Determination of Available Capacity in Gas Transmission Networks in Europe*

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Abstract

A market for gas transmission capacity has emerged from the unbundling of formerly vertically integrated gas supply and transmission companies. This restructuring has been initiated by the liberalisation process in Europe. Third party access rules to transmission capacity are being developed and implemented in order to enhance competition. One important requirement for effective competition is adequate provision to the market of information about the amount of capacity that a system is able to provide. This implies that capacities are calculated in a consistent manner over time as well as across networks. The paper does not question the performance of physical network models but focuses on the network assumptions (*input*) necessary to simulate the available transmission capacities (*output*). Underlying concepts and principles are discussed which determine the adequate

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choice of network assumptions (*scenario*) for the calculation of available capacity. All system conditions, uses and limits must be considered in order to accurately assess the capabilities of a transmission network. Especially the way the network is being utilized (*by the users*) and operated (*by the system operator*) varies continuously over time. Hence, the amount of capacity that a network infrastructure is able to offer is neither fixed nor constant. The paper considers various trade-offs which lead to another outcome for the same network, e.g. more firmness (*reliability*) means less available capacity. Procedures for calculating available capacities are addressed covering ways to define the adequate firmness of capacity and to make the appropriate amount of firm capacity available to the market.

Keywords: unbundling of gas companies, gas transmission networks, third party access, calculation of available capacity, firm capacity

JEL-Classification: L95, K23, L51, L12, D43

1. Introduction

The development of competition and the convergence to an internal European gas market require that capacities in gas transmission network are calculated and provided in a consistent manner both over time and across networks. The network users have to be adequately informed about the amount of capacity that a network is able to provide[1]. The dynamic nature of networks as well as the natural monopoly situations, without industry-wide standards at the moment, gives a large flexibility to transmission system operators (TSOs) for calculating and providing capacity. These circumstances do not necessarily guarantee that networks are efficiently operated and that capacity is offered on a fair and non-discriminatory basis to all network users, large and small.

[1] See Guidelines for Good Practice (GGP2) in the final conclusions of the 7th meeting of the European Gas Regulatory Forum, Madrid, 24-25 September 2003. Regarding the calculation of available capacity, reference is made to e.g. ETSO (2001) for electricity transmission and NERC (1996,2005), RMPG (2001) for natural gas transmission in the US.

This paper addresses from a regulatory point of view the issue of calculating available capacities in interconnected gas transmission networks. The aim is to develop a calculation framework that is helpful to look at incentives to ensure that the right amount of capacity is made available to market participants. This objective does not necessitate the design of calculation methods that would fit for each European transmission network and neither is there a need to question the performance of physical network models currently used by network operators[2]. The focus is put on the network assumptions (*scenario*) necessary for simulating network performance and the matching between the scenario and the contractual commitments with network users regarding the reliability of transmission services[3]. The distinction between the calculation method used by the network flow model and the selected scenario assumptions is important. The calculation method has to correspond to the physics and particularities of the network and is as such not optional. On the other hand, there is much more flexibility in the choice of the network assumptions to design scenarios for simulating network performance.

The paper is structured as follows. Section 2 addresses capacity definitions and determinants. The general scheme for calculating available capacity in gas transmission networks is discussed in section 3. Section 4 assesses the trade-off between reliability of service and the amount of available capacity. The importance of "force majeure" events for calculating available capacity is addressed in section 5. Section 6 is devoted to scenario building. Section 7 presents a general calculation procedure. Finally, conclusions are listed in section 8.

2. Available capacity and determinants

The calculation of available capacity involves a number of variables that require definition. Figure 1 shows capacity definitions which are used in this paper[4]. Capacity is defined as normal cubic meters

[2] Excellent work regarding gas flow modelling can be found in the deliverables of the EU "E-Gasgrid" project, see e.g. Basso *et al.* (2004a,b). See also GIE's position paper on available capacities (GIE, 2004).
[3] See e.g. also the comments of CEER on GTE's (Gas Transport Europe) report on calculation of available capacities, CEER (2003).
[4] This paper applies the definitions of the European Directive 2003/55/EC and the Proposal for a regulation on conditions for access to the gas transmission networks (COM(2003 741, 10.12.2003).

per unit of time (m³(n)/h). The total useful capacity is equal to the total theoretical capacity (technical capacity) minus the capacity reserved by the TSO for system integrity and operational requirements.

