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Working Paper

European traded gas hubs: the markets have rebalanced

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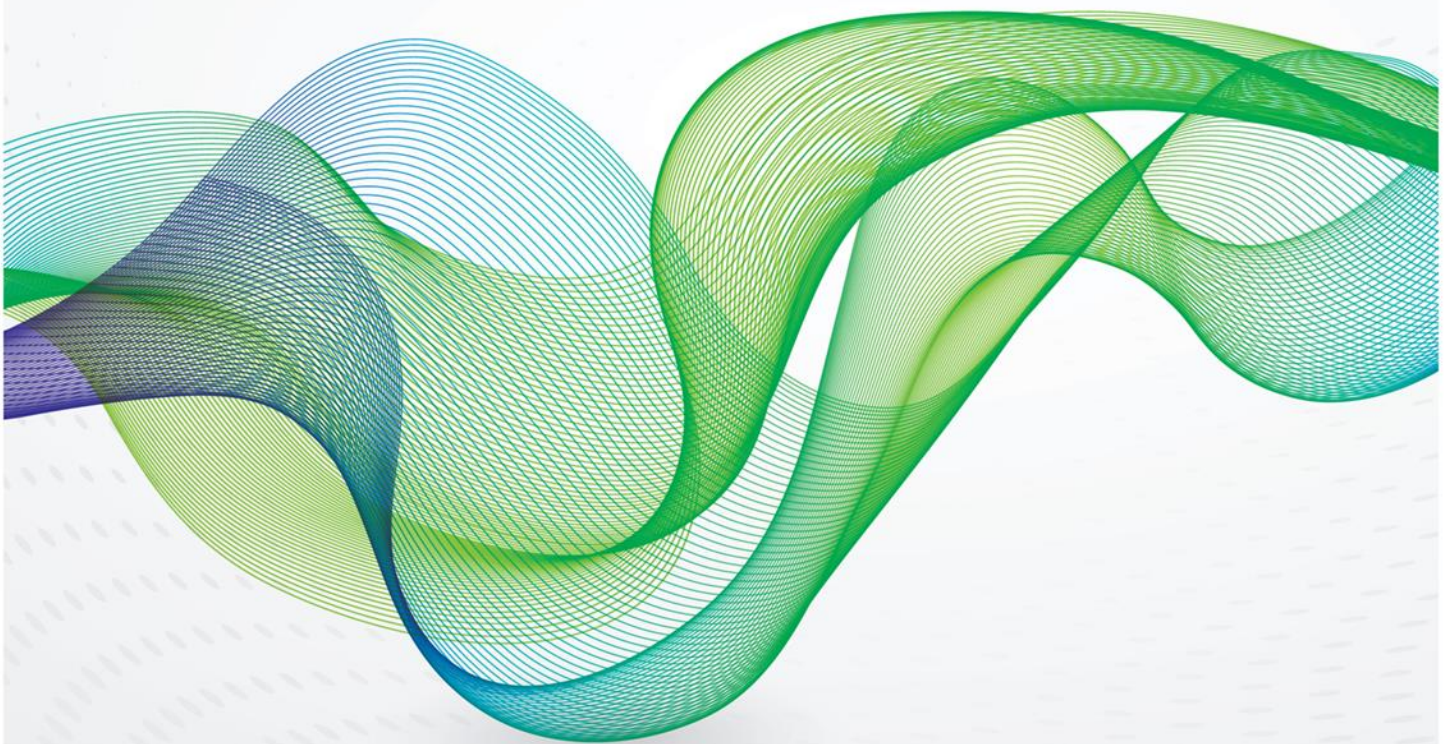
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July 2024

European Traded Gas Hubs: the markets have rebalanced





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Executive Summary

European gas markets experienced a very turbulent period from 2020 to 2022, starting with a large fall in demand due to the global pandemic, followed by a renewed surge in demand in 2021, especially in Asia, and finally, the rapid fall in Russian pipeline gas supplies to Europe due to the war in Ukraine.

All these events led to the lowest ever northwest European gas prices at the end of May 2020,¹ then several strong rallies led to four successive 'highest ever' prices,² the most recent being in August 2022. After each of those rallies, markets retraced back down to around €60/MWh. There was one last smaller but equally steep rally at the end of 2022, resulting in a high on 7th December 2022 when the THE³ closed at €149.11/MWh.

The focus of this paper is to review the European traded gas markets during 2023 to see whether they have remained uncertain, volatile and have the potential to revisit those highs or, by contrast, whether they can be said to have 'rebalanced' to any degree. The paper analyses the results of the author's 5 Key Elements, as well as the effect of large LNG imports, and five long term market trends (traded volumes development, Month Ahead prices and the spreads between hubs, price convergence, correlation and volatility).

All of Europe now has a gas hub of sorts, ranging from the very small 'nascent' balancing and spot trading hubs; to the 'inactive' hubs that might have a little more spot and prompt trading but often very little or no curve trading; to the medium 'poor' hubs in Belgium, Czech Republic, and Spain that do trade more products but still in relatively low volumes; to the larger 'active' hubs in Britain, France, and Germany that do trade reasonable volumes and also in more types of products. All of these are dwarfed by the only 'mature' benchmark hub in Europe, the Dutch TTF.

