model specification should not lead to too large changes in the distribution of the inefficiency scores. If it is possible to transform the maintained efficiency distribution into normal or half normal - say by calculating R(Fi)= Fi -1 where Fi is the efficiency of TSO i - then we can use the test statistic

$$\sum_{i=1}^{I} R(F_i)^2 / \sum_{I=1}^{i} R(F_i^*)^2$$

and evaluate this in a F(I,I) distribution with large values critical to test if the Fi estimated under a hypothesis H is reasonable given a maintained hypothesis H*, cf. e.g. Banker (1996).

6.13 We have also found that the general idea of robustness is more important that advanced econometric tests. We would therefore propose that a model should be compared with a set of conceptually meaningful alternative specifications to document that the results are not too much affected by reasonable model changes.

6.14 The idea of robustness may lead also to the idea of using a best off approach, i.e. to make two or more conceptually sound models and/or to use two or more state-of-the-art benchmarking methods, and to let the efficiency of individual firms be determined as the maximum of the efficiencies.

6.15 A numerically robust model dampens, or at least does not amplify, small perturbations of the reference data for performance. However, in regulation, the robustness of the model specification to changes in the operation processes, accounting reporting standards and financing policy is an equally important issue. A model specified in such a way that it draws on a process- or accounting specific specification will either unnecessarily hamper innovation, which might increase cost, or prompt for periodic revision of the model specification, which lowers regulatory commitment. Likewise, a variable specification that implicitly assumes a certain financial policy, such as full ownership of network asset as opposed to leasing or renting agreements, will also be vulnerable to future changes that may be potentially cost efficient. This aspect of robustness implies naturally that a regulatory model should opt for aggregation on the input side as to remain independent of changes in process, but should be disaggregated on the output side to correctly record the performed services and avoid dependency on implicit service specifications. A robust model for regulation is a model that consistently gives feasible and reliable, if not optimal, estimates of efficiency with a model specification (e.g. variables, methods, parameters) that stays constant or that is updated only gradually in a systematic fashion (inflation adjustment, price parameters etc.).

Outlier detection

6.16 Best practice (frontier) models in general and DEA in particular are sensitive to possible data problems in frontier units. This suggests that extra care is needed in the control of the data from such units. In practice, this involves an iterative process of doing trial estimations, to detect TSOs that might be outliers and set the frontier. Such units have to be fed back to data validation and in some cases this may lead to the identification of reporting problems. Having fixed them, the process has to be repeated to make sure that the data of the frontier units are of good quality. This is a time consuming process that has to be repeated whenever new data are collected. It is however, an important task and not one that can be done effectively without the benchmarking since the benchmarking gives a clear indication of the relevance of different units.

6.17 The identification of TSOs to check more carefully can use in particular four approaches.

6.18 One is to identify the number of times a TSO serves as a peer unit for other TSOs. If a TSO is the peer for an extreme number of units, either it is a very efficient unit – or there are possibly some mistakes in the reported numbers.

6.19 The other approach is to investigate the impact on average efficiency from unilateral elimination of the TSOs. If the elimination of one TSO leads to a significant increase in the efficiency of sufficiently number of units, there are again good reasons to check this more carefully.

6.20 Thirdly, one can do so-called shell analysis where the idea is to study the impact of groups of TSO, like the ones in the first shell, the second shell etc., cf. also Agrell and Bogetoft(2002). As the cost function is peeled this way, one shall check the shells with a significant impact on efficiency while there is less reason to continue the controls when the average efficiency is only improving slightly when a shell is eliminated.

6.21 Finally, one can use super-efficiency calculations to determine units with extreme super-efficiencies that are often associated with outliers, c.f. Banker and Chang(2005). Other outlier detection methods designed with particular focus on frontier models have also been considered, for example Wilson(1993).

6.22 In addition to these four methods, the data analysis might benefit from so-called order-m efficiency. The idea here is to evaluate a given TSO against the costs of the least costs TSO in a sample of m units that all provided at least the same of all services under the same or more difficult structural conditions. Of course, the order- m efficiency will depend on the sub-sample selected and for each unit, we have therefore done Monte-Carlo simulations picking the m units at random from the full population some 1000 times.

6.3 Static and dynamic efficiency measures

6.23 Ideally, a performance evaluation should measure effectiveness i.e. the extent to which it is possible to improve the overall goal of the TSO. In reality, this is complicated since the operator pursues multiple goals (e.g. security of supply and market facilitation) that are not easily aggregated. Moreover, we generally lack information about the possible transformation of resources to services of real operators.

6.24 In real evaluations or benchmarking exercises, we therefore go from measuring effectiveness to efficiency, e.g. the ability to provide the same or more services with the same or less resources. In addition, we go from absolute efficiency by measuring against an empirical norm as established by comparison with other units or by including information derived from actual practices. The latter corresponds to the establishment an empirical model, and the former to the measurement of efficiency relative to the estimated model.

6.25 Different approaches can be used to estimate the empirical model against which the performance of the TSOs shall be evaluated. The three most relevant in an attempt to benchmark European gas TSOs are the unit cost approach, the DEA approach, and the SFA approach.