Figure 1. Capacity definitions for gas transmission.

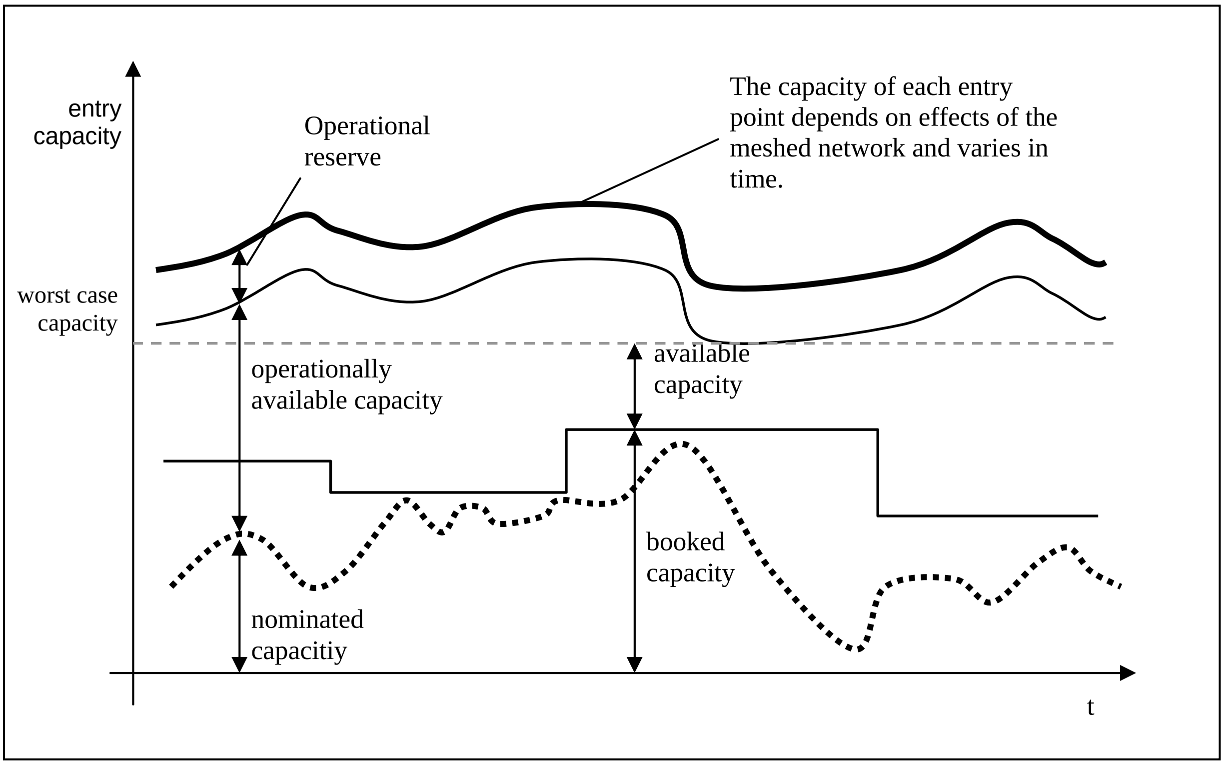


Figure 1 illustrates the variation in time of the capacity (and load) of one particular entry point in a network and the breakdown.

- the technical capacity and useful capacity vary in time because of network effects;
- the operational reserve is thought to be constant in this diagram;
- the booked capacity changes in steps because different shippers (*network users*) may book different schedules;
- the nominated capacity changes very strongly in a probabilistic way;
- the available capacity is the difference between the minimum technical capacity minus the operational reserve and the booked capacity according to the applied network flow scenario;

- the operationally available capacity is greater than the available capacity and varies continuously. It changes due to the changing of technical capacity and nominated capacity in a probabilistic way. Ideally, this operationally available capacity should be brought to the market, at least partially and not necessarily on a firm basis. This is an important way of maximisation of available capacities.