In 2023, trading picked up significantly, set against a general fall in physical volumes. When comparing the 2022/23 year on year difference, Europe as a whole had a 40% rise in traded volumes, whilst physical demand fell by -18%. All countries had higher traded volumes except Belgium, Great Britain and Romania and all had lower physical demand, except Bulgaria, Denmark and Romania.

The most important metric is the traded gas hubs' churn rate since in this one metric all others are necessarily reflected: if there are many participants, trading many different products in large quantities, then the churn rate is likely to be high. The net and gross churn rates for the 10 main hubs were studied in this paper and the results for 2023 show that there is only one European benchmark hub, the Dutch TTF, standing far ahead of all the others and the only hub considered as 'mature', plus one regional sterling marker price, the British NBP.

The author's 2022 paper concluded that there was indeed an 'LNG effect' on traded volumes in those countries that imported large additional cargoes of LNG. Although the results are less clear for 2023, there was a large increase in traded volumes and churn rate at the Dutch TTF and the Netherlands was the only country with an increase in LNG sendout in 2023 compared to 2022.

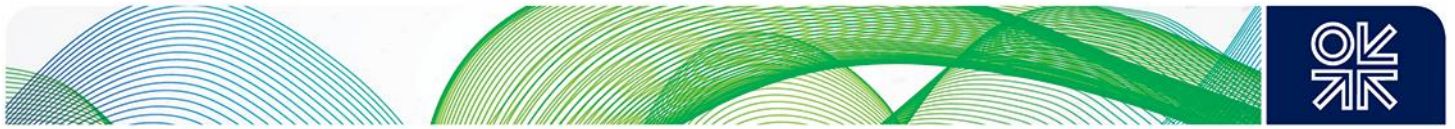
The urgent need since 2022 to bring additional volumes of LNG into Europe resulted in an expansion of new LNG terminal and FSRU projects, in particular in the Netherlands and in Germany, and this has already led to greater traded volumes at the Dutch and German hubs.

Having examined each of the 5 Key Elements in detail, as well as several complimentary analyses, it is clear that the Dutch TTF is far and away the leading European traded gas hub, used by many more market participants than any other hub, has a very high traded products score, with far greater total traded volumes than all the others put together. TTF also accounts for 81.5% of all European gas

¹ On 21st May 2020, the lowest ever price was €3.61/MWh at the NBP.

² On 5th October 2021, NBP closed at €119.57/MWh; on 21st December 2021, NCG closed at €180.98/MWh; on 8th March 2022, NCG closed at €218.30/MWh; and on 26th August 2022, NCG closed at €320.25.

³ Although the German NCG (later THE) was the highest hub in four of those highs, the other NW European hubs were very close.



trading, for 56% of all OTC trading, and 87% of all exchange trading. TTF also has the highest Tradability Index score, only missing one point on one of the 'balance of month' contracts, and finally, by far the greatest churn rate.

This paper also reviewed the longer term trends at eight selected hubs, namely the British NBP, the Dutch TTF, the Belgian ZEE and ZTP, the German THE, the Austrian VTP, the French TRF, and the Italian PSV, to determine whether or not the traded gas markets have continued to trade erratically into 2023, or whether there is an emerging pattern to suggest that they have 'rebalanced'.

Month Ahead spreads are commonly traded in the European gas markets, principally because it is the MA contract that is most used in pricing underlying physical contracts and therefore, it is the MA contracts, OTC and especially exchange futures, that are most used in the risk management of physical gas portfolios.

The graphs in this paper show that it was the French TRF versus Dutch TTF spread that recorded the highest differential during the turbulent trading period of 2022, but the other main European hubs also saw wide variations in their basis prices to TTF. The TTF/TRF spread has over time been marginally negative but in 2022 went positive due to the large quantities of LNG imported into France; however, from early October 2022 the TTF premium fell quite sharply, and even went a touch negative in early January 2023, before stabilising over the course of the year. Although there was a brief small increase in Q4-2023, it fell back again in early 2024.

With regards to the spreads between TTF and the THE, PSV and VTP hubs, the most extreme of these three hubs was the Austrian VTP and although that hub's spread against TTF has rebalanced from 2023, there have still been some variations, both positive and negative to the benchmark TTF. The THE and PSV have mostly settled back down to a similar pattern as pre-2022.

The actual correlation coefficients of some of the main 'pairs' of hubs show near perfect correlation of the three large NWE LNG importers to the benchmark TTF before and since the extraordinary market conditions in 2022. The three other sets of correlation coefficients between TTF and the German THE, Austrian VTP, and Italian PSV, showed greater correlation throughout the whole four year period. The absolute price correlations and the correlation coefficients all show that the markets in these six selected NWE hubs did rebalance and have remained pretty much in line to this day with the markets prior to 2022 and before.