Unit cost approach

6.26 A useful approach in a small sample benchmarking exercise is to estimate *unit costs or cost equivalents*. In a network, the main cost drivers are typically the different assets. It is impossible to estimate their contribution to costs directly using DEA or econometric techniques because the number of observations is typically small and the number of different asset types is large. Instead, relative costs are estimated using either cost allocation rules from accounting or engineering models calibrated to projects where detailed cost information is available. Once the relative weights, the unit costs or the cost equivalents are established, we can construct a few cost-aggregated "size of grid" or "net volume" metrics, such as

$$\text{Netvolume}(g) = \sum_{k=1} K(g) v_k N_k, \qquad g = 1, \ldots, G$$

where k=1,…,K(g) are the different assets in group g (say, pipelines), N_k is the number of assets of type k, and v_k is the relative costs of these assets compared to that of other assets in the same group.

6.27 Once these Net-volume metrics are established, we can measure the relative efficiency of the TSOs by comparing their aggregated unit costs UC

UC = Actual cost / Sum of net-volume.

6.28 To the extent we can allocate actual costs to different asset groups, we can also do group wise unit cost evaluations.

6.29 In a more advanced approach like DEA, one can then use the Net-volumes(g); g=1,.., G, as the main cost drivers. This means that we restrict the relative prices inside the groups but let the DEA model determine the relative weighting of the different groups.

6.30 A specific example involving this approach is the *e^3GRID* benchmarking project that we have conducted to evaluate some 22 national electricity transmission system operators from 19 different countries.

6.31 The unit cost approach is useful on its own, in part because it is closely related to the key performance indicators used in many companies for benchmarking purposes, and it is a natural first step before the introduction of more advanced frontier based benchmarking techniques like DEA and SFA.

DEA and SFA models

6.32 Econometrics has provided a portfolio of techniques to estimate the cost models for networks, illustrated in Table 12 below. Depending on the assumption regarding the data generating process, we divide the techniques in *deterministic* and *stochastic*, and further depending on the functional form into *parametric* and *non-parametric* techniques. These techniques are usually considered state of the art and are advocated in regulatory applications provided sufficient data is available.

Table 12 Model taxonomy.

	Deterministic	Stochastic
Parametric	Corrected Ordinary Least Square (COLS) Greene (1997), Lovell (1993), Aigner and Chu (1968)	Stochastic Frontier Analysis (SFA) Aigner, Lovell and Schmidt (1977), Battese and Coelli (1992), Coelli, Rao and Battese (1998)
Non-Parametric	Data Envelopment Analysis (DEA) Charnes, Cooper and Rhodes (1978), Deprins, Simar and Tulkens (1984)	Stochastic Data Envelopment Analysis (SDEA) Land, Lovell and Thore (1993), Olesen and Petersen (1995)

6.33 Corrected ordinary least square (COLS) corresponds to estimating an ordinary regression model and then making a parallel shift to make all units be above the minimal cost line. Stochastic Frontier Analysis (SFA) on the other hand recognizes that some of the variation will be noise and only shift the line – in case of a linear mean structure – part of the way towards the COLS line. Data Envelopment Analysis (DEA) estimates the technology using the so-called minimal extrapolation principle. It finds the smallest production set (i.e. the set over the cost curve) containing data and satisfying a minimum of production economic regularities. Like COLS, it is located below all cost-output points, but the functional form is more flexible and the model therefore adapts closer to the data. Finally, Stochastic DEA (SDEA) combines the flexible structure with a realization, that some of the variations may be noisy and only requires most of the points to be enveloped.

6.34 A fundamental difference from a general methodological perspective and from regulatory viewpoint is the relative importance of flexibility in the mean structure vs. precision in the noise separation. This means that there are two risks for error that cannot be overcome simultaneously. These are 1) the risk of specification error, and 2) the risk of data error.

6.35 The inability of the model to reflect and respect the real characteristics of the industry is related to the *specification error*. Avoiding the risk of specification error requires a flexible model in the wide sense. This means that the shape of the model (or its mean structure to use statistical terms) is able to adapt to data instead of relying excessively on arbitrary assumptions. The non-parametric models are by nature superior in terms of flexibility.

6.36 The inability to cope with noisy data is called *data error*. A robust estimation method gives results that are not too sensitive to random variations in data. This is particularly important in yardstick regulation with individual targets – and less important in industry wide motivation and coordination studies. The stochastic models are particularly useful in this respect.

6.37 It is worthwhile to observe that the two properties may to some extent substitute each other. That is, the flexible structure allowed by non-parametric deterministic approaches like DEA may compensate for the fact that DEA does not allow for noise and therefore assigns any deviation from the estimated functional relationship to the inefficiency terms. Likewise, the explicit inclusion of noise or unexplained variation in the data in SFA may to some extent compensate for the fact that the structural relationships are fixed a priori, i.e. the noise terms may not only be interpreted as a data problem but also as a problem in picking the right structural relationship. As an illustration of this it has been found that SFA efficiencies are often larger than the DEA efficiencies as long as the model is somewhat ill-specified., i.e. when the inputs and outputs are inappropriately chosen. The reason is that SFA in this case assigns the variations to the noise term while DEA assigns everything to the efficiency term. As the model is extended to include inputs that are more relevant and outputs, the two methods have been found to produce quite comparable results.

6.38 The relevance of the parametric models like SFA in the benchmarking of European gas TSOs is restrained by the small data sample that is expected. This does not make these approaches completely irrelevant, however. For sure, the model will have to be simple, using for example just one or two cost driver to explain costs. A relevant cost driver, however, could be the normalized grid size (net volume) constructed in a unit cost approach. Taking this approach, the SFA estimation may be considered an extension of the unit cost approach that better separates noise and inefficiency. More advanced applications may be possible if a panel data set is established or if we derive information from larger, international datasets, e.g. about the relative importance of two cost drivers.

