Network interconnectivity and capacity reservation behaviour: an investigation of the Belgian gas transmission network*

Chris Cuijpers♣ and Dominique Woitrin♦

Commission for Electricity and Gas Regulation (CREG), Belgium

Presentation at the 7th Conference on Applied Infrastructure Research, Berlin, 10-11 October 2008

Abstract

Lack of cross-border integration explains largely why natural gas markets remain basically national in scope, with levels of concentration similarly high as when the liberalisation process commenced. The paper presents the results of an assessment of the upstream/downstream capacity of the Belgian natural gas transmission network which is highly interconnected with adjacent networks and fosters important transit activities. It is shown that the tendency to a better market coupling still suffers from important mismatches of capacity provisions on both sides of cross-border interconnections. Moreover, shippers use gas transmission networks more and more from a commercial portfolio perspective which goes beyond the traditional security of supply purpose of network designs. Capacity booking rates appear to be significantly higher than the underlying physical gas flows. From these findings, the paper contributes to a better understanding of the market barrier created by contractual congestion at cross-border interconnection points. The paper argues that contractual congestion is a symptom of suboptimal cooperation of adjacent network operators and lack of effective mechanisms to bring booked but non-used capacity back to the market, rather than an indicator for an overall need to increase investment budgets.

Keywords: Natural gas transmission network, Cross-border interconnection, Available capacity, Capacity reservation, Congestion Management

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

---

* This paper is based on a more elaborate CREG study [(F)080515-CREG-765] of the Belgian Import Capacity for Natural Gas available on www.creg.be. The study has benefited from capacity data discussions with a number of network operators and discussions with Geert Clauwaert, Geert Van Hauwermeiren, Ivo Van Isterdael and other colleagues. The views expressed in this paper are those of the authors alone and do not bind CREG in any way.

♣ Corresponding author. Commission for the Regulation of Electricity and Gas (CREG), rue de l'industrie 26-38, 1040 Brussels, Belgium, Tel:+32(0)2.289.76.63; Fax:+32(0)2.289.76.39; E-mail: chris.cuijpers@creg.be. Chris Cuijpers is principal advisor at the CREG and chairman of the task force on calculation of available capacities in European natural gas transmission networks of the CEER-Council of European Energy Regulators.

♦ Dominique Woitrin is director of the "Directorate of the technical operation of the markets" at the CREG.

1 Introduction

One of the headline findings of the recently completed EC Competition Directorate major review of the EU's gas markets is a lack of network integration (EC 2007). Insufficient or unavailable cross-border capacity and different market designs hamper market integration. Limited access to capacity at both sides of cross-border interconnection points appears to constitute an important market barrier to the development of effective gas competition (EC 2008).

The paper presents the results of an assessment of the upstream and downstream capacity at cross-border interconnection points of the Belgian natural gas transmission network. Eight adjacent pipeline networks, operated by different companies, are coupled with the Belgian transmission network. The high interconnectivity level of the Belgian network, the diversity of gas sources and the important role at the crossroad for transit require special attention to network coupling for operational reasons as well as for access to markets and competition.

Mismatches of levels of available capacities on both sides of cross-border interconnections are evaluated by examining differences in maximum technical capacities as well as divergent booking behaviour of shippers[1]. Mismatches in technical capacities may be considerable due to poor cooperation between network operators in streamlining the linkages between networks. Coherent approach in tuning network coupling is necessary to facilitate market access and asks for coordinated investments between adjacent network operators.

On the other hand, transit shippers appear to apply for more firm transmission capacity in Belgium than they have booked upstream. Approximately 42% of firm capacity booked for transit has no underlying gas contract and is reserved for sourcing and routing flexibility. This practice shows that the transmission network is being used more and more for commercial purposes and that demand for capacity is no longer a mere derivative of the peak flow in gas consumption. However, capacity reservation for arbitrage is one of the factors that has given rise to the current situation of contractual

[1] In this paper 'shipper' is used as synonym for 'network user', a customer or potential customer of a transmission network operator.

congestion[2]. The paper advocates that network operators should release capacity which is reserved but not always used. It should be possible to offer reserved but non-nominated[3] capacity on day-ahead markets in addition to facilitate trading on secondary capacity markets[4].

Many studies (EC 2007, EC 2008, CEPA 2008, Ghiosso 2007, Gruber 2007, etc.) confirm that, as long as there are bottlenecks on the transmission capacity market there can never be talk of a genuine competitive pricing of natural gas where producers and suppliers are forced into maximum efficiency. Limited and/or inadequate capacity supply constitutes an obstacle for market access, helps shippers (incumbents) who have transmission capacity at their disposal, and endangers the business plans of new and small entrants. This does not mean that the transmission network alone is the key to a competitive natural gas market, but it is a key critical success factor.

The structure of the remainder of the paper is as follows. Section 2 presents briefly the Belgian interconnected gas transmission network. The approach and methodology of the assessment of the cross-border interconnection points are discussed in Section 3. Section 4 comments on the results of the upstream cross-border interconnection assessment and Section 5 on the downstream cross-border interconnection assessment. Section 6 is devoted to the evaluation of the evidence delivered by the previous two sections and proposes some recommendations. Finally, Section 7 summarises the main findings.

2 Belgian Gas Transmission Network

For a gas import country, security of natural gas provisioning and the entry of possible new natural gas suppliers depend on the degree of interconnection with the upstream networks. For a transit country the interconnections with the downstream networks also count. On the basis of this fact, this paper

[2] 'Contractual congestion' means a situation where the level of firm capacity demand exceeds the technical capacity. This situation does not necessarily imply 'physical congestion', a situation where the level of demand for actual deliveries exceeds the technical capacity at some point in time (EC 2005).
[3] 'Nomination' means the prior reporting by the shipper to the transmission network operator of the actual flow that he wishes to inject into or withdraw from the network (EC 2005).
[4] 'Secondary market' means the market of the capacity traded otherwise than on the primary market. The primary market means the market of the capacity traded by the transmission network operator (EC 2005).

focuses on the availability and reservation of the interconnection capacity of the Belgian natural gas transmission network with the surrounding networks.