The volatility graph for the benchmark TTF alone from 2007 to 2023 shows that the average volatility in the two year period before the first big rise in gas prices in the summer of 2021 was 68.28%; the average TTF volatility in the most volatile 13 months from Q4-2021 to Q4-2022, both in terms of extremely high absolute levels and steep rises and sharp dips, was 137.36%; and the average TTF volatility in December 2023 was 73.75%. For now at least it appears that to a large extent the TTF market has also rebalanced in terms of volatility.

After a period of very high volatility for the whole of 2022, levels have both come back down and stabilised somewhat and with a broad convergence across the four lowest hubs by the end of 2023. This trend is less visible with the Belgian and French hubs.

On a global scale, HH is the North American benchmark hub and remains a leading global gas benchmark, used to price LNG cargoes to Asia and Europe. It is now closely followed by TTF which is not only the benchmark for its immediate sphere of influence but increasingly so for all of Europe and also globally. NBP remains a regional benchmark hub for the British Isles and some LNG pricing. The JKM is currently the only feasible price marker in Asia, but is very far from being an active and reliable one.

The actual results also show that the trading at TTF has rebalanced and indeed, gone from strength to strength. The other European hubs can also be said to have rebalanced on the whole, with some exceptions, particularly at some emerging hubs. With regards to the analyses on long term trends, price spreads, price correlation and price volatilities they also show to a large degree that the markets have rebalanced. Finally, Henry Hub and JKM trading has also rebounded.



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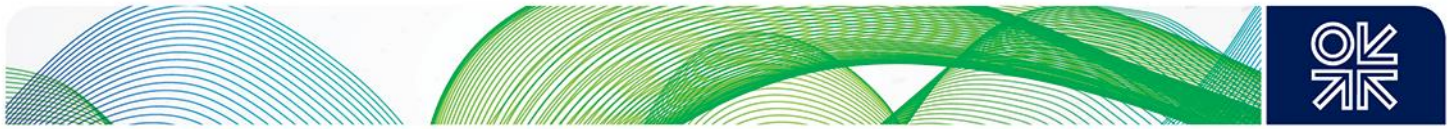


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1. Introduction

The author has been following the development of the European traded gas hubs over many years and has already published a number of papers and insights on the subject.⁴ He is now also following the development of traded gas markets in Asia and the relative importance of global gas pricing benchmarks.

In the six years to the end of 2020, there was a gradual convergence of hub prices, including JKM, whilst oil and oil-indexed prices remained mostly dearer. However, in 2020 and 2021, the European traded gas markets experienced two successive years of quite unexpected and extreme external factors which had a pronounced effect on wholesale prices and the whole trading environment generally.

This period saw in the last week of May 2020, the lowest ever⁵ Month Ahead (MA) traded prices.⁶ There then followed a long rally leading to the then highest ever price in December 2021.⁷ Following a brief period of market readjustment, the unfolding crisis in Ukraine led to more volatile and higher prices in 2022, culminating in the 'new' highest ever price at the end of August 2022.⁸

Not only were those prices extreme, but the protracted rally leading to the first highest price level in October 2021 was the longest ever seen and the historic high volatility rates, as well as displaying some very sharp peaks and troughs, also recorded the highest ever levels in March 2022.

The highest ever European gas volatility rate was on the French TRF on the 15th and 16th March 2022, with the Belgian ZEE hub just behind, the only two gas hubs to ever have a volatility rate of 300% or more.⁹ By contrast, the steepest ever fall in prices occurred from the end of August to the end of October 2022, falling about €260/MWh in just two months.

There were also some interesting points to note regarding the traded volumes at the gas hubs, with a shift away from over-the-counter (OTC) trading towards more exchange trades, and disparate results from hub to hub, with some falling badly during 2020 and 2021, whilst others maintained or even improved their overall traded volumes. During 2022, there was a mixed picture, with six of the main hubs analysed falling in overall traded volumes, including the benchmark TTF, whilst at the remaining four hubs the traded volumes increased.

In light of the above, the author believes it is important to review the longer term trends to see whether or not the traded gas markets have continued to trade erratically into 2023, or whether there is an emerging pattern to suggest that they have 'rebalanced'. The purpose of this paper therefore is to analyse the results of the trading data in 2023 for the European traded gas hubs, to determine not only their trading activity and their relative ability to be used by shippers to risk manage their portfolios, but also to review the prices and volatilities of the traded markets to assess whether the European traded gas hubs have indeed 'rebalanced' or not.

It will look at the TTF in particular, as this hub has for several years now been the pre-eminent European hub. Was the fall in volumes in 2022 just a temporary set-back, or have they recovered in 2023? This is important as TTF has for several years now¹⁰ been the most liquid by far in Europe and has been

⁴ All of which are listed in the Bibliography and are available to download from the OIES website: <https://www.oxfordenergy.org/authors/patrick-heather/>

⁵ Using the Heren/ICIS closing Month Ahead daily prices data series from 1st January 2006.

⁶ TTF Month Ahead closed at €3.54 on 28th May 2020; that same day NBP was the lowest priced hub, closing at €3.27/MWh.

⁷ On 21st December 2021, TTF Month Ahead closed at €180.31 and the Czech VOB the highest of all, closing at €181.43/MWh.

⁸ On 26th August 2022, Europe's highest ever gas prices were reached with NCG closing at €320.25 and VTP closing at €319.74.