Use and misuse of DEA and SFA techniques

6.39 The use of state-of-the-art benchmarking techniques like DEA and SFA requires particular knowledge of the pros and cons of these methods which in turn requires a deep understanding of the underlying technicalities of the methods.

6.40 DEA and SFA models are easy to use – and easy to misuse. It is easy to suggest a model and to run the software necessary to estimate DEA and SFA models. Indeed, a lot of software is freely available, provided in part by us, see for example Bogetoft and Otto (2011a,2011b). However, it is a non-trivial task to perform a benchmarking study in a proper way. The point is that from a scientific perspective these methods are still young methods that do not come with a fully developed set of indicators of possible estimation problems. The consultants should therefore have a very good understanding of the underlying technicalities of the methods, since only by understanding the geometry of the mathematical programming problems and the intricacies of numeric optimization of the likelihood functions can the consultants make sure that the methods are put to good use rather than misused.

6.41 The importance of understanding the details of the methods is further accentuated by the frontier nature of the analysis. A wrongly specified model may lead to grossly misleading conclusions. A DEA model that does not include all relevant cost drivers, for example, will suggest excessive saving potentials.

Alternative efficiency measures

6.42 Once a benchmark model has been established, it can be used to gauge the performance of TSOs in several ways and also inform the NRAs about related regulatory questions like how to evaluate proposed investment expansions. The innovative use of established models is often overlooked in the literature but it is very important, not the least in the case of benchmarking European gas TSOs, since NRAs may have different needs and also TSOs collecting data will have a natural expectation to learn as much as possible from the effort.

6.43 The two most obvious efficiency measures is the Totex and Opex efficiency

Totex efficiency = Actual Totex/ Model Totex

Opex Efficiency = Actual Opex/ Model Opex.

6.44 The latter can be measured disregarding the Capex usage, but a better approach is to derive it as a conditional efficiency (or a directional efficiency), i.e. as the efficiency of Opex usage conditional on not using more Capex.

6.45 To cope with the small sample problem we might also consider extending the DEA approach with weight restrictions. This provides a middle way between the unit cost approach that has fixed weight, and the traditional DEA approach, where cost driver weights are entirely free. Using weight restricted efficiencies, we are able to work with more cost drivers in a small dataset. Of course, it is very important that the weight restrictions make conceptual sense and preferably have an empirical basis. To ground the weight restrictions empirically, one can consider estimating parametric models on international data like the FERC data and to derive the weight restriction from these, see below.

6.46 A further set of measures that can be derived from a model is the marginal cost of service extensions. In all model approaches, one can answer what-if questions like: What is the expected extra cost of extending the service area, the size of the network, the number of meters etc.

6.47 To the extent a panel data set is established, it is also possible to construct dynamic efficiency measures, both in the unit cost and in the DEA/SFA models. The general idea of dynamic measures is to decompose performance in a TSOs into:

1) Individual catch up to best practice, and
2) Frontier shift or general improvements in best practices.

6.48 Again, this can be useful to information NRAs since regulations have traditionally stipulated a so-called firm-specific Xi and panel-general X factors.

Structural corrections

6.49 Needless to say, the relative performance evaluation of the TSOs shall ideally be corrected for differences in the structural conditions. Thus, a TSO forced to live with the difficulties of special climate, topology, particularly dispersed costumers etc. shall not be compared directly with TSO without these challenges.

6.50 There are several ways to correct for such differences and to test their importance.

6.51 In a DEA framework, ordinal structural variables can be used to group the TSO and to only compare a TSO against TSOs working under less favorable conditions. If the structural variables are interval scaled, we can instead include them as pseudo non-controllable inputs or outputs. The only difficulty with this approach is that several of the variables one can think of have a different nature than the usual resource oriented inputs and outputs. This means that the underlying assumptions about DEA in terms of convexity and scale may not make sense. This is often the case with ratio oriented structural variables. In such cases, one will instead have to rely on a second stage analyses. In a second stage analysis, the efficiency scores are regressed against the structural variable to determine the general impact of these. Next, the efficiencies are corrected for the impact of these variables using the regression model. Often, an OLS estimation is used and in large samples with low efficiency levels like in the German context, this is a quite safe approach. Nevertheless, if one analyzes ordinary efficiencies as opposed to superefficiencies, one should ideally take into account the truncated nature of the dependent variable, the efficiency, i.e. one should use a truncated regression a la Simar and Wilson (2004) or a TOBIT regression following Tobin(1958).

6.52 In an SFA framework, the correction for structural variables even if they are captured by ratios, can be handled as an integral part of the maximum likelihood estimation by parameterizing the inefficiency distribution with such variables, cf. Battese and Coelli(1993). Of course, one can also use a second stage approach like in DEA but there seem to be some advantages of the former approach, cf. Coelli and Perelman(1999).

6.53 In some case, we are not interested to correct the efficiency scores for the structural variables but we are interested to know if the model is biased against one type of TSO rather than another, e.g. TSOs with old rather than new grid assets due to the accounting cost of capital. In such cases, one can make non-parametric tests, like classical Mann-Whitney(1947) and Kruskal and Wallis(1952) tests, in addition to the second stage regressions.