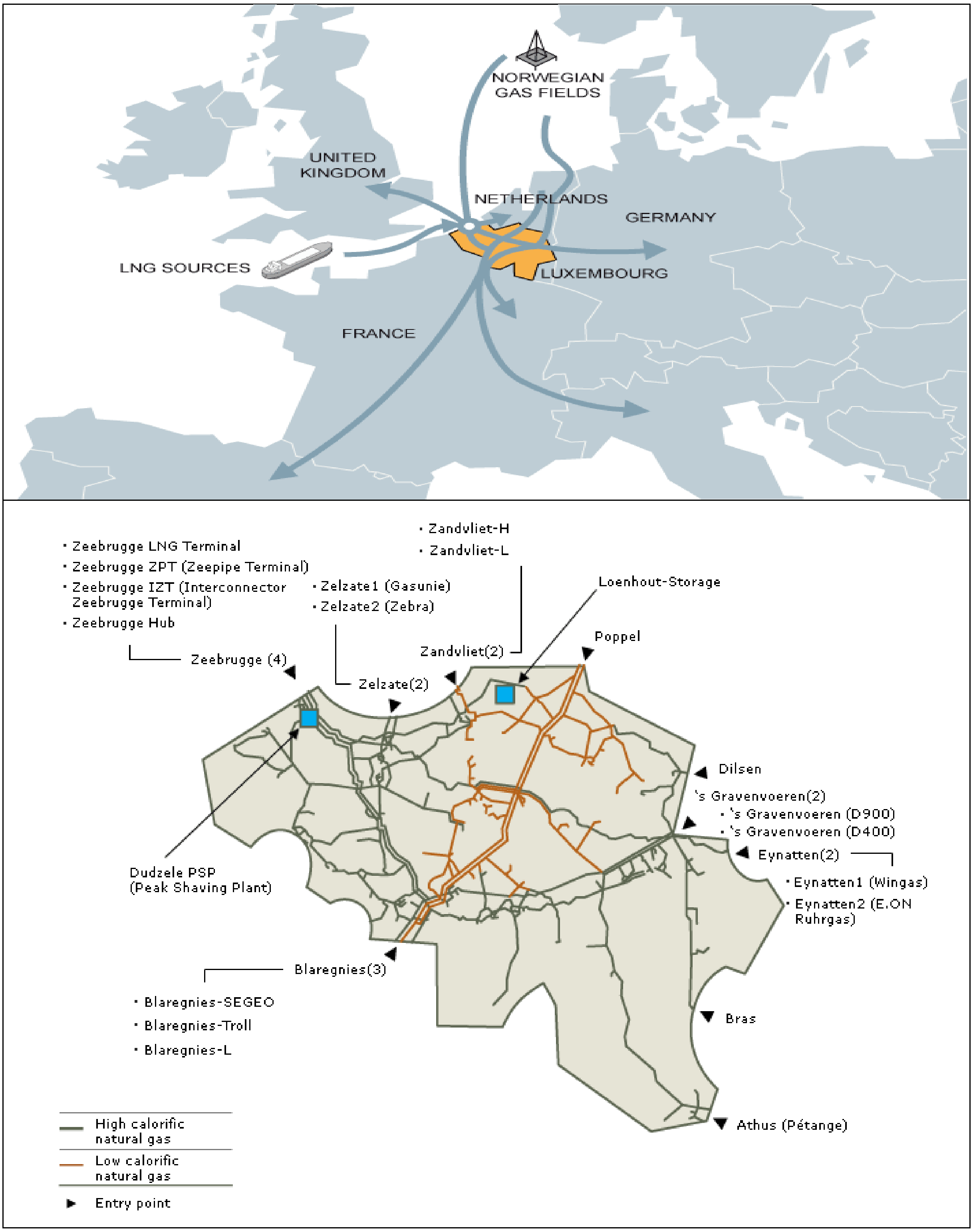
Figure 1 depicts the natural gas transmission network operated by Fluxys[5] characterised by the separate transmission network for high calorific gas (H-gas) and the separate transmission network for low calorific gas (L-gas)[6]. The main pipelines of the H-gas network are: the 'TROLL' pipeline with the parallel 'Flemish pipeline' between Zeebrugge and Blaregnies, the 'VTN' pipeline between Zeebrugge and Eynatten, and finally the 'SEGEO' pipeline between 's Gravenvoeren and Blaregnies. The 'VTN' pipeline is the only bi-directional pipeline that can physically be switched into forward mode (from Zeebrugge towards Eynatten) and reverse mode (from Eynatten towards Zeebrugge). The 'Dorsales' are the L-gas pipelines between Poppel and Blaregnies.

The main upstream pipelines are: the bi-directional 'Interconnector' between Bacton (in UK) and Zeebrugge, the Zeepipe pipeline which links the North Sea production fields with Zeebrugge. There are two important German axes that connect to the Belgian transmission network at Eynatten: the northerly 'WEDAL' pipeline operated by Wingas Transport and the southerly 'TENP' pipeline operated by E.ON Gastransport. Finally, there is the pipeline that links Emden in the north-west of Germany with 's Gravenvoeren and runs across the Netherlands. After the 'Zeepipe', this is an important pipeline for the supply of Norwegian natural gas.

[5] Fluxys is the operator of the natural gas transmission network in Belgium. The company operates transmission for the national market as well as for transit, the storage facilities, the Zeebrugge LNG terminal and the Zeebrugge Hub (www.fluxys.com).

[6] The calorific upper value of H-gas can legally vary from 9,606 to 12,793 kWh/m³(n) (from Norway, U.K., Russia, Qatari LNG etc.). The average of 11,630 kWh/m³(n) is used in this paper. The calorific upper value of L-gas can legally vary from 9,528 to 10,746 kWh/m³(n) (from the Netherlands). The average of 9,769 kWh/m³(n) is used in this paper.

Figure 1. The Belgian natural gas transmission network.



www.fluxys.com

The current physical entry points at the national border for the H-gas market are: (i) the LNG terminal (mainly Qatari LNG), (ii) the Zeepipe terminal (ZPT) (Norwegian gas), (iii) Zandvliet H (since mid

2004, from the Netherlands), (iv) Obbicht (Dilsen) (from the Netherlands), (v) ‘s Gravenvoeren (from the Netherlands). In addition the Interconnector Zeebrugge terminal (IZT) is a physical import point from the UK if the VTN pipeline is switched into forward mode, and alternatively Eynatten 1 (WEDAL) and Eynatten 2 (TENP) are physical import points if the VTN pipeline is switched into reverse mode. The interconnection point at Eynatten is mainly booked for transit both in reverse mode (import from Germany) and forward mode (export to Germany). Other points can eventually be used conditionally as an entry point by means of backhaul capacity booking[7]. The underground storage facility of Loenhout and the Dudzele peak shaving plant (PSP) are also entry points of the H-gas transmission network, mainly for the supply of a peak flow.