⁹ TRF volatility was 301% on both days, ZEE was 300%.

¹⁰ The Dutch TTF hub overtook the British NBP in terms of total traded volumes in 2016 and, in 2022, represented very nearly 76% of all European traded gas volumes.

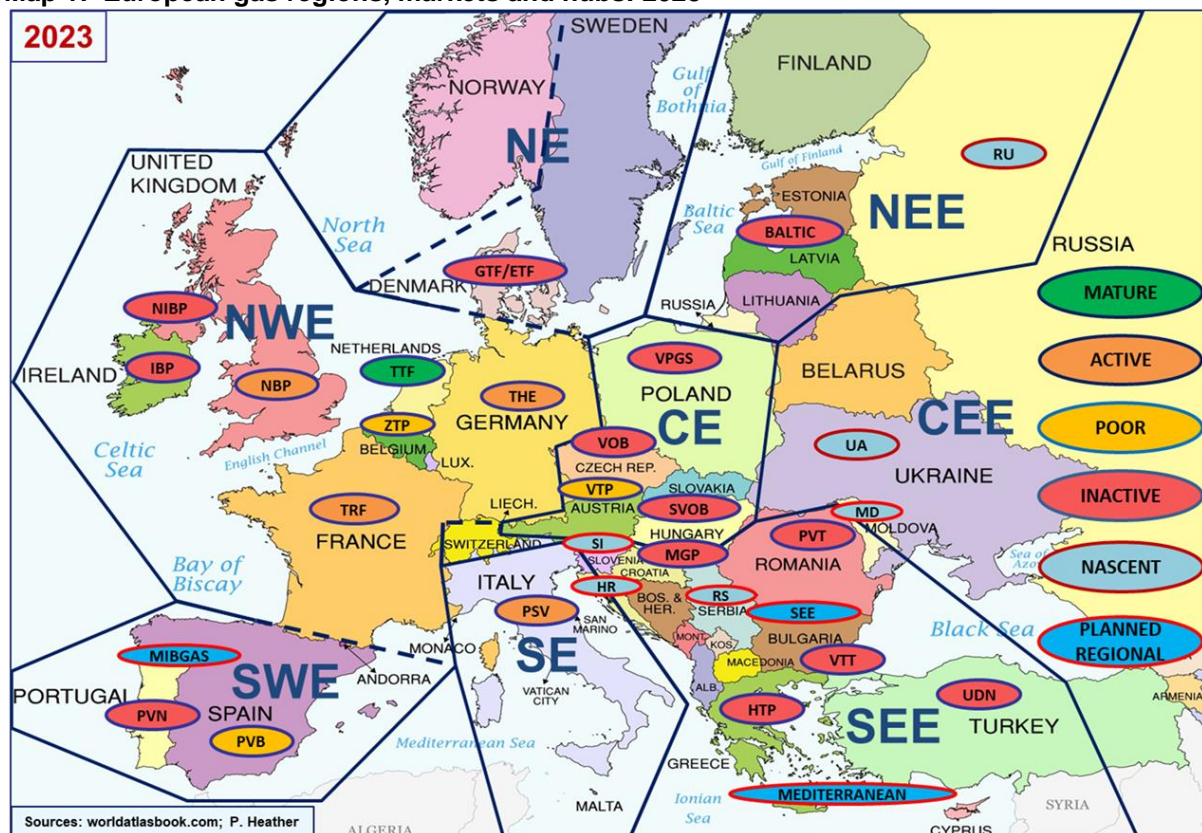


widely used as the reference price for physical wholesale gas contracts. Furthermore, TTF had started to gain a role as a global benchmark and this paper will analyse if this remained the case in 2023.

2. An overview of the European traded gas hubs

Map 1 shows all European gas hubs¹¹ operational at the end of 2023. The colour scheme indicates which hubs are categorised¹² as 'Mature', 'Active', 'Poor' and 'Inactive'. There is now just one Mature hub, the Dutch TTF; the British NBP lost it's 'mature' status in 2021 and is now classified as Active, alongside three other hubs, the German THE, the French TRF, and the Italian PSV; and three Poor hubs, the Austrian VTP, the Spanish PVB, and the Belgian ZTP; all of the remaining hubs are classed as Inactive; the Belgian ZEE ceased trading at the end of September.

Map 1: European gas regions, markets and hubs: 2023



There is also a change in nomenclature from 'Planned National' to 'Nascent' as there are now officially 'hubs' in Slovenia, Croatia, Serbia, and Moldova. However, as with some of the emerging 'Inactive' hubs, the author does not include these hubs in the analysis as there are insufficient data available.

In Croatia, there is virtually no OTC trading and no exchange trading, although balancing trades are performed on a digital platform operated by the Transmission System Operator (TSO). In Slovenia, a virtual trading point was established in late 2015 to primarily enable balancing operations to conform with the EU directives;¹³ these are carried out on a web application. However, the author was unable to

¹¹ Appendix 11.1 lists all of the European gas hubs, their name and year of inception.

¹² As defined by the Author, following his 5 Key Elements analysis; see Chapter 3.1 of this Paper.