6.4 Supplementary use of US data

6.54 To cope with the limited number of observations in a study of the European gas TSOs, one may consider supplementing with US data. There is a rich set of data on US gas networks available from FERC (Federal Energy Regulatory Commission). In addition, several US academics have collected additional data that might be made available to the consultants. An obvious idea is to use US data to enrich the database used in the European gas study.

6.55 Of course, the supplementary use of such data comes at the risk of comparing firms working under rather different conditions. It is not our recommendation to use such data directly for static analyses. However, an indirect use for dynamic analyses, to support the setting of weight restrictions or to detect patterns over time, may be feasible.

6.56 One of the advances in the recent DEA literature is that it is possible to make DEA models where the number of cost drivers can vastly exceed the number of observations if there is relevant information available about the relative weights of the cost drivers. The information does not need to be exact, like in a unit cost approach. Partial information suffices. The use of partial weight information to vastly expand the number of inputs and outputs one can include in a DEA model is demonstrated in Olesen and Petersen (2002) where they estimated a hospital model with more than 700 outputs using less than 100 decision making units by introducing bounds on the relative costs of different outputs.

6.57 We do not recommend working with a very large number of cost drivers, but we suggest that it can be useful to work with the unit cost elements individually as different outputs, and to supplement with other information about structural characteristics like density. We can then use weight restrictions derived from US data to ensure that the model estimated on European data can still discriminate the TSOs in terms of performance. In this way, an empirical sound foundation for the weight restrictions can be created while avoiding making direct comparisons between US and

European firms. The correctness of this approach would rely on a model specification that is equally valid for the entire sample, likely a technical efficiency model.

6.58 In the dynamic analysis, we can similarly benefit from comparison with US data. It does not make sense to directly compare the European TSOs to the US TSOs, and to estimate incumbent static inefficiency in European TSOs from a comparison with the US firm. However, in a dynamic analysis, the question is how the changes have evolved, i.e. how the distance between firms and the frontier have evolved and how the frontier has shifted. This means that the level of efficiency cancels out, and comparison with a frontier involving US firms does not obscure the evaluation unless there are reasons to expect that the dynamics are substantially different, e.g. that the rate of technological progress is much faster in the US than in Europe. A priori, this is not a very plausible assumption. One can further safeguard the analysis against this situation by norming the catch-up estimated for the European TSOs in such an approach to a best practice European standard by comparing the European catch-ups relative to each other. Alternatively, alternative hypotheses regarding the differences in frontier shift could be tested with other data, depending on the results and insights.

7. Process planning

In this Chapter we provide a sketch of a possible project organization that would address the many requirements necessary to undertake an international benchmarking. However, the description is neither exhaustive nor unique; other project processes may be possible and the final organization will be the design of the consultants selected in case of a launch.

7.1 Overall process

7.01 The project, as any large undertaking involving the coordination of numerous countries and different stakeholders requires a careful organization. To facilitate the organization and coordination of the project, the process shall be divided into different work packages and phases, and clear milestones shall be defined. The Phases relate to the intervals between Milestones during which project management shall assure coordination between WPs.

7.02 The particular challenges posed by the project organization are linked to the specificities of international benchmarking of energy networks:

1) Data quality assurance is imperative
2) Confidentiality of data must be assured
3) Communication need to be clear, fast and complete
4) Results need to be well explained, documented and justified

7.03 The challenges above naturally lead to the implementation of some standard procedures in project management of this type. E.g., the data quality criterion requires careful preparation of all data guidelines, the templates for use, the data validation procedures and protocol for data updates.

7.04 Below we expand on some of the elements, but it will of course be the responsibility of the consultants to specify the details of the process and the resources to be allocated to the different tasks and phases.

7.05 The project process has at least six types of components that partially overlap (items (b) and (c) are preferably initiated or fully completed prior to the main project):

a. *Undertake methodological work based on econometrics, convex analysis, and efficiency and productivity analysis to solidify the underpinnings of the models.*

b. *Develop clear asset and cost data definition guides to ensure precise understanding and assure comparable date amongst the TSOs.*

c. *Establish data collection routines between the coordinators and the involved TSO, including clear routines for submitting and evaluating TSO specific claims.*

d. *Establish an interactive process based on regular workshops each forwarding one element of the methodology towards the final result. Documentation regarding data definitions, preliminary results, weight sensitivities and elicitations, should be produced and disseminated in due time etc. prior to workshops and time shall be allocated to ensure the full discussion of this material.*

e. Data validation and verification with internal and external partners cross validation in the sample and asset studies with external data.

f. Final reporting, detailed confidential reports and ideally individualized versions of the report to each participant NRA-TSO.

7.2 Reporting

Single point of contact

7.06 Communication in the project must be structured to assure efficiency, transparency and to comply with the strict confidentiality requirements.

7.07 All general interaction, requests etc. from project members shall be handled by a helpdesk. In case questions would need input from an econometric or a technical team, the information shall be forwarded and the response passed through the same channel.

7.08 Project management, document and data handling shall ideally be using a secure online platform. In this way, all relevant parties have access to the same information, and clear logs can be kept as to all activities.

7.09 All normative information, such as guides, briefs, rulings or instructions shall also be passed through a project platform or similar to assure version management and to verify receipt. Impartiality and integrity of the process can be enhanced in this manner by simultaneously providing information from the consultants to the project participants

7.10 All releases of pre-run data for validation, interim or final results shall be made through the platform at the appropriate level of authority. All access to data is logged and monitored. This procedure guarantees that confidential data stays so, which is not the case when email is used for project communication.