Statistics for the Belgian natural gas market can be found in CREG (2004, 2008a)[8]. The main indicators are summarised hereafter. The total Belgian natural gas consumption in 2007 amounts to 189,3 TWh (17,12 billion cubic meters - bcm)[9]. The Belgian H-gas market represents 72,7% and the L-gas market represents 27,3% of the total Belgian gas consumption in 2007. The number of active shippers supplying the Belgian national market has increased progressively from one in 2002 to six in 2007 and further to nine mid 2008. It is expected that the number of active shippers will increase to twelve in 2009.

The physical transit gas flows amount to approximately 35 bcm of which 73% is for France, 18% for the UK, 6% for Germany and 3% for Luxemburg. Approximately 25 shippers are active in transit activities and the Zeebrugge Hub is an important platform for these shippers.

[7] Hitherto the network operator has only offered conditional backhaul capacity. This is virtual capacity created by booking in counter-flow. Without guaranties of gas flows from the shippers, the backhaul booking is by definition conditional and thus non- firm.

[8] Another interesting background information of the Belgian gas transmission network, but however not necessary for the understanding of the analysis in this paper and therefore out of scope, are the network code, rules and principles for access to the network proposed by the network operator and approved by the CREG (Fluxys 2008a, 2008b).

[9] Public distribution: 43,6%; large industry: 26,4%; power plants: 30,0% (CREG 2008).

3 Interconnectivity Assessment: Approach and Methodology

The analytical part of the paper addresses the technical transmission capacity[10] and the booked firm transmission capacity[11] on both sides of each cross-border interconnection point[12]. Only transmission capacity offered as firm is included and the situation is estimated for 1 May 2008. In order to estimate the capacities on the other side of the interconnections at the border, use is made of information made available on line by the neighbouring network operators[13] and direct contacts. Unfortunately not all network operators use the same units and where necessary conversions are made into the units used by the Belgian network operator Fluxys. In this study, capacity is expressed in $m^3(n)/h$ where an average energy content of 11,630 $kWh/m^3(n)$ (or 41,868 $MJ/m^3(n)$) is used for H-gas, and an average energy content of 9,769 $kWh/m^3(n)$ (or 35,168 $MJ/m^3(n)$) is used for L-gas.

At the moment there are not yet any international guidelines for the calculation of technical and available transmission capacities[14]. This makes comparisons of available capacities over time and between network operators difficult. The lack of standard procedures partly explains the often sizeable differences between available capacities on either side of the interconnections. Some conclusions of Cuijpers and Pinon (2005, 2006) are repeated here for a good understanding of the assessment, it is first and foremost important to take account of the following comments: (i) the technical entry and exit capacities at the interconnections are not fix over time and may vary according to the boundary conditions, the way the network operator runs the network and the underlying network scenarios to calculate the network's capability, (ii) the technical entry and exit capacities are calculated according

---

[10] 'Technical capacity' means the maximum firm capacity that the transmission system operator can offer to the network users, taking account of system integrity and the operational requirements of the transmission network (EC 2005).

[11] This concerns total booked firm transmission capacity, the capacity underwritten for the long term and the short term. 'Firm capacity' means gas transmission capacity contractually guaranteed as uninterruptible by the transmission network operator (EC 2005).

[12] A more elaborated study on the Belgian import capacity can be found in CREG (2008b).

[13] There are eight adjacent operators: Interconnector operator : www.interconnector.com; Zeepipe operator : www.gassco.no; Dutch network operator : www.gastransportservices.nl; the Dutch local pipeline operator: www.zebrapijpleiding.nl; German network operators : www.wingas-transport.de and www.eon-gastransport.de; Luxemburg network operator : www.soteg.lu and French network operator www.grtgas.com.

[14] The CEER/ERGEG task force on available capacity calculation is active in this area. For background information, reference is made to www.energy-regulators.eu.

to a “worst-case” network scenario to guarantee the firmness of firm capacity. Therefore published firm capacity levels are relatively low. Less stringent network scenarios would lead to a higher availability of transmission capacity.

If for example the German network operator E.ON Gastransport reports that in May 2008 the firm exit capacity at EYN2 is 613 k.m^3(n)/h, this does not necessarily mean that E.ON Gastransport would not be able to supply a higher flow rate at Eynatten with the same network, and thus without extra investments, but in a different operational mode. Ascertaining the maximum amount that E.ON Gastransport would carry over at Eynatten would call for a network simulation to be carried out, based on the “best-case” network scenario.

There is also the marketing of non-firm capacity that can be interrupted. This supply can also vary and be subject to different conditions. Nothing rules out the possibility of an network operator offering, on top of the firm capacity, for example a further 20% in non-firm capacity, which is guaranteed in 90% of cases. In addition to international agreements on the capacity calculation procedure, there is also a need for transmission services to be geared to each other internationally. International coordination between network operators is becoming increasingly important. Interoperability issues and the lack of bundled services at cross-border interconnection are major bottlenecks for access.

This background is useful but does not detract from the analysis that follows and which mainly looks to capacity bookings. Booked firm capacities are a fixed item of information and are fairly comparable services. In this analysis an examination is made of differences in firm capacity booking levels. When shippers book more firm capacity downstream than upstream for instance, there is an overbooking of firm downstream capacity. When a network operator sells more firm capacity than what the network can provide, there is an overselling of firm capacity. These notions will be further elaborated in the next sections.

4 Upstream Interconnection Assessment

There are 10 upstream cross-border interconnection points where gas is physically entering into the Belgian gas transmission network (*I=10*). Table 1 presents for each upstream cross-border interconnection point i, the technical exit capacity of the upstream network ($UTEX_i$), the technical entry capacity of the Belgian network ($BTEN_i$), the booked firm exit capacity in the upstream network ($UBEX_i$), the booked firm entry capacity of the Belgian network ($BBEN_i$) with a breakdown for firm capacity bookings for the national Belgian market ($BBEN_i^{nat}$) and for border-to-border transit through Belgium ($BBEN_i^{transit}$).

There are two indicators for mismatches at the upstream cross-border interconnections: (i) the technical capacity mismatch rate ρ_i calculated as the ratio of the technical entry capacity of the Belgian network and the upstream technical exit capacity at interconnection *i* ($\rho_i = \frac{BTEN_i}{UTEX_i}$), and (ii) the booking mismatch rate μ_i calculated as the ratio of the booked firm entry capacity in the Belgian network and the upstream booked firm exit capacity at interconnection *i* ($\mu_i = \frac{BBEN_i}{UBEX_i}$).