The capacity of a transmission network depends on static and dynamic elements, as well as on operational constraints:

- the static elements are the technical characteristics of the network itself. These elements include the network architecture (positioning of the entry points, of the exit points and of the inner nodes; design of the arcs between the nodes; presence of other equipments which modify the properties of the flow) and the specific properties of the arcs and other equipments. In a gas transmission network, these properties include:
    - the diameter of the pipelines on each arc or portion of arc;
    - the roughness of the pipeline material on each arc, which has an influence on the pressure losses;
    - for other equipments, such as valves or compression and heating facilities, the technical characteristics of these equipments.
- The dynamic elements refer to the way the network is being utilized (by the users) and operated (by the system operator). These elements vary continuously over time. For a gas transmission network, these variables include:
    - the properties of the gas injected/delivered at the entry/exit points (pressure, temperature, chemical composition);
    - the distribution of the nominations between the various entry points of the network;
    - the usage of the flexibility services offered by the system operator;

- the consumers’ gas demand at each exit point;
- the operating mode of the ancillary equipments by the network operator.

- The operational constraints are the boundaries set on each variable by the different parties. In particular:
  - the minimum/maximum pressure guaranteed at the interconnection points;
  - the operator requires a number of gas properties to remain within tight boundaries at each entry point;
  - the operator requires the gas supply (at the entry points) and off-take (at the exit points) to be the same, within certain margins;
  - the consumers require a minimum gas pressure at their exit point; this pressure threshold varies from consumer to consumer;
  - the operating limits of the ancillary equipments, typically on the volume flow and thermodynamic properties.

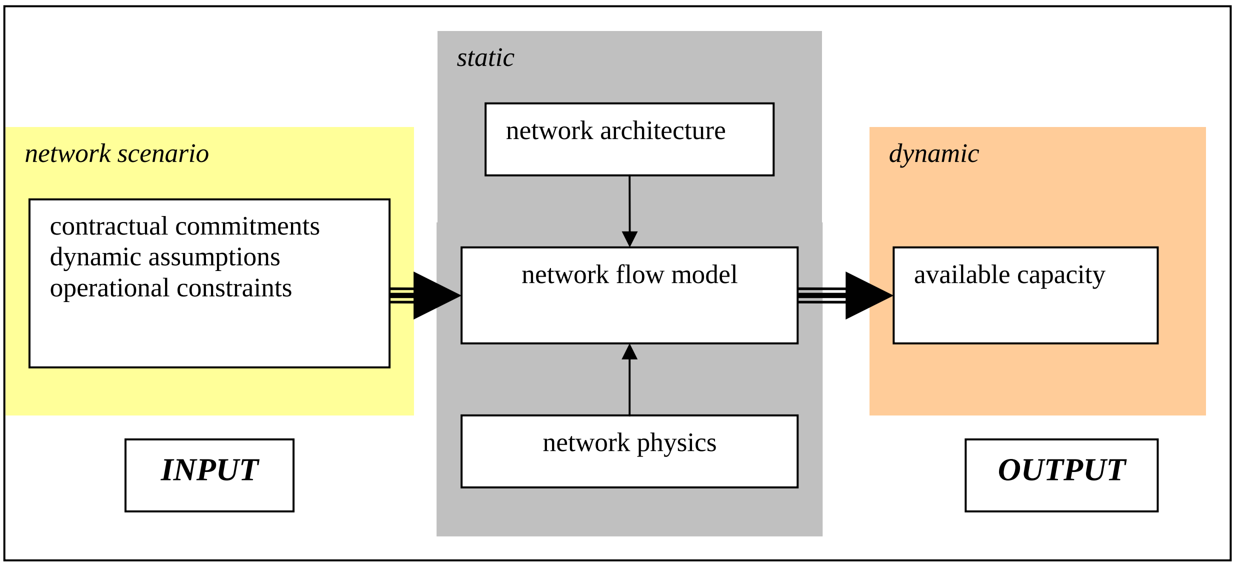
Because of the dynamic elements, the transmission capacity available in the network varies continuously. The dynamic elements are becoming more and more important because of the shift from a single-shipper environment to a multi-shipper. Furthermore, the uncertainty of dynamic factors increases drastically in a competitive market. Obviously, the more interconnected and meshed network, the more dynamic the network physics and consequently the more complex the calculation of available capacities. Making adequate assumptions about the variables is therefore necessary to estimate properly the capacity available in the network. System users have to be aware that available capacities vary as function of these determinants.