7.11 All input of data for collection, but also formal approval of data prior to runs or after review by experts, shall be made through a web interface on the platform. Transmission of data in other formats or means void the confidentiality agreements. Data for processing shall stay in the relevant TSO area for the member, who may continuously follow any updating or corrections that are made during the validation phase.

Access rules

7.12 Clear rules must be defined as to who can access which information and who can alter data. The idea must be to limit information sharing to an absolute minimum and to only combine and share information according to clearly defined agreements and only to the extent that it truly facilities the analyses.

7.13 Unless specifically rejected, the regulator shall have read-only access to all TSO areas under their jurisdiction. In addition, each regulator disposes of a domain where specific regulatory rulings may be exchanged.

Data reporting

7.14 The data submission might be organized in three stages. The first data set (DS1) can contain raw data on grid assets and audited costs from annual reports; followed by decomposed cost data. A second data set (DS2) could concern additional material for operator specific cost drivers. A possible third data set (DS3) may contain data and documentation for approved specific cost drivers. This distinction avoids confusion when a single dataset becomes "unstable" due to unsynchronized updates and corrections. A single data collection with updates of any data item is not likely leading to a feasible process flow, since the initial estimates will have to be reiterated.

7.3 Workshops

7.15 Monthly progress meetings and 3-4 open workshops will constitute important events to monitor internal data collection status, signal and address potential reporting problems, discuss methodology and general data definition questions and to inform about intermediate and final results.

7.16 Although all NRA members may assist in all monthly meetings, a periodic electronic project brief might suffice to keep all participants informed about the project events at lower cost. A smaller set of open project meetings at crucial milestones (cf. Table 13) is however intended to gather most participants. At these latter meetings, important information will be released, explained and discussed.

Table 13 Open project meetings

Activity	Date	Milestone
Workshop I (kick-off)	X	M0
Workshop II (data collection)	X+3 month	M1
Workshop VI (static results)	X+6 month	M4
Workshop X (dynamic results)	X+9 month	M7
Workshop XII (final results)	X+12 month	M9

7.4 Project phases

7.17 The project shall be divided into different phases. It is the responsibility of the consultancy team as part of the bidding process to design these phases, but the following provides a series of some nine phases that may naturally be required.

M0-M1 Preparation

7.18 In this initial phase, the project management prepares the project setup with the client, defining the dates of milestones, prepares confidentiality and participation agreements. An electronic secure project platform is initialized. The methodological preparation involves updating and adaptations of existing material for the release of reporting guides, as well as the start of development work in specific areas, such as quality modeling. The preparation may ends with the first data workshop (W II).

7.19 The project members identify their functional assignments, familiarize themselves to the project platform and prepare the data collection internally.

M0-M1 Data Collection Guides

7.20 To ensure that the whole project can be undertaken in a reasonable time horizon, the data collection guides must be carefully prepared prior to data collection workshop at M1.

M1-M2 Data Collection

7.21 The data collection phase (DS1) should start at W II where the data reporting routines and the Guides (Assets, Annual Reports, and Cost Decomposition) are presented.

7.22 The TSOs collect, validate and submit the data, potentially after repeated interaction with the consultancy team.

M2-M3 Data Validation

7.23 During the data validation phase, the submission DS1 should be validated internally by the consultant's economic and technical teams, as well as by the external auditors in selected parts (costs) if applicable. Detected deviations are to be signaled and clarified with the TSOs. The phase ends with the final submission of the audited data. Internally, the data collection continues for exogenous cost drivers, quality indicators and socio-economic indicators as the outcome from the methodological development.

M3-M4 Calculation 1

7.24 Once a stable database has been established, the project proceeds to calculate the static scores, to internally validate them and to determine the full decomposition and link to exogenous cost drivers. The results are documented in R1 and presented at the end of the phase. However, care should be taken before publishing interim results based on data still under validation or subject to substantial corrections (if relevant for the method). Such interim disseminated results tend to be focal points for the rest of the analysis, even if the data material is updated. A compromise here to assure feasibility within a reasonable time frame could be to disseminate measures of model fit (explanatory power) and average values for selected metrics, but only if the data material is judged stable enough.

M4-M5 Calculation 2

7.25 In this stage, the larger time series data from US TSO (DS4) is compiled and validated, open to all participants. The calculation (2) is made with the methods defined, ideally both statically and dynamically to explore trend effects and to determine the expected productivity improvement rate for efficient operators with highest precision. The results from calculation 2 can also be used to study certain trade-off ratios (weight ratios) that can inform the following steps regarding the slope of the efficient frontier also for the EU reference set.

M5-M6 TSO Specific Cost

7.26 The TSO shall be given an opportunity to submit documentation and additional information regarding potential omitted operator specific factors to be included (DS2). The submissions, shall follow a specific Guide, and be reviewed and validated by a Technical Team, if necessary through the elicitation of additional internal or external information. The Econometric and Technical Teams decide on the list of operator specific conditions and disseminate any changes to asset classification, valuation of capex or opex impact or cost allocation solutions. All TSOs may now complement their submission DS1 with the new conditions as to form the final data set DS3.

M6-M7 Calculation 3

7.27 In this phase, the project shall perform the dynamic analyses based on the submission DS3 and the established times series, the results are analyzed, validated, controlled and documented in R2. Using the frontier analysis in DS3, certain weight restrictions may be obtained for (a subset of) the variables in the static model using the DS2 data. The static results are updated with the DS3 data set and revalidated internally for the final report.