Two capacity booking rates at the upstream cross-border interconnections are calculated: (i) the upstream capacity booking rate ε_i calculated as the ratio of the upstream booked firm exit capacity and the upstream technical exit capacity at interconnection *i* ($\varepsilon_i = \frac{UBEX_i}{UTEX_i}$), and (ii) the Belgian capacity booking rate σ_i calculated as the ratio of the booked firm entry capacity in the Belgian network and the technical entry capacity of the Belgian network at interconnection *i* ($\sigma_i = \frac{BBEN_i}{BTEN_i}$). The more ε_i and σ_i converge to 1, the more the interconnection point *i* gets contractually congested.

Table 1. Situation at the upstream cross-border interconnection points of the Belgian gas transmission network (H-gas and L-gas; in k.m³(n)/h)

	$UTEX_i$	$BTEN_i$	ρ_i	$UBEX_i$	$BBEN_i$	μ_i	$BBEN_i^{nat}$	$BBEN_i^{transit}$	ε_i	σ_i
LNG terminal	1.700	1.700	1,00	1.200	1.200	1,00	600	600	0,71	0,71
ZPT *from N*	1.655	2.600	1,57	1.655	3.888	2,35	656	3.232	1,00	1,50
IZT *from UK*	2.283	3.640	1,59	2.283	3.258	1,43	888	2.370	1,00	0,90
Zandvliet H *from NL*	120	310	2,58	120	120	1,00	120	0	1,00	0,39
Obbicht *from NL*	200	200	1,00	200	200	1,00	200	0	1,00	1,00
SGRV *from NL*	963	1.325	1,38	963	1.321	1,37	450	871	1,00	1,00
EYN1 *from D*	475	1.050	2,21	475	861	1,81	216	645	1,00	0,82
EYN2 *from D*	613	830	1,35	536	729	1,36	6	723	0,87	0,88
Poppel L *from NL*	2.815	3.730	1,33	2.811	2.790	0,99	1.490	1.300	0,99	0,75
Zandvliet L *from NL*	200	200	1,00	200	200	1,00	200	0	1,00	1,00
TOTAL	**11.024**	**15.585**	**1,41**	**10.443**	**14.567***	**1,39**	**4.826**	**9.741**	**0,95**	**0,85**

ZPT: Zeepipe terminal; IZT: Interconnector Zeebrugge terminal; SGRV: 's Gravenvoeren; EYN: Eynatten

* There is an overselling of entry-capacity at ZPT: sold firm entry capacity amounts to 3.888 k.m³(n)/h while the network can only guarantee 2.600 k.m³(n)/h. Therefore $\sum_{i=1}^{I} BBEN_i$ without overselling amounts to 13.279 k.m³(n)/h. Note that the average $\overline{\sigma_i}$ is calculated by correcting for overselling in order to make it representative.

Technical Capacity Mismatch

Table 1 shows an important mismatch between the technical exit capacity in the upstream network and the technical entry capacity of the Belgian network. The technical entry capacity of the Belgian natural gas transmission network is equal to or higher than the upstream exit capacity for all the upstream cross-border interconnection points. According to the average technical capacity mismatch rate $\overline{\rho_i}$, the Belgian technical entry capacity is 41% higher than the technical exit capacity of the upstream networks. In other words, the Belgian entry capacity is capped at a level of 71% due to insufficient upstream capacity. The total Belgian entry capacity amounts to approximately 136,5 bcm/y (15.585 k.m³(n)/h) while the upstream exit capacity amounts to approximately 96,6 bcm/y (11.024 k.m³(n)/h). This is an important finding and will be further discussed in Section 6.

Firm Capacity Overselling

Table 1 shows that $UBEX_i \leq UTEX_i$ for all upstream cross-border interconnection points i. No observations are made where upstream network operators appear to sell more firm exit capacity than their network can guarantee. On the Belgian side of the upstream cross-border interconnection points, however, there is one interconnection where more firm entry capacity is sold than the Belgian network is able to guarantee. At the *Zeepipe* terminal (ZPT) 3.888 k.m³(n)/h firm entry capacity is sold while the network is only able to inject 2.600 k.m³(n)/h from that interconnection point (an overselling of 50%). Clearly shippers want firm entry capacity on the Belgian gas transmission network from that important delivery point of Norwegian gas in order to safeguard arbitrage possibilities: arbitrage between supply on the Belgian market (via the Zeebrugge Hub for instance) and transit in addition to arbitrage between transit routes and markets. The Belgian network operator guarantees the firmness of the overbooked entry capacity. There are no conflicts in that respect. At all times the shipper in question can nominate natural gas flows in a different way. The fact that the Belgian network operator sells more firm entry capacity than the network is able to transport from this interconnection point may be explained by the knowledge that the 814 km offshore pipeline is only able to transport 1.655 k.m³(n)/h or, depending on the circumstances and therefore conditionally, an extreme flow of 2.100 k.m³(n)/h. This is an interesting finding and as such not in conflict with the rules but implies contractual risks for the network operator Fluxys if at a given moment the Zeepipe flow were physically to be increased up to a level higher than 2,600 k.m³(n)/h. This practice of firm capacity overselling must be based on guarantees from the adjacent operators.

Contractual Congestion

Since mismatches of technical capacity exist on cross-border interconnections, a distinction should be made between possible congestion at each side of the cross-border interconnection point. There is almost no spare upstream exit capacity nor downstream entry capacity, there is a general situation of contractual congestion at major interconnection points. The total upstream technical exit capacity is booked for 95% ($\overline{\varepsilon_i}$). On the Belgian side, corrected for the observed capacity overselling, the total technical entry capacity of the Belgian gas transmission network is booked for 85% ($\overline{\sigma_i}$). Of the total 14.567 k.m³(n)/h booked entry capacity in Belgium, 4.826 k.m³(n)/h (33,1% share) is intended for the Belgian market and 9.741 k.m³(n)/h (66,9% share) for border-to-border transit through Belgium. The fact that two-thirds of the entry capacity is booked for the international transit market strongly influences the paths for developing competition in Belgium. In general, it should be an advantage since these considerable gas volumes may be incorporated in the international portfolio management of the shippers. They may optimise their international positions by e.g. swapping pipeline gas for storage gas etc. and in this respect, Belgium may be an interesting market. However, mainly due to a different treatment of transit activities and inland transmission, this behaviour is poorly observed but further regulatory initiatives will foster this market behaviour[15].