3. Capacity calculation

The calculation of available capacities is generally based on computer simulations[5]. Network models depend on static and dynamic characteristics as well as on operational constraints. The static features depend on technical characteristics of the network itself (network architecture and physics). The dynamic elements refer to the way the network is being utilised by the users and operated by the TSO. These elements vary continuously over time. The operational constraints are the boundaries set on each variable by different parties (e.g. minimum pressures).

Making appropriate assumptions about the variables is necessary to robustly and accurately estimate the capacity available in the network, i.e. the scenario used will drive the output. This has to be done in a framework where capacity definitions are adequately specified. This calculation scheme is illustrated in figure 2.

Figure 2. Scheme of calculating available capacity.



available capacities are not absolute but vary in function according to
the selected underlying network assumptions

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what you get out of a network model (*available capacities*) is what you put in (*scenario*)

network scenario = contractual commitments + dynamic assumptions + operational constraints

[5] An application to the Belgian gas transmission network can be found in CREG (2004).

System operators have generally the best knowledge of the network physics and the network architecture. The physical modelling of the system is, however, not sufficient to calculate system performance. Before capacities can be calculated network models have to be fed with a large set of data and conditions related to initial and boundary conditions of the network. Many of these parameters are exogenous and they are subject to a varying degree of certainty:

- to calculate available capacity it is necessary to first estimate a network scenario and the first step in undertaking this is to identify the contractual commitments of the TSO (e.g. booked capacities and contractual pressure specifications);
- the dynamic assumptions refer e.g. to the way the network is operated by the TSO and to the behaviour of the net users. Model forecasts and statistical analysis of historical data provide valuable information to elaborate these assumptions;
- the necessary capacity for operational needs of a TSO has to be calculated according to the requirements for the efficient operation of the transportation facilities (safeguarding system integrity) including any operating margin necessary to ensure the security and reliability of the system, e.g. in case of sudden imbalance of a shipper or in case of a network breakdown.

Different flow patterns and configurations lead to strongly different capacity distributions in the network. The dynamic and probabilistic nature of system simulation outcomes regarding available capacity calculation necessitates transparent calculation procedures in order to inform the market correctly about the transmission services offered. It is crucial that the calculation principles are harmonised as far as possible and that any differences are understood and made clear to all parties.

4. Trade-off between reliability and amount of available capacity

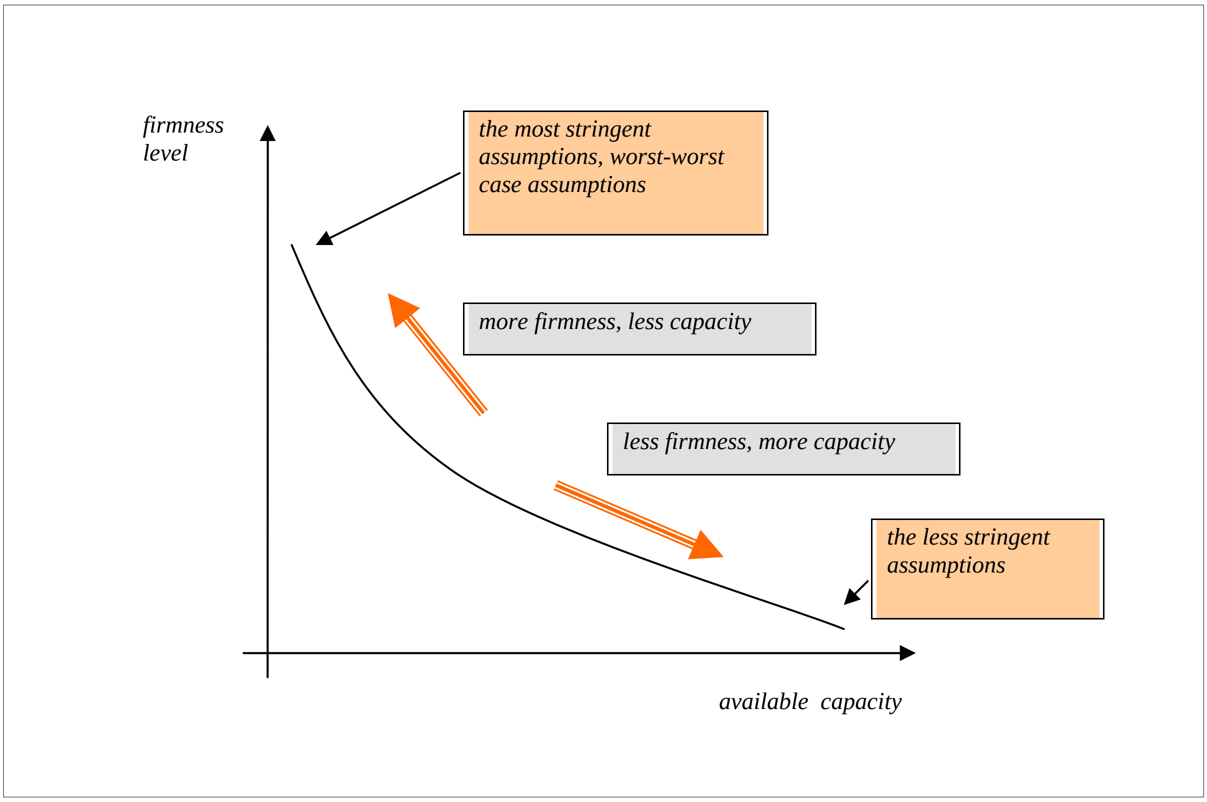
The following relationship is a key in the calculation of available capacity: the more (less) stringent the dynamic assumptions and operational constraints, the less (more) available capacity, the more (less) firmness of the available capacity[6]. Firm capacity is defined as a service offered to customers