M7-M8 Report

7.28 The final phase shall start with the release of the preliminary draft of the final report in two versions; confidential and open. All project members can review the drafts for completeness and correctness; proposed changes are compiled, evaluated and potentially executed by the project management. After the review period, production is made of the final versions R3 (open and confidential), including a number of potentially customized reports (R3C) for each NRA and/or TSO.

7.5 Auditing

7.29 The benchmarking study contains three types of information: cost data extracted from the accounting systems of the operators, technical data concerning assets and operations reported by the operators, as well as contextual data partially or fully obtained through public sources (EUROSTAT, national geographical data, etc.).

7.30 The validation of the cost allocation and the consolidation of the decomposed data should be controlled prior to submission. Irrespective of how the auditing is done, the data collection project should produce guidelines to determine the extent of this control and the eligibility of the party charged with the task (external, internal, NRA). One option is to use third-party independent audits for aggregated cost data, but the value of such control depends on the level of decomposition necessary in the model.

7.31 The technical data, as described above, is preferably left for project-based audits based on DS1 observations, R1 peer-status and DS2 submissions. Of particular importance is the reliability and veracity of technical data pertaining to operators designated as peers in the benchmarking.

7.32 The compilation of public and submitted data as well as the calculations themselves should also be open for audit by a third party as well as by control from each submitting operator (concerning their own data). The consultants should maintain records and documentation for each step in the calculations as to enable ex post validation of the results.

8. Feasibility analysis

In this chapter we proceed to a short summary of the feasibility of a regulatory benchmarking for gas transmission system operators in Europe.

8.1 Analysis of minimum number and type of TSOs participating

8.01 As discussed initially in Chapter 2, there are in total 37 eligible TSOs (full members of ENTSOG) whereof 29 are members of GTE. The minimal number of TSOs participating is easily derived using a conservative assumption regarding model (DEA rather than unit-cost analysis) and a single observation year for the first run. A conventional recommendation for the dimensionality of the reference is given by max{3nm, 3(n+m)} where n is the number of inputs and m the number of outputs. For an expected model size, $n = [1,2]$ and $m = [3,6]$ we obtain a recommended dataset of at least 12 up to 36 TSO. Practically, for a dataset of 20 TSO, a single-input model (e.g. TOTEX cost efficiency) can have up to six output parameters, although this would be highly unlikely.

8.02 However, given the suggested approach using supplementary US data for dynamic estimates, the minimal number of TSOs can be in theory be reduced to a much lower number, since weight restrictions block extreme positions on the frontier. Thus, a realistic assessment here is that 15 TSOs provide an initial workable set for a pan-European benchmarking.

8.2 Analysis of data collection

8.03 The data collection proposed in the project goes beyond that of comparable projects for electricity transmission or gas distribution. The reason for this higher requirement is the ambition to provide stronger engineering construction cost estimates than in the more output-oriented models. The results are then closer to the observed values that lower the burden in the second round of data collection for operator-specific conditions and exceptions. We also believe that the data collection of technical engineering cost estimates enables value-added analyses *per se* for both NRAs and TSOs.

8.04 Nevertheless, the reporting burden may be higher than acceptable for some smaller TSOs. Here, the idea to split the benchmarking into two projects, where the first data collection project proceeds the full project, is a useful instrument to assess which data can be obtained easily from the TSOs. Undertaking this analysis with reasonable time available and in close collaboration with the TSOs warrants higher initial reporting quality and lower loss of time in the (more expensive) main project.

8.05 However, a separate data collection project naturally entails coordination problems with the full project. Unless the consultants organizing the data collection are aligned and deeply familiar with the intended use of the obtained data in the benchmarking, time and effort could be lost in collecting data of limited value at large costs.

8.06 Thus, our recommendation is to tender the two projects in the same call, but as two separate projects with phased starting dates and/or acceptance criteria. Given the specifications in this study combined with the NRA reporting guides used in DE, UK and NL, we consider the data collection to be feasible for a reasonable set of TSOs.

8.3 Analysis of comparability

8.07 As discussed at length in Chapter 6, the gas transmission operators are subject to a number of complicating factors that limit a priori comparability. However, as the most important cost-driving differentiating factors are related to topology and terrain conditions facing new construction of pipeline assets.

8.08 First, using the rigorous approach outlined in Chapter 6 for deriving engineering cost estimates for standard unit costs, the comparability of the network operators will increase significantly.

8.09 Second, on the capex side labor cost differences, currency differences and local values for land, easements and activated planning costs contribute to the variability in the unit cost estimates. The benchmarking methodology proposed here corrects for these differences by restructuring the asset cost base and eliminating non-comparable items.

8.10 Third, on the opex side differences in local regulations and market definitions for value-added services, congestion management and LNG operations are important sources to opex variability. Here, the recommendation is to limit the scope in the first study to a transport-transit focus using the core assets (pipelines with compressors and control systems) for direct benchmarking. This cautious approach enables better validation of cost allocation even for a small dataset. Later, the scope of the benchmarking may be enlarged using the same or compatible data definitions.

8.11 In summary, given the measures suggested to ensure structural comparability, we foresee a data material that is at a level, equal or superior to that of similar regulatory benchmarks.