Capacity Overbooking

Another important mismatch can be found in the comparison of the booked levels of firm capacity at both sides of the upstream cross-border interconnections. It appears that shippers book more firm entry capacity in the Belgian network than what they have booked in the upstream adjacent networks. Given the "matching-rule"[16] for the national market, which provides for a tallying between entry and exit, it can be assumed that the overbooking of 4.124 k.m^3(n)/h of firm entry capacity can be attributed to transit activities. This means that 42,3% of the booked firm entry capacity for transit purposes concerns overbooking. The following factors, which may reinforce each other, may account for these capacity overbooking:

- transit shippers book firm capacity on several routes in Belgium in order to safeguard possibilities of arbitrage between different markets when the opportunity presents itself;
- shippers simultaneously book capacity for the Belgian market and for transit;
- shippers without transmission capacity upstream book firm entry capacity in the prospect of possible natural gas deliveries/purchases at the border;
- shippers convert interruptible transmission contracts upstream into downstream firm transmission contracts for the sake of certainty, e.g. to be sure that capacity will be available when opportunities appear.

[15] In accordance with EU regulation, initiatives are ongoing to move to an equal treatment of transit and inland transmission. There is a new Code of Conduct under construction which will meet these objectives (see public consultations on www.creg.be).
[16] This is a Belgian variant of the widespread "rucksack" principle where capacity goes with the customer.

The phenomenon of overbooking is commercially understandable and proves that arbitrage is important in the portfolio management of the shippers. The fact that the network operator allows overbooking is also rational insofar as no more firm capacity is allocated than which can be guaranteed as firm and as long as effective mechanisms are in place which guarantee that booked but non-used capacity is brought back to the market[17]. Moreover, the network operator is not always in a position to identify cases of overbooking.

5 Downstream Interconnection Assessment

There are 9 downstream cross-border interconnection points where gas is physically exiting the Belgian gas transmission network ($J=9$). Table 2 presents for each downstream cross-border interconnection point j, the technical exit capacity of the Belgian network ($BTEX_j$), the technical entry capacity of the downstream network ($DTEN_j$), the booked firm exit capacity in the Belgian network ($BBEX_j$), the booked firm entry capacity in the downstream network ($DBEN_j$).

There are two indicators for mismatches at the downstream cross-border interconnections: (i) the technical capacity mismatch rate θ_j calculated as the ratio of the technical exit capacity of the Belgian network and the downstream technical entry capacity at interconnection j ($\theta_j = \frac{BTEX_j}{DTEN_j}$), and (ii) the booking mismatch rate τ_j calculated as the ratio of the booked firm exit capacity in the Belgian network and the downstream booked firm entry capacity at interconnection j ($\tau_j = \frac{BBEX_j}{DBEN_j}$).

Two capacity booking rates at the downstream cross-border interconnections are calculated: (i) the Belgian capacity booking rate γ_j calculated as the ratio of the booked firm exit capacity in the Belgian network and the technical exit capacity of the Belgian network at interconnection j ($\gamma_j = \frac{BBEX_j}{BTEX_j}$), and (ii) the downstream capacity booking rate φ_j calculated as the ratio of the booked firm downstream

[17] It is the lack of mechanisms to bring non-used capacity back to the market that makes the practice of overbooking distortive, at least if the network is in a situation of contractual congestion.

entry capacity and the downstream technical entry capacity at interconnection j ($\varphi_j = \frac{DBEN_j}{DTEN_j}$). The more γ_j and φ_j converge to 1, the more the interconnection point *j* gets contractually congested.

Table 2. Situation at the downstream cross-border interconnection point of the Belgian gas transmission network (H-gas and L-gas; in k.m³(n)/h).

	$BTEX_j$	$DTEN_j$	θ_j	$BBEX_j$	$DBEN_j$	τ_j	γ_j	φ_j
IZT *to UK*	3.100	2.911	1,06	2.750	2.911	0,95	0,89	1,00
ZZ1 *to NL*	585	210	2,79	640	210	3,05	1,09	1,00
ZZ2 *to NL*	585	300	1,95	723	300	2,41	1,24	1,00
EYN1 *to D*	810	489	1,66	675	263	2,57	0,83	0,54
EYN2 *to D*	640	256	2,50	382	256	1,49	0,60	1,00
BLAR H *to F*	2.363	2.114	1,12	2.363	2.114	1,12	1,00	1,00
BRAS *to Lux*	160	160	1,00	100	100	1,00	0,63	0,63
PET *to Lux*	60	60	1,00	58	58	1,00	0,97	0,97
BLAR L *to F*	1.300	981	1,33	1.300	981	1,33	1,00	1,00
TOTAL	**9.603**	**7.481**	**1,28**	**8.991***	**7.193**	**1,25**	**0,92**	**0,96**

IZT: Interconnector Zeebrugge terminal; ZZ: Zelzate; EYN: Eynatten; BLAR H: Blaregnies H-gas; PET: Pétange; BLAR L-Blaregnies L-gas

* There is an overselling of exit-capacity at ZZ1 and ZZ2: sold firm entry capacity, for both, amounts to 1.363 k.m³(n)/h while the network can only guarantee an exit of 1.170 k.m³(n)/h. Therefore $\sum_{j=1}^{J} BBEX_j$ without overselling amounts to 8.798 k.m³(n)/h. Note that the average $\overline{\gamma_J}$ is calculated by correcting for overselling in order to make it representative.

Technical Capacity Mismatch

The general situation at the downstream cross-border interconnection points is comparable to the observations made at the upstream cross-border interconnection points. The technical exit capacity of the Belgian natural gas transmission network is equal or higher than the downstream entry capacity for all the interconnection points. According to the average technical capacity mismatch rate $\overline{\theta_J}$, the Belgian technical exit capacity is 28% higher than the technical entry capacity of the downstream networks. In other words, the Belgian exit capacity is capped at a level of 78% due to insufficient downstream capacity. The total Belgian exit capacity amounts to approximately 84,1 bcm/y (9.603 k.m³(n)/h) while the downstream entry capacity amounts to approximately 65,5 bcm/y (7.481 k.m³(n)/h).

Firm Capacity Overselling

Table 2 shows that $DBEN_j \leq DTEN_j$ for all the downstream interconnection points j. Downstream network operators appear to sell not more firm entry capacity than their network can guarantee. On the Belgian side of the downstream cross-border interconnections, however, there are two interconnections where more firm exit capacity is sold than the network is able to guarantee. At Zelzate where two pipelines cross the Belgian-Dutch border, 640 k.m³(n)/h firm exit capacity is sold at ZZ1 (interconnection Fluxys - Dutch Zebra pipeline operator) and 723 k.m³(n)/h is sold at ZZ2 (interconnection Fluxys - Dutch GasTransportServices) while the network is only able to transport 585 k.m³(n)/h at each of both the cross-border interconnections. There is an overselling of firm exit capacity of 9,4% at ZZ1 and 23,6% at ZZ2. Overselling of firm capacity entail contractual risks for the Belgian gas transmission operator should the entry capacity in the Netherlands be greater that the exit capacity in the Belgian gas transmission network. Monitoring and coordination between the adjacent network operators are therefore important.