¹³ According to the European Federation for Energy Traders (EFET), "Slovenia has nudged ahead of Croatia in terms of market design, though Croatia is more widely traded" (EFET 2023 Press Release: <https://www.efet.org/files/documents/231106%20GC%20PR%20Hub%20Scores%202023.pdf>)



find any sources referring to actual trading at either hub, whether OTC or Exchange, balancing, spot, or curve trading.

Moldova and Serbia are cited in the EFET 2023 Review of Gas Hubs Assessments and the reports' associated press release¹⁴ where they are described as having been added, but their scores indicate still only basic hub design, reflecting part-implementation of EU rules, rather than genuine reform that will lead to wholesale trading.

Ukraine has continued the process of liberalising its energy markets and does have some limited OTC gas trading, as well as some exchange trading on the UEEx.¹⁵ This is remarkable given the substantial challenges the country currently faces but it must be said that there is wide support for creating a competitive gas market, including from the European Bank for Reconstruction and Development, US Aid, the European Energy Committee and the Ukrainian Ministry of Energy.

The Greek gas hub showed strong growth in 2023, albeit from a very low first year start,¹⁶ to record a total of 9.03TWh traded on the HEnEx trading platform; however, there were still no OTC trades reported.

In Denmark, there has been an almost total drop in trading over the past two years due to the redevelopment of the offshore Tyra gas field, but especially due to the reinforcement works on the Danish transmission system linked to the Baltic Pipe project to carry gas to Poland. The latter was completed and inaugurated in late 2022, with the Tyra field redevelopment completed in Spring 2024. Despite there being no recorded OTC trades and no exchange futures trades, the exchange spot trades totalled 52.78TWh, higher than the combined OTC and exchange totals in 2021 and 2022.¹⁷

Overall, there was a resurgence in gas trading across the European hubs,¹⁸ with increased traded volumes,¹⁹ despite a fall overall in the underlying physical volumes.²⁰ All countries had higher total traded volumes compared to 2022, except for three (Britain, Belgium, and Romania); all countries had lower physical volumes, except for three (Denmark, Romania, and Bulgaria). The increase in total trades against the fall in total physical volumes resulted in the gross churn for all of Europe rising above 10 times,²¹ the first time this has ever happened. However this is mainly due to the large increase in trading in the Netherlands and that country's associated increase in churn rate.²²

At a European level, total OTC trading recovered slightly in 2023 (9% increase), whereas exchange spot trading fell just 4%. The big difference in 2023 was the very large increase in exchange futures and options trading, up 54% on 2022. However, there were some very wide variations from country to country: apart from the four countries²³ that did not report any OTC trades, the rise in OTC trading varied from +10% in the Netherlands and a huge +148% in Slovakia; however, in five countries the OTC trades fell, from -5% in France, to -80% in Hungary (and as there were no OTC trades reported in Denmark in 2023, that resulted in a fall of -100%).²⁴

All but five countries²⁵ saw an increase in their exchange futures trading, from just +2% in Britain, to +206% in Bulgaria (albeit from a low number); and all but three countries²⁶ saw an increase in the gross

¹⁴ See Footnote 10.

¹⁵ Ukrainian Energy Exchange: <https://www.ueex.com.ua/eng/>

¹⁶ The Hellenic Energy Exchange gas platform finally went live in March 2022 and recorded 2.87TWh of spot trades.

¹⁷ In 2021 the total was 49.69TWh (32.11 OTC, 17.58 Exch) and in 2022 the total was 35.60TWh (17.99 OTC, 17.62 Exch).

¹⁸ The Author analysed the data for the hubs in 16 countries: Austria, Belgium, Britain, Bulgaria, Czech Republic, Denmark, France, Germany, Hungary, Italy, Netherlands, Poland, Romania, Slovakia, and Spain.

¹⁹ 79,719TWh in 2023, compared to 57,032TWh in 2022, an increase of 40%.

²⁰ 5,771TWh in 2023, compared to 6,996TWh in 2022, a decrease of 18%.

²¹ The European gross churn in 2023 was 13.81, compared to 8.15 in 2022.

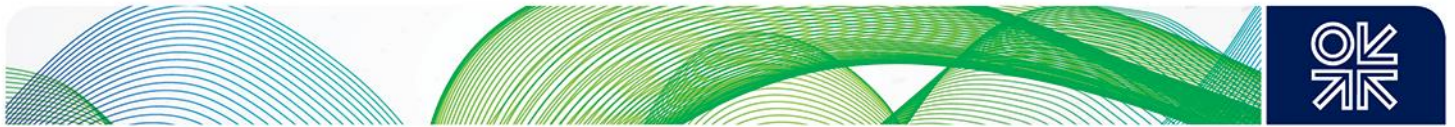
²² The detailed breakdown of all the figures can be seen in the Churn Matrices tables in the Appendices.

²³ Poland, Romania, Bulgaria, and Denmark.

²⁴ The other two countries that recorded a fall in OTC trading were Britain with -13% and Belgium with -42%.

²⁵ Austria, Belgium, Denmark, Italy, Romania.