8.4 Analysis of model specification

8.12 The risk with a small number of observations (TSO) and a rich dataset (for each TSO) is that the resulting model specification will be too large (in terms of the number of variables) and still too weak (in terms of statistical properties). The analysts may resort either to ad hoc reviews (not really benchmarking) or to highly stylized models (to keep discriminatory power), both unsatisfactory approaches for a reliable regulatory benchmark.

8.13 The approach proposed for the gas transmission benchmark acknowledges the limited number of observations, but leverages this but differentiating the reference sets for the static (EU) and the dynamic (US) analysis. The dynamic approach is clearly feasible since FERC collects data for the US utilities since many years, although the data will require careful cleaning and review before analysis. The second use of the dynamic analysis to inform weight restrictions in the static model is also interesting, since it enables a somewhat larger model dimension without absurd marginal results for small reference sets. However, this requires at least partial symmetry in the static and dynamic models, which is non-trivial due to missing variables. Moreover, the weight restrictions can only be limited to certain ratios that are present in the two model specifications, which requires econometric skills.

8.14 Finally, the use of DEA or unit cost analysis for the static model seems relevant with respect to the types of networks at hand. Here, a caveat must be made for the use of unit cost analysis (assuming constant returns to scale) on data clearly revealing differences in the type of typology (meshed vs. radial networks) unless explicitly represented in the model.

8.15 In summary, the model specification approach is feasible, timely and reflecting state-of-the-art within the area of benchmarking.

8.5 Analysis of process features

8.16 Two risks are frequently present in terms of the benchmarking process in international projects; delays due to reporting problems and data validation issues.

8.17 The data collection process is as mentioned ambitious to enable a rich engineering-cost model already in the first run. However, this presumes that the TSOs indeed are able to supply the critical data for the selected scope (at least) by the deadlines set. The first suggestion in the analysis aims at separating the data collection to a smaller pre-project, sorting out definitions in consultation processes that could lead to better and more well-accepted reporting standards, more reliable reporting tools and adequate preparation time for the TSOs to undertake the data collection.

8.18 However, a phased approach may not be possible due to legal reasons (consultant doing the first phase could create unfair competition for the second tender) or for coordination issues (two different consultants pursuing incompatible strategies for data collection and model specification, respectively). Thus, to assure feasibility in this regard we recommend investigating a larger tender with two lots combined with an option to pursue the full project.

8.6 Analysis of benchmarking results

8.19 A regulatory benchmark is primarily pursued for and by the NRAs. In their monitoring role, they need to estimate two parameters; an operator productivity improvement rate (X) and, if relevant, the individual incumbent cost efficiency at a base year (Xi). As discussed above, the modeling approach proposed aims at guaranteeing the two parameters already from the first run, with the limitations stated. Provided sufficient resources are allocated to the data collection and validation, the approach will give good estimates for both parameters and thus be of informative value for the principals.

8.20 In addition, the TSOs will retain valuable information in the proposed process through individualized reports, direct comparisons with open data peers and the engineering standard cost analysis for construction costs. Assuming that the consultant possesses the technical staff to interpret and communicate the results to the participants, the benchmark will be of value also for the operators in a time of investment and consolidation.

8.7 Contingency planning

8.21 Three risks can be foreseen in this type of project:

1) Too little data to estimate a reliable model
2) Data errors provoke model changes and disrupt analysis
3) Time delays forces re-planning

8.22 The first risk (data scarcity) should be addressed in the planning prior to any project, as done in the proposal. In the case participating TSOs unexpectedly would fall out, a project should be able to provide data from other sources or using a different technique for the given run.

8.23 The second risk (data errors) is to be mitigated with careful, repeated and multi-stage data validation through technical, economic and output perspectives. The advantage with frontier methods, such as DEA, is that resources can be prioritized to peer-unit analysis to assure feasible frontiers. Nevertheless, the necessary competencies in terms of econometrics and technical systems (see "use and misuse of DEA") must be assured by the consultants.

8.24 The third risk (delays) is without any doubt the most serious process problem. A project facing initial delays may be forced to abridge review periods, data validation rounds, activity analyses and techno-economic audits. This may then limit the interpretation of the results to superficial findings. A well-planned project should explicitly address these concerns by using parallel processes rather than sequential, by providing some multiple sources of information and data, and by setting priorities for the different project activities.

8.25 From a feasibility perspective, the proposal in the pre-study is not complete and cannot be evaluated with respect to its contingency planning. This said, the elements regarding tiered data collection, multiple methods, auditing and the delimited scope presented in the proposal all contribute to higher process reliability.

9. Summary

Closing the study, we return to the questions initially asked in Chapter 1 to formulate some tentative answers.

9.1 The value of benchmarking

9.01 A benchmarking as the setup in this study is primarily designed to provide information to the NRAs, it corresponds in choice of method and data to the classical criteria of a systematic performance assessment with rather cautious assumptions on cost causality and generality. An additional but likely equally important value to the NRAs would be the establishment of a common data collection protocol and an associated data access that would enable other types of assessments, e.g. due diligence for expansion investment budget proposals and approval of goodwill resulting from horizontal acquisitions. Finally, the study shows that even an initial study could produce dynamic estimates if panel data is used from other jurisdictions. The attractiveness of this output should be weighted against the inconvenience of having different reference sets for static and dynamic assessments.