Contractual Congestion

As was the case for upstream cross-border interconnection points, there is also a situation of contractual congestion at downstream cross-border interconnection points. Corrected for the observed capacity overselling at ZZ1 and ZZ2, the total downstream exit capacity is booked for 92% ($\overline{\gamma_j}$). On the other side of the border, the total downstream technical entry capacity is booked for 96% ($\overline{\varphi_j}$).

Capacity Overbooking

It appears that shippers, logically transit shippers, book more firm exit capacity in the Belgian network than what they have booked in the adjacent downstream networks. Transit shippers book 9.603 k.m³(n)/h downstream firm exit capacity while they book on the other side of the interconnection only 7.481 k.m³(n)/h firm capacity (22,1% less). This may be explained by the fact that transit shippers rather book firm capacity on the upstream routes and once arrived at the network that covers their gasresale market, they optimise their portfolio in another way and buy for instance more interruptible capacity.

Table 1 has shown that transit shippers book 9.714 k.m³(n)/h firm entry capacity for border-to-border transit through Belgium. However, transit shippers seem to book only 8.911 k.m³(n)/h firm cross-border exit capacity to exit the Belgian network. This means that transit shippers save 803 k.m³(n)/h on exit capacity by allocating e.g. two network entry bookings to the same cross-border exit booking.

6 Understanding and Recommendations

Previous analytical sections provide evidence for a better understanding of the status of network coupling, the capacity sales of the operators and the bookings of the shippers. Mismatches of technical capacity and booking levels at both sides of the interconnections were estimated as well as phenomena like capacity overselling by network operators and firm capacity overbooking by shippers were detected. Not these practices of overselling and overbooking as such, but rather the lack of mechanisms to respond adequately to these new phenomena in order to guarantee an efficient network use, slow down the process of market integration and the appearance of effective gas-to-gas competition. This section discusses the main findings presented in Table 3 and 4, and presents some recommendations and remedies where needed according to rules for efficient and non-discriminatory access to networks (EC 2003, 2005).

Table 3. Indicators upstream cross-border interconnection points of the Belgian gas transmission network.

Indicator	Evidence	Comment
Technical capacity mismatch	$\frac{\sum_{i=1}^{I} BTEN_i}{\sum_{i=1}^{I} UTEX_i} = 1{,}41$	The technical entry capacity of the Belgian gas transmission network is 41% higher than the technical exit capacity of the upstream networks.
Upstream firm capacity overselling	no	
Downstream firm capacity overselling	$\frac{BBEN_{i=ZPT}}{BTEN_{i=ZPT}} = 1{,}50$	There is one upstream cross-border interconnection point where on one side more firm capacity is sold than the network is able to transport. At ZPT, 50% more firm entry capacity is sold than technically available.
Upsteam exit booking rate	$\frac{\sum_{i=1}^{I} UBEX_i}{\sum_{i=1}^{I} UTEX_i} = 0{,}95$	95% of the upstream exit capacity is booked (firm).
Downstream entry booking rate	$\frac{\sum_{i=1}^{I} BBEN_i}{\sum_{i=1}^{I} BTEN_i} = 0{,}85$	85% of the downstream entry capacity of the Belgian network is booked (firm).
Capacity overbooking	$\frac{\sum_{i=1}^{I} BBEN_i}{\sum_{i=1}^{I} UBEX_i} = 1{,}39$	39% of the booked firm entry capacity of the Belgian gas network is not firmly booked upstream

Table 4. Indicators downstream cross-border interconnection points of the Belgian gas transmission network.

Indicator	Evidence	Comment
Technical capacity mismatch	$\frac{\sum_{j=1}^{J} BTEX_j}{\sum_{j=1}^{J} DTEN_j} = 1{,}28$	The technical exit capacity of the Belgian gas transmission network is 28% higher than the technical entry capacity of the downstream networks.
Upstream firm capacity overselling	$\frac{BBEX_{j=ZZ1}}{BTEX_{j=ZZ1}} = 1{,}09$ $\frac{BBEX_{j=ZZ2}}{BTEX_{j=ZZ2}} = 1{,}23$	There are two downstream cross-border interconnection points where on one side more firm capacity is sold than the network is able to transport. There is an overselling of 9,4% at ZZ1 and 23,6% at ZZ2.
Downstream firm capacity overselling	no	
Upstream exit booking rate	$\frac{\sum_{j=1}^{J} BBEX_j}{\sum_{j=1}^{J} BTEX_j} = 0{,}92$	92% of the exit capacity of the Belgian network is booked (firm).
Downstream entry booking rate	$\frac{\sum_{j=1}^{J} DBEN_j}{\sum_{i=1}^{I} DTEN_j} = 0{,}96$	96% of the downstream entry capacity is booked (firm).
Capacity overbooking	$\frac{\sum_{j=1}^{J} BBEX_J}{\sum_{j=1}^{J} DBEN_j} = 1{,}25$	25% of the booked firm exit capacity of the Belgian gas network is not firmly booked downstream.

Divergence between Contractual and Physical Network Use

The shift to a multi-shipper environment has removed the supply portfolio management from the traditionally vertically integrated utility and dispersed it to individual supply companies who look only at their own operations when making decisions on gas sourcing and route planning. The value of the optimal mix of gas sources and route flexibility in order to supply markets where the highest returns on gas can be get is only little affected by the transmission tariffs. This certainly holds once the gas is sourced within the EU and shippers optimise their portfolio to arbitrate between different EU markets. The capacity needs derived from the commercial portfolio management of the various shippers differ in nature and in quantity from the capacity needs of the formerly vertically integrated gas utilities. While in the past transmission capacity was derived from the expected peak gas flows in order to guarantee security of supply in a market, nowadays competing shippers derive their capacity demands according to the optimal route flexibility and balancing needs derived from their sourcing portfolios. The commercial flexibility request for each portfolio (for route flexibility, balancing purposes) and the growing number of suppliers are the drivers for the divergence between the physical capacity needs and the commercial capacity needs. This phenomenon explains the gap between contractual congestion and physical congestion.

Congestion Management: Release of Capacity Overbooking

Shippers book more firm capacity in Belgium than what they can avail themselves as for certain upstream. This practice shows that the network is being increasingly used to commercial purposes and that the demand for capacity is no longer merely a derivative of the peak flow of Belgian gas consumption.