[6] This relationship motivates e.g. that cost-reflective tariffs have to be proportional to the firmness level. The network efficiency is strongly determined by the reference reliability level for firm capacity.

under schedules or contracts that anticipate no interruptions, except for “force majeure”. It can be described as the guarantee that the nominations once accepted will effectively be carried out, except in emergencies including extreme operational circumstances. Based on simulations, the likelihood of such flow reductions can be assessed.

Figure 3 shows the trade-off between firmness and the amount of availability of capacity. A trade-off has to be promoted which meets market demand in a liberalized environment and guarantees that the maximum capacity is made available to the market according to the expected level of firmness. It is acknowledged that the market is inelastic concerning firmness and requires very high level of reliability of transmission. However, it is not sure that the network users would like to pay substantially more in order to reach a guarantee of one in one million years instead of one in twenty years for instance.

Figure 3. The trade-off between the firmness level and the amount of available capacity.



The scenario characteristics determine the firmness and the associated amount of available capacity decline with the level of firmness. The question of firmness is therefore a prerequisite for calculating available capacities. Consequently, TSOs sell firm capacity according to a firmness level which has been beforehand defined, implicitly or explicitly. Up to now, firmness of firm capacity is taken as granted in the sense that only "force majeure" events cap firmness. Each TSO offers firm capacity according to a firmness level determined by his choice of network flow assumptions and simulation procedures. Hence, current practices lead to firmness levels of firm capacity which differ strongly from TSO to TSO. Obviously, TSOs sell a double service: an amount of capacity and an associated quality label, namely the reliability (*firmness*) level. Transparency is needed in order to put a maximum of available capacity on the market and this under controlled firmness levels.

5. Contractual "force majeure" events

The reliability guarantee of firm capacity is generally capped by contractual "force majeure" clauses. These clauses protect the TSO against extreme emergencies and inform the network user of the degree of reliability. Hence, capacity may be offered as firm as soon as the delivery is guaranteed under all circumstances except in case of contractual force majeure events. Force majeure is a common law concept and means superior or irresistible force that excuses a failure to perform. It is a cause that is beyond the control and without the fault of negligence of the party excused i.c. the TSO. Force majeure events also must not have been reasonably foreseeable. If this law definition is applied by TSOs for the provision of firm capacity, the performance of a network must be simulated according to theoretical worst case scenarios in order to guarantee the provision of capacity under any circumstance. Only emergencies due to unforeseeable technical failures like e.g. pipeline incidents and "acts of God" would justify a release of responsibility of the TSO.