²⁶ Belgium, Denmark, Romania.



churn rates, with the Netherlands recording the greatest absolute rise, by +37.82 (or 60%), resulting in a gross churn of just over 100 times.

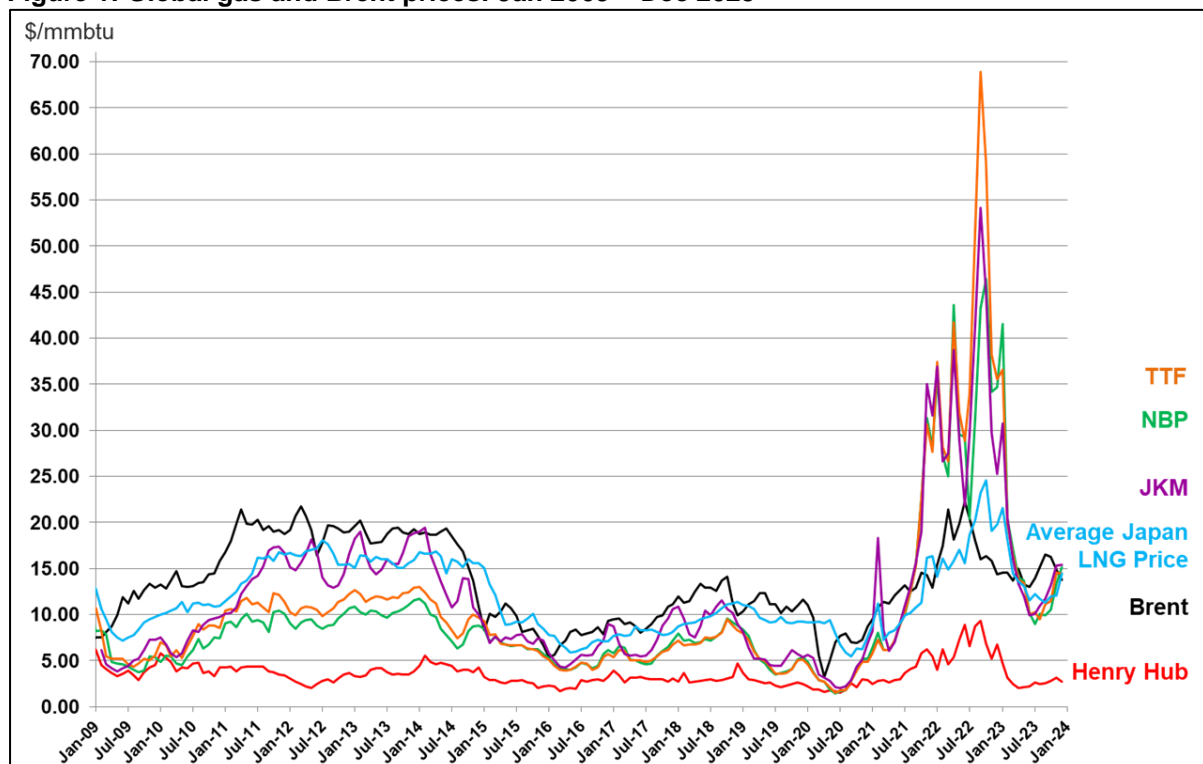
More detail will be given in Chapter 3.2 below but the Dutch TTF is once again forging ahead of all the other European hubs, in every criterion reviewed in the 5 Key Elements.

3. Review of the 5 Key Elements in 2023

Before we review the 5 Key Elements pertaining to European gas trading, it is useful to place European gas in the context of its global equivalents and the crude oil market. This is especially relevant after the turbulent period in energy trading following the Covid-19 pandemic, the ensuing energy ‘crisis’ that started in the summer of 2021 and the war in Ukraine in 2022, which all contributed to a disruption to global economies and led to higher commodity prices.

Figure 1 shows the relevant global gas and Brent oil prices over a fifteen year period from January 2009 to December 2023, from which the extraordinary period of high and volatile²⁷ energy prices of 2021 and 2022 can clearly be seen.

Figure 1: Global gas and Brent prices: Jan 2009 – Dec 2023



Sources: S+P Global Platts, EIA, Argus, CME; M. Fulwood, P. Heather

It also clearly shows how all of these energy prices collapsed from Q4-2022²⁸ to reach their recent lows in the summer²⁹ of 2023, before slowly consolidating. The four gas benchmark hubs have however eased back a touch in late 2023 or January 2024, although Brent and the oil indexed Japan Average have continued to edge higher.

²⁷ See Chapter 7(d).

²⁸ Brent prices started to fall from June 2022.

²⁹ Henry Hub as early as April, Brent, JKM and Japan Average in June, NBP in July, and TTF in August.



Table 1: Global gas and Brent price changes (%)

\$/MMBtu	Brent	HH	NBP	TTF	JKM	Japan Ave
Ave 2023	14.54	2.74	15.40	15.12	14.91	13.83
Jul-21	13.21	3.62	10.00	10.28	12.02	9.92
Difference	10.1%	-24.3%	54.0%	47.1%	24.1%	39.4%
\$/MMBtu	Brent	HH	NBP	TTF	JKM	Japan Ave
Dec-23	13.79	2.71	15.18	14.48	15.41	14.47
15yr Ave	13.39	3.50	9.66	10.57	11.89	11.86
Difference	3.0%	-22.7%	57.2%	37.0%	29.6%	22.1%

Sources: Taken from the data behind the global gas and Brent price figures.