The fact that transit shippers book more firm entry capacity in Belgium than what they have available upstream, is not in itself a distortive practice in a competitive environment and can be explained by the commercial motive of being able to react to arbitrage opportunities. Shippers are thus prepared to bear extra costs for overbooked firm capacity with a view to commercial opportunities in the case of natural gas supplies.

However, the network management must react to this in a targeted fashion by making as much capacity that has been reserved but is not always used, available again to other shippers who wish to make use of it. The lack of such a mechanism is one of the reasons for the current situation of contractual congestion in Belgium at some major entry points. Overbooking of demand could in large measure flow back to the shippers if there was a liquid day-ahead market where booked but non-nominated capacity was re-offered to the shippers, and a liquid secondary market.

Moreover, a congestion policy (contractual congestion) will remain important given that there will always be the possibility, in a free and volatile market, of shippers shifting to specific entry points in function of fluctuating market conditions, resulting in (temporary and contractual) congestion. There is evidence that the actual capacity utilisation at some points in the network is at times substantially below available capacity. In Belgium, as elsewhere in the EU, there is very limited availability of capacity on secondary markets.

The phenomenon of overbooking is commercially explainable and proves that arbitrage is important in the portfolio management of shippers implying the existence of expected opportunities in which the expected arbitrage profits outweigh the extra expenses for additional firm transmission capacity. The fact that the network operator allows overbooking is also rational insofar as not more firm capacity is allocated than that which can be guaranteed as firm and as long as there are effective mechanisms in place to bring the booked but non-used capacity back to the market[18]. Otherwise, overbooking will be distortive and artificially block market access. Moreover, the network operator is not always in the position to identify cases of overbooking.

The high level of overbooking offers a major potential for day-ahead markets where booked but non-nominated capacity flows back to the shippers. It is to be recommended that capacity on the day-ahead market not only be offered as interruptible capacity, but also in packages of firm capacity for a specific period. Capacity overbooking offers considerable potential for a liquid secondary market, certainly if shippers are obliged to offer all unused capacity on the secondary market. However, more initiatives have to be taken in Belgium, and elsewhere in the EU, to organise effective capacity trade on

[18] Reference is be made to congestion management principles better known as "use-it-or-lose-it" mechanisms and anti-hoarding mechanisms (CEER/ERGEG guidelines can be found on www.energy-regulators.eu).

secondary markets. Together with the adjacent operators, the network operator should (certainly in times of congestion) assess the overbooking and on the basis of this assessment calculate the transmission network capability, with a view to ensuring that as much firm transmission capacity as possible is freed up.

Granting more firm capacity than is available, both at entry and exit points on the border, is of a different kind, in which the operator of the transmission network is the responsible party. There is no 'a priori' objection for the network operator granting more firm capacity than is available, but this can only be done provided that the network operator can continue to guarantee all transmission contracts. Available capacities are not a static factor, and the operator can avail itself of tools, including commercial tools, with which to meet all its obligations. In any case a prudent approach should be adopted to capacity overselling.

Offering more firm entry capacity than what the flow rate can provide for upstream is an interesting form of overselling. In theory the network operator can offer 'unlimited' firm entry capacity in this case, as long as the technical maximum upstream flow is known for certain. However, this "unlimited" overbooking should take account of the fact that the upstream capacity is not a fixed factor. There is nothing to prevent the upstream network operator from effecting a reinforcement, and in this case, in the event of overselling downstream, the downstream operator could find itself in contractual problems because its network is inadequate. The conclusions regarding firm capacity overselling are:

- As long as the technical entry capacity at an interconnection is greater than the technical upstream exit capacity, there can be no talk of congestion of entry capacity. As long as this inequality holds, firm entry capacity can be booked.
- In this respect too, closer cooperation and agreements between neighbouring operators are advocated, in order to meet the demand for transmission capacity effectively.

Neighbouring network operators should find out from each other how much the maximum entry and exit capacity are for each interconnection. Technically this means that the interconnection point's availability is calculated according to the best-case scenario. This maximum availability constitutes a very useful piece of information for the downstream network operator in order to optimise capacity allocation.

Network Coupling: Coordination with Adjacent Network Operators

Unfortunately operators of gas transmission networks are still developing their networks from a too isolated point of view, and there is a lack of cooperation. This shortfall is visible in the occasionally sizeable differences in available capacities on the two sides of cross-border interconnections. This in itself is an impediment for shippers. It can partly be explained by commercial arguments, given that reinforcements and new pipelines may be in competition between network operators. However, there is no getting round the fact that investment decisions increasingly have to be made in consultation between network operators in order to guarantee efficient interconnections. Lack of effective unbundling of network operators makes a dialogue only focuses on capacity coordination issues not evident and slows down the objective of effective network coupling.

Timely capacity supply is essential for market access and competitive pricing of natural gas: this requires communication with shippers and adjacent network operators. There is a need for coordination between network operators: a gearing of downstream entry capacity to upstream exit capacity and vice versa. Belgium is already very heavily interconnected with its neighbouring transmission networks. The Belgian natural gas market has highly differentiated supply routes, the most important of which accounting for less than 25% of supply. This marked interweaving of the Belgian natural gas transmission network within the European network potentially makes access for new players more flexible. However, it should be stated that the national market can only reap full benefit from these international connections if transit and internal transmission are treated on an equal footing (EC 2005, see also footnote 15).

Consultation and agreements between network operators could contribute towards a better network coupling, but cooperation is also needed at operational level because the management of a network on which more and more shippers are active, becomes increasingly difficult if it is done on a 'stand alone' basis. This certainly applies to a relatively small network with large number of interconnections, such as the Belgian transmission network, where the predictability of natural gas flows is not evident. Substantial improvements in efficiency could no doubt still be made. Transmission network access issues appear to present a important market barriers to the development of effective competition in the Belgian gas market.

Given the relatively large number of interconnections providing linkages between the Belgian gas transmission network and the adjacent networks it might seem plausible that the relevant geographic market stretches beyond the Belgian national borders. However, this is obviously not the case. It would require significantly more linkages with contiguous networks and increased convergence in network codes and regulatory regimes before the market could be considered to extend beyond Belgium. This may occur over time, through European Commission efforts to create a single European gas market, and related schemes such as the ERGEG's Gas Regional Initiatives (see e.g. Halldearn and Joosten 2008). Which aim to create cross-country regional markets based on local hubs. However, we do not believe that these initiatives are not sufficiently advanced to consider that Belgium is fully integrated with the wider North West European natural gas markets to date.