This approach was adequate for the gas business before the market opening since worst case situations due to behavioural failures of network users could easily be controlled by the vertically integrated companies (single-shipper environment). Furthermore, entry and exit points for gas delivery were known beforehand and valid for relatively long periods. In a liberalised environment the performance of networks depends more and more on the behaviour of different network users (multi-shipper environment) and this lies largely beyond the control of the TSO. This means that under the traditional force majeure definitions, performance of networks have to be calculated according to scenarios which cover also worst case circumstances caused by the behaviour of network users (3rd parties), even if such distortive behaviour was never observed in the past.

Depending on the capacity allocation regime, the TSO can only guess the capacity needs of any incremental capacity use[7] and will take the worst case estimation with the consequence that available capacity will decline drastically (e.g. assuming the worst-case entry point and the worst-case exit point which has consequently the largest impact on system performance). Obviously, this choice of scenarios according to the traditional force majeure definition has a major impact on the amount of available capacity that can be brought to the market. It is inevitable, certainly for capacity allocation regimes which offer large freedom to the network users in their choice of route e.g. pure "entry-exit" regimes, that also extreme behavioural situations are included in the contractual force majeure events. This raises the question of which list of force majeure events is adequate in a multi-shipper gas market.

This paper proposes that capacity may be offered as firm as soon as the legal security of supply requirements are met[8]. Capacity with a risk to be interrupted/reduced which is higher than this firmness standard, is considered as non-firm and interruptible capacity. This standard firm may differ from country to country according to the national security of supply standards. Furthermore there are countries with no specific regulation at the moment. Therefore, it may be appropriate to introduce "European firm" capacity which meets a common firmness level. The EU Directive 2004/67/EC concerning measures to safeguard security of natural gas supplies constitutes a basis for this procedure, in applying amongst other criteria, the coldest weather periods statistically occurring (EC 2003). A key standard is e.g. the minimum "1 in 20" winters guarantee for households. Household

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[7] Assumptions have to be made not only for already booked capacity but also on the more uncertain characteristics of incremental capacity use. For instance, the assumption whether all booked capacity will be nominated simultaneously and the assumption regarding the incremental off-take location are hypotheses with dominant consequences on the amount of available capacity offered to the market.

[8] Reference can be made to EC (2001, 2003) for security of supply in the EU and e.g. CREG (2004), Cuijpers (2003) and Pinon & Cuijpers (2003) for the Belgian situation.

supplies must be secured during peaks statistically occurring every 20 years. However, Member States are free to add minimum standards, including e.g. levels of security of supply for their national electricity system if it depends on gas supplies.

6. Scenario building

Once standard firm is defined or alternatively once "force majeure" events are defined, the question of the corresponding network scenario for simulation raises. Generally, there exist various scenarios - depending on the specification of the underlying set of assumptions – which yield the same firmness level. In order to be sure that the right amount of available firm capacity is calculated, the most adequate scenario has to be specified that meets the firmness standard. This corresponds to the maximisation of available firm capacity according to reasonable criteria for a predefined level of firmness, e.g. standard firm.

In order to calculate the maximum amount of available firm capacity, the network flow assumptions should respect the required firmness levels derived from the security of supply standards. Network parameters for which no security standards are determined, are set at levels not according to theoretical worst cases but according to observed worst cases taking into account the adequate force majeure events[9]. This method is illustrated in table 1 and yields to a matching between the network scenario and both the legal security of supply requirements and force majeure definition.

[9] This means that if the use of 'observed worst case' is not appropriate for whatever reason, an adequate force majeure cap for that determinant has to be agreed and applied consistently.