9.02 The TSO value of regulatory benchmarking is normally limited. However, some attention has been spent in this study on suggesting technical data that are relevant and informative for the operators, as well as anticipating the need for TSO dissemination and feedback in the process plan. The exact mode of interaction and information dissemination cannot be given in a feasibility study, it will depend to the participating TSO and the level of trust that can be established among the project participants. Nevertheless, it seems both desirable and attainable to require individual reports with a relatively high level of decomposition down to best-practice and average-cost performance as to provide the TSOs with value for their investments in data collection and validation. One may also imagine more collaborative, voluntary formats where TSOs could ask for specific analyses on e.g. the non-EU data material compared to their operations.

9.2 The reference set(s)

9.03 The number of GTSO in Europe is not high, but not smaller either than the number of electricity TSOs. Thus, a priori there is no immediate reason to reject the suggested list in Chapter 2 of GTSO eligible for participation. In addition, in case of data shortfall two other ideas are worthy of consideration here:

9.04 First, the limitation of the relevant scope in Chapter 3 to 'pipeline transport and transit' opens for inclusion of data also for regional gas transmission operators (RTO), if relevant and provided a sufficiently good cost model can be derived. This would alleviate the data requirements and enable analyses that are more stringent. However, the inclusion of RTO would be subject to stringent cost reviews and analysis of the cost structural difference between the relevant costs for the GTSO and for the RTOs.

9.05 Second, the inclusion of non-EU observations for dynamic or structural analyses is interesting. Although a full correction for all static differences seems difficult, the hypothesis that technological change should be comparable deserves attention.

9.3 The initial scope

9.06 The analysis in Chapter 3 argues that gas transmission operations currently exhibit heterogeneity and lack of convergence in the task definition in certain areas, such as market facilitation and system operations. To achieve a reliable benchmark, the study suggests an initial focus that is oriented to the core tasks of transport and transit using the pipeline assets. Notwithstanding, the data collection sections in Appendix A and B also cover other assets and activities, such as LNG terminals and gas storage, highlighting that data definitions can be developed already now for future use.

9.07 The initial scope is probably a reasonable compromise to achieve feasibility. Care should be taken by the consultants to collect and review all relevant cost data as to avoid distortions due to asymmetric cost allocations among GTSOs.

9.4 Frontier analysis and engineering cost analysis

9.08 Chapter 6 largely advocates that frontier analysis is preferable in this context. The method is economically sound, requires few a priori assumptions and makes only mild hypotheses on the production space. The recommendation is not surprising, most regulatory benchmarking uses frontier analysis, in particular DEA, less so SFA due to the data requirements.

9.09 However, the approach to address heterogeneity is different in this study as compared to earlier work. Other projects have used either simple second-stage analyses of a few indicators (Jamasb et al., 2007) or a very detailed cost-submission scheme with deductions from benchmarked cost (e^3GRID, 2009, 2012). Neither approach is considered as optimal in this context, the first can be seen as lacking in precision, the second as too much dependent on accounting definitions and consultants' judgments. Here, a more direct assessment of pipeline cost differences is suggested to develop an engineering cost norm; in simplest form a weighted sum of asset intensities where the weights depend on the environmental severity. Assuming linearity in the cost structure, the validation of these norms could be done with regression if data is available. The use of aggregates facilitates the application of DEA as the curse of dimensionality is mitigated.

9.5 An interactive international project

9.10 The project planning in Chapter 7 depicts a demanding but exciting adventure for both NRAs and TSOs. Feasibility must be assured by several structural means; such as the double competence technical-econometric skills among the consultants, enough time prior to data collection to consolidate data collection definitions, clear and enforced auditing rules, a transparent yet information safe project platform format and an interactive workshop system with well-prepared sessions.

9.11 The success of a project of this type will crucially depend on the planning and initiative of the consultants managing the process. Of particular importance here are the impartiality and commercial independence of the project managers, as the project will handle sensitive data subject to strict confidentiality.

9.12 However, it is also necessary to clearly adjust the expectations of all project participants as to avoid delays, cost overshoots and frustration. As mentioned above, a credible stance would be to signal the project as a NRA-project with a set of well-defined and relevant TSO-benefits.

9.6 Feasible but challenging

9.13 The detailed feasibility summary in Chapter 8 gives green lights to all dimensions, but the difficulties are not hidden. Clearly, a seminal project of this type will require tight cooperation between technical and econometric experts to find a good cost model, to ensure the quality of the data and to validate the robustness of the results.

9.14 Nevertheless, the challenges and resources necessary should be put in proportion not only to the immediate benefits of the results potentially obtained in the first run, but also to the long-run direct and indirect benefits of improved production information and international best-practice exchanges. Analogously to the early projects in electricity transmission in 2003 and 2005, leading to the successful international projects in 2009 and 2012, audacity married to perseverance is a pledge of excellence.

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Appendix

SUMICSID SPRL (GROUP)
Rue Maurice Lietart 56
B-1150 Brussels, BELGIUM
Tel: +32 26 75 15 23
Fax: +32 27 06 53 58

belgium @ sumicsid.com

SUMICSID AB (SWEDEN)
Burs Galtungs 776
S-623 49 Stånga, SWEDEN
Tel: +46 498 48 31 96
Fax: +32 27 06 53 58

sweden @ sumicsid.com

SUMICSID APS (DENMARK)
Fru Ingesvej 19
DK-4180 Sorø, DENMARK
Tel +45 57 83 15 18
Fax: +45 57 83 15 18

denmark @ sumicsid.com

http://www.sumicsid.com