The author believes that this does, for now, indicate that the traded gas markets have indeed 'rebalanced', albeit at a slightly higher level than the long term average, except for Henry Hub which continues to stay at very low levels and lower than before the price spike.

The extreme gas market volatility and the exceptional and unprecedented high gas prices in 2021 and 2022, as well as significantly increased volumes in some of the emerging hubs led the author to rethink last year the methodologies used in his analysis of the 5 Key Elements.

3.1 A note on methodology

The author revised in 2022 the methodologies used in his analysis of the 5 Key Elements; the new methodologies are more precise and should help the reader better understand the variations in maturity and development across the now many traded gas hubs in Europe, including the emerging hubs. These have continued to be applied in the 2023 analysis presented in this paper.

The main difference in the new methodologies is the addition of a new 'lowest' category in each of the elements, represented by a pale brown colour, to the previous 'traffic light' Green, Amber, Red colours in the tables: the full methodologies are shown in footnotes to each of the tables.

As previously, each Element will have its own scores and then they will be amalgamated in the Summary of the 5 Elements, in order to determine the overall ranking, which will also have a revised lowest banding that will determine the 'Inactive' hubs.

For Key Element 1 'Active Traders', the new brown category will be where the number of active traders is less than 10, and if the hub score is less than 10.

For Key Element 2 'Traded Products', the new brown category will be where the hub score out of a total of 56, is less than 8.

For Key Element 3 'Traded volumes', the new brown category will be where the total traded volumes are less than 100TWh.

For the 'Traded volumes - emerging hubs', the same methodology will now apply.

For Key Element 4 'Tradability Index', the new brown category will be where the score is less than 5/20.

For Key Element 5 'Churn rates', the new brown category will be where the net or gross churn is less than 1.

The Summary of the 5 Key Elements table will show the new colour scheme for each of the elements and there is a slight change to the two lowest categories: 'Poor' hubs will now be for scores of 4-7/15 (previously 5-7/15), shown in amber on the Map; and 'Inactive' hubs will now be for scores of 1-3/15 (previously 1-4/15), shown in red on the Map.

Although the Belgian ZEE hub ceased trading at the end of September 2023, it has been included in the 5 Key Elements results, but left out of the final summary table and has been taken off the 2023 hubs map above.



3.2 Results of the 5 Key Elements in 2023

Trading activity continued to increase in 2023, after two difficult years in gas trading, which in turn attracted more participants. Table 2 shows the number of 'active'³⁰ participants at each of the selected hubs; the more active participants there are, the more liquidity there will be in a market. The methodology recognises the importance of curve trading over spot, as it is this that is most often used to risk manage a participant's portfolio and to hedge physical contracts.

Table 2:³¹ Key Element 1: Market participants: 2023

2023	OTC Active Traders*				
HUB	Hub Score [^]		S/P/M**	Q/S/Y***	Hub Score [^]
	2021	2022	2023	2023	2023
TTF	164	275	80	60	200
NBP	142	127	55	40	135
THE	110	187	40	25	90
TRF	40	116	37	19	75
PSV	92	96	28	20	68
VTP	70	125	26	16	58
ZTP	26	76	27	14	55
PVB	45	52	20	13	46
VOB	27	50	22	11	44
ZEE	20	13	5	4	13

* The estimated number of traders who regularly trade.
 ** Spot / Prompt / Months contracts; *** Quarters / Seasons / Years contracts.
 ^ Hub score calculated as (1xS/P/M) + (2xQ/S/Y).

Sources: 2021: based on conversations with 3 market participants (very difficult to get responses given the market conditions);

2022: based on survey results from 3 market participants, with 1 broker input;

2023: based on survey results from 5 market participants, with 1 broker input.

In 2023, the author was fortunate to receive greater input from market participants which should result in a more accurate survey and therefore the results should not be directly compared on a like for like basis with the two previous years. The results do indicate however that last year's estimates were probably a little on the high side for all the hubs. Although the final hub scores are in some cases quite different, most of the hubs remain in the same rankings as previously except for the 'middle' three hubs which have changed: the French TRF has overtaken the Italian PSV and the Austrian VTP is now behind both of those, which is an accurate reflection of the traded volumes results.

Once again, the Dutch TTF is way ahead of all the other hubs with a calculated 'score' of 200, ahead of the British NBP with a score of 135, which is still a very good score and the only other hub with a score above 100. Only four hubs have 20 or more 'active' curve traders. TTF is by far the leading gas

³⁰ The criterion used in the survey is how many traders trade at least once per week; the spot/prompt includes the Month Ahead contract.