Network Efficiency: New Investment and Transmission Model

When network management techniques and services are exhausted in order to meet the shipper's demand, additional transmission capacity is required. Creation of transmission capacity not only occurs by means of network extensions but also, and primarily, by means of a range of services aimed at having as much unused capacity as possible (including that which has been booked) flow back to interested shippers. In order to reinforce market access, and as and when shippers become active on the transmission network, the operator is expected to provide for a network management that develops services that are customised to the shippers.

Based on the promotion of free market forces and the need for flexibility for shippers, the network must be able to offer additional capacity to make arbitrage possible. This may call for targeted network extensions, but first and foremost requires a different way of running the network in the form of a bespoke service for shippers. This trend is in line with the evolution towards an entry/exit model as championed by the European Commission. In consultation, a new balance has to be found between the capacity offered and the shippers' demand that goes beyond the transmission requirement estimated on the supply flow.

The current congestion problem appears not so much to be a problem of physical transmission capacity, since the Belgian transmission network scores well in respect of the physical transmission capacity available in the upstream and downstream networks. This general picture does not detract from the fact that reinforcements are urgently needed at some interconnections. The congestion problem appears to point more to a management that is not leading to a full utilisation of the network's availability. This means that the way in which the transmission network's availability is turned into services customised to the shippers could still be improved.

Operational network management is increasingly dependent on shipper's behaviour which is not easily predictable since prompted by commercial considerations and thus volatile. From this point of view, the need for an active and permanent congestion policy, certainly for local entry points, is in itself not a problem, and in this way a contribution can be made towards optimal use of the network. Physical congestion, on the other hand, needs to be detected and assessed in good time, with a view to the necessary reinforcements.

This analysis shows that the network management is confronted with a new dynamic in which the shippers are the driving force. The challenge for the network operator consists in anticipating developments on the capacity market, and not just the flow demand at peak periods, and using these insights to further refine the investment model, the network management and the commercial operating model.

7 Conclusions

Network coupling supporting cross-border market access for shippers continue to be a major concern for those who strive for the ideal of a well-functioning internal EU gas market. This paper, by examining the Belgian gas transmission network interconnected with eight adjacent networks, intended to provide evidence and a better understanding of the capacity mismatches at cross-border interconnection points. The provision of capacity by the network operators as well as the capacity booking behaviour of shippers were assessed. Evidence shows that the cross-border entry capacity of the Belgian gas transmission network is capped by the capability of the upstream network to transport to Belgium. Analogously, there is also more technical exit capacity available in the Belgian network than the downstream networks can offer.

While capacity mismatches at cross-border interconnections were an issue that was generally known - at least the existence - and may also be explained as a heritage of the past, the assessment of the booking behaviour of the shippers and capacity sales at cross-border points has revealed some new phenomena which deserve further regulatory attention. It was presented that there is a large amount of firm capacity overbooking explaining to some extent the situation of contractual congestion at cross-border interconnections. This observation shows that shippers use the gas transmission network more and more from a commercial perspective and one may consider that this is a positive sign for the emergence of effective competition. This explains the divergence between the contractual network use and the physical use. However, this entails that on the capacity side, the network operators should adapt more quickly to new methods of network operation, network design and develop new transmission services. To solve contractual congestion and improve market access, the gap between contractual use and physical use should be narrowed by e.g. bringing booked but non-used transmission capacity back to the market.

While the phenomenon of capacity overbooking is as such not distortive, it becomes distortive in the case of contractual congestion and the absence of mechanisms to bring non-used capacity back to the market. Overselling of firm capacity is a practice which is less straightforward. Network operators may sell e.g. more firm cross-border entry capacity if they know with certainty that the upstream network is not able to transport more. This phenomenon, which was less known as a practice, deserves further attention and may contribute to higher network efficiency and to meet the market needs. This shows that not only shippers start to use networks with a commercial objective but also network operators do. Obviously, this practice goes beyond the traditional sole objective of security of supply and carries the trigger for effective competition.

References

CEPA-Cambridge Economic Policy Associates (2008), Structure and Functioning of the Natural Gas Market in Belgium in a European Context, final report, www.creg.be.

CREG-Commission for Electricity and Gas Regulation (2004), Belgian Indicative Plan for the Provision of Natural Gas 2004-2014, www.creg.be.

CREG-Commission for Electricity and Gas Regulation (2008a), Annual Report 2007, www.creg.be.

CREG-Commission for Electricity and Gas Regulation (2008b), Monitoring of the Import Capacity for Natural Gas 2008, study (F)080515-CREG-765, www.creg.be.

Cuijpers C. and J.P. Pinon (2005), Determination of Available Capacity in Gas Transmission Networks in Europe, paper presented at the 4th Conference on Applied Infrastructure Research, Berlin.

EC-European Commission (2003), Directive 2003/55/EC Concerning common rules for the internal market in natural gas and repealing Directive 98/30/EC, Brussels.

EC-European Commission (2005), Regulation No 1775/2005 on conditions for access to the natural gas transmission networks, Brussels.

EC-European Commission, Competition DG (2007), DG Competition Report in Energy Sector Inquiry, SEC(2006) 1724, http://ec.europa.eu/comm/competition/sectors/energy/inquiry/index.html.

EC-European Commission, report from the Commission to the Council and the European Parliament. Progress in creating the internal gas and electricity market, COM(2008) 182 final.

ERGEG-European Regulators' Group for Electricity and Gas (2007), Calculation of Available Capacities: Understanding and Issues – An ERGEG Public Consultation Paper, Ref. C06-CAP-06-03, www.energy-regulators.eu.

Fluxys (2008a), Main Conditions: Basic Principles for the Transport Model, www.fluxys.com.

Fluxys (2008b), Network Code: Procedures, www.fluxys.com.

Ghiosso I. (2007), Regulation and development of natural gas interconnection facilities in Europe, paper presented at the 2nd Workshop on Energy Economics and Technology, Enerday, Dresden.

Gruber T. (2007), Cross-border Trade in Electricity and Gas. Obstacles to Effective Competition from Regulatory Standpoint, Academy of European Law, Trier.

Halldearn D. And G. Joosten (2008), A Vision and a Roadmap for the Gas Regional Initiative North West, http://www.e-control.at/portal/page/portal/EER_HOME/EER_INITIATIVES/GRI/North_West.

Pinon J.P. and C. Cuijpers (2006), The Marketing and Calculation of Gas Transmission Capacity in the EU, paper presented at the 23rd World Gas Conference, Amsterdam.