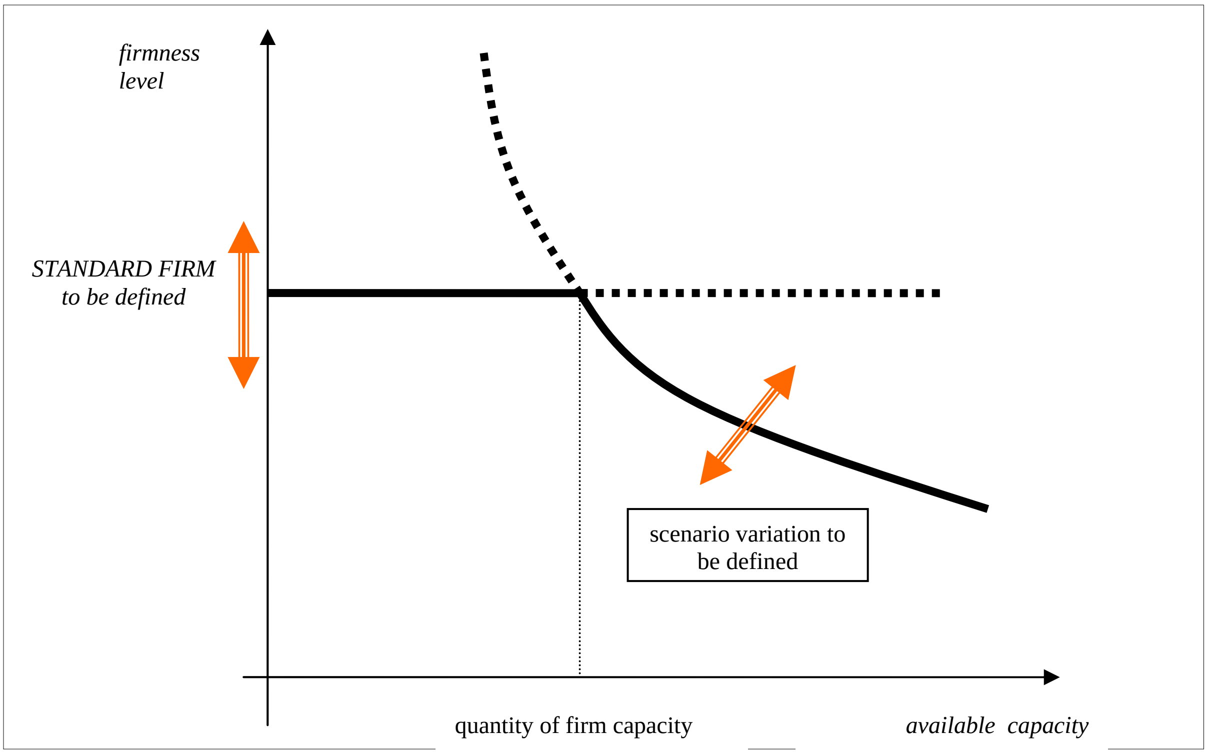
Table 1. Network flow scenario building in order to derive firm capacity according to minimal security standards (1).

network flow assumptions	**legal standard or observed worst case**
1. operational margin	according to safeguard system integrity
2. disruption of national supply	national standard otherwise observed worst case
3. secure supply to households	1 in 20 years peak day consumption
4. direct customers which can not switch to another fuel	national standard otherwise observed highest consumption (extrapolated)
5. security of national electricity system	maximum consumption of those power plants paying for firm gas transport (extrapolated)
6. availability of storage	national standard otherwise observed worst case
7. synchronisation of capacity utilisation (nomination/reservation)	observed worst case (*and not necessarily the assumption that all categories of users need peak capacity at the same point in time*)
8. exit locations	for inland exits observed worst case; for cross-border points, the booked capacity
9. pressure values	observed worst case (*and not necessarily the worst theoretical case; contractual lowest inlet and highest outlet pressure)*
10. combination of entry flows	observed worst case
etc.	etc.
sum of assumptions defines the network flow scenario for deriving the amount of standard firm capacity	*product of standards gives the failure risk of standard firm capacity.*

(1) the list in the first column is based on the list presented in the EU Directive 2004/67/EC concerning measures to safeguard security of natural gas supplies

Figure 4 illustrates the result of simulation a network scenario that matches the legal security of supply obligations and the contractual “force majeure” events.

Figure 4. Standard firm determines the amount of firm capacity.



7. Calculation procedure

The proposed standard calculation procedure is summarized in figure 5. The first step is to set an appropriate firmness level to which the calculated amount of capacity has to correspond. Secondly, a scenario has to be composed that matches the firmness level and guarantees that the appropriate amount of firm capacity is calculated. In addition, it is asked for openness on how available capacity is maximised. These two steps are the most difficult part of the procedure. Once arrived at this stage, it is straightforward to simulate the scenario and to deliver the corresponding available amount of capacity as output.

Figure 5. Standard procedure for calculating available capacity.