³¹ The methodologies used in this table are: (S/P/M): Green: ≥ 60 ; Amber: < 60 ; Red: < 25 ; Brown: < 10 ; (Q/S/Y): Green: ≥ 20 ; Amber: < 20 ; Red: < 10 ; Brown: < 5 ; (Hub): 1xSPM/2xQSY: Green: ≥ 100 ; Amber: < 100 ; Red: < 45 ; Brown: < 10 .



hub in Europe and attracts not only physical traders but financial, institutional and speculative traders also.

The next best hub is the German THE³² with a score of 90 and although this is less than in the previous two years, it is still very respectable. Less positive is that there were only an estimated 25 'active' curve traders and again this reflects the curve traded volumes as shown in the traded products table below. By contrast, there are still very large volumes of spot trading, especially on the exchange platform.

Table 3:³³ Key Element 2: Traded products: 2023

2023		Product evaluation based on absolute volumes*																	
HUB	SCORE/56	OTC	SCORE /28	CLEARING	WD DA	BOW WIE WDNW BOM	MA MONTHS	QUARTERS	SEASONS	YEARS (CAL + GAS)	EXCHANGE (% SHARE)	SCORE /28	BALANCING TRADES	SPOT PROMPT	FUTURES MONTHS	FUTURES QUARTERS	FUTURES SEASONS	FUTURES YEARS	OPTIONS MONTHS
TTF	49	Y	24	Y	Y	Y	Y	Y	Y	Y	ICE EEX CME	93 >6 <1	25	Y	Y	Y	Y	Y	Y
NBP	40	Y	22	Y	Y	Y	Y	Y	Y	Y	ICE EEX CME	>99 <1 0	18	Y	Y	Y	Y	Y	Y
THE	35	Y	18	Y	Y	Y	Y	Y	Y	Y	EEX ICE	>98 <2	17	N	Y	Y	Y	Y	Y
TRF	26	Y	13	Y	Y	Y	Y	Y	Y	Y	EEX ICE	>99 <1	13	N	Y	Y	Y	Y	N
PSV	25	Y	16	Y	Y	Y	Y	Y	Y	Y	GME EEX	53 31 16	9	Y	Y	Y	Y	Y	Y
VTP	21	Y	11	Y	Y	Y	Y	Y	Y	Y	EEX ICE	>99 <1	10	N	Y	Y	Y	Y	N
PVB	15	Y	7	Y	Y	Y	Y	Y	Y	Y	MIB EEX	66 34	8	N	Y	Y	Y	Y	N
ZTP	14	Y	7	Y	Y	Y	Y	Y	Y	Y	EEX	100	7	Y	Y	Y	Y	Y	N
VOB	12	Y	7	Y	Y	Y	Y	Y	Y	Y	EEX	91 9	5	N	Y	Y	Y	Y	N
ZEE	4	Y	3	Y	Y	Y	Y	Y	Y	Y	EEX	100	1	N	Y	Y	Y	Y	N
*KEY:		GREEN: ≥/600TWh AMBER: <600TWh BLUE: <250TWh RED: <50TWh GREEN: ≥/500TWh AMBER: <500TWh BLUE: <100TWh RED: <30TWh																	
GREY:		Hubs column based on OTC + Exchange 'score'/56; OTC column based on 'score'/28; Exchange column based on 'score'/28																	
No volumes		ICE=ICE or ICE/Endex EEX=EEX CME=CME Europe MIB=MIBGAS Y=AVAILABLE N=NOT AVAILABLE																	

Sources: OTC: LEBA, ICIS; Exchange: ICE, ICE-Endex, EEX, CME, GME; MIBGAS; P. Heather

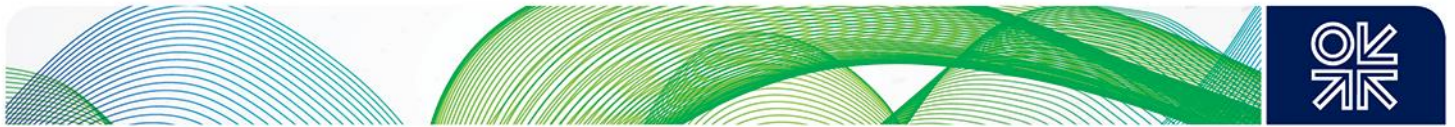
France is once again ahead of Italy, which reflects the increase in the traded volumes at TRF, mainly due to the continued large volumes of Liquefied Natural Gas (LNG)³⁴ that have been imported and subsequent regasification and distribution through the national grid. This has been an important benefit for TRF trading as, if the LNG cargoes were priced based on the destination hub, this would potentially involve LNG sellers hedging their side of the transaction at that hub; even if they were not priced at the destination hub, the sellers and buyers would be trading at the national hub as it would necessarily be 'delivered at the hub' once regasified.

A good measure of a hub's maturity is the types of products available to trade and their traded volumes, which are a good indication of whether a market is used for balancing or risk management. Table 3 shows all the traded products for each of the hubs, both OTC trading on the left and exchange trading on the right.

³² Trading Hub Europe (THE), the merger of the previous two hubs, NCG and GPL, commenced trading on 1st October 2021.

³³ The methodologies used in this table are: (Products): as per Key in table; (Hub score/56): Green ≥/42; Amber <42; Red <16; Brown <8.

³⁴ See Chapter 4 for a detailed explanation.