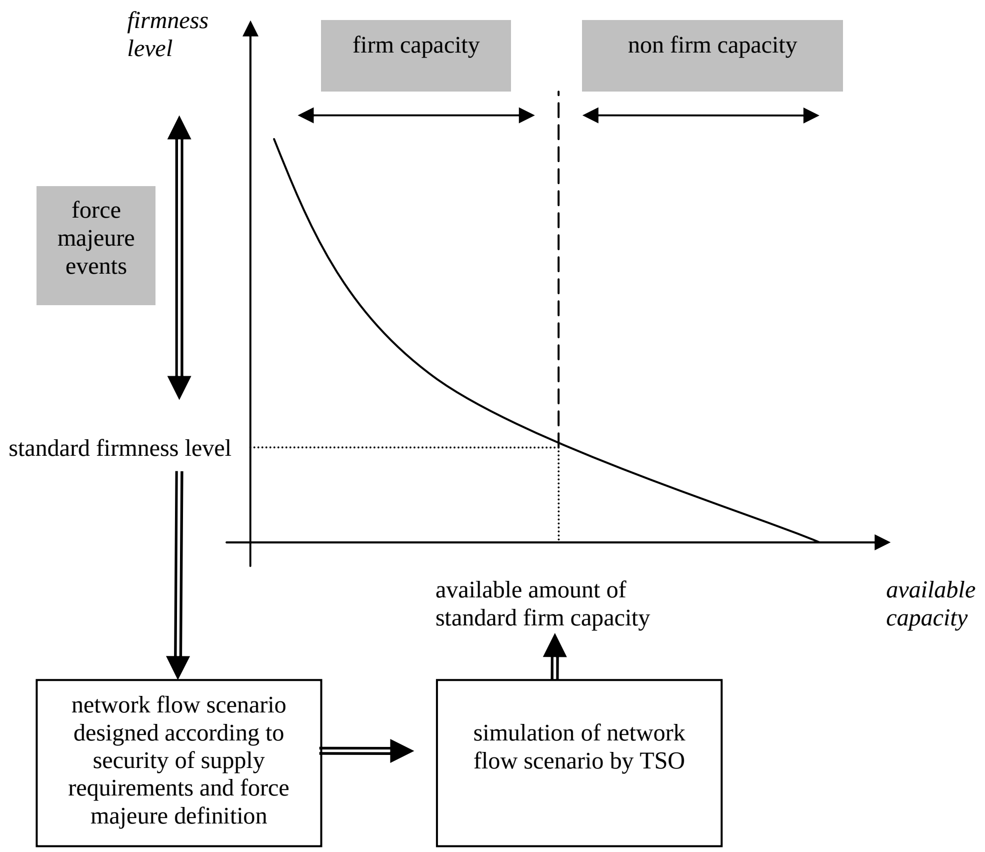
Calculation procedure

Step 1: an agreement on the standard firmness level

Step 2: design of the scenario to guarantee that the appropriate amount of firm capacity is made available on the market

Step 3: scenario simulation with appropriate network model

Step 4: simulation outcome: amount of available firm capacity



8. Conclusions

The creation of a single European gas market requires a convergence of standards. This holds also for the calculation of available transmission capacity. The calculation framework of scenarios and procedures needs to be uniform - as much as possible - to ensure consistent information from European TSOs and that the right amounts of capacity are made available on the market.

It is shown that the intrinsic dynamic and probabilistic nature of network transmission performance explains the dependence on scenario assumptions for the calculation of available capacities. Hence, transparent and consistent calculation principles are needed in order to inform the market correctly about the quality level of transmission services offered. The trade-off between the amount of available capacity offered and the associated firmness has to be transparent, has to meet market demand in a liberalized environment. The network scenario determines the firmness and the associated amount of available capacity declines with the level of firmness. The question of firmness is therefore a prerequisite for calculating available capacities.

It is argued that the offer of firm capacity solely based on an accumulation of theoretical worst case network assumptions is not appropriate to meet the market expectations. Furthermore, the opportunity costs in terms of available capacities are considerable.

It is proposed that capacity may be offered as firm as soon as the legal security of supply requirements are met taking into account reasonable force majeure events. Capacity with a risk to be interrupted higher than this firmness standard, is considered as non firm (or interruptible) capacity.

The presented calculation framework needs further investigation together with all the parties involved in the European gas market. Especially an upgrade of the force majeure definition adequate in a multi-shipper environment together with the practical design of security of supply requirements need attention in order to made the proposed framework applicable throughout Europe.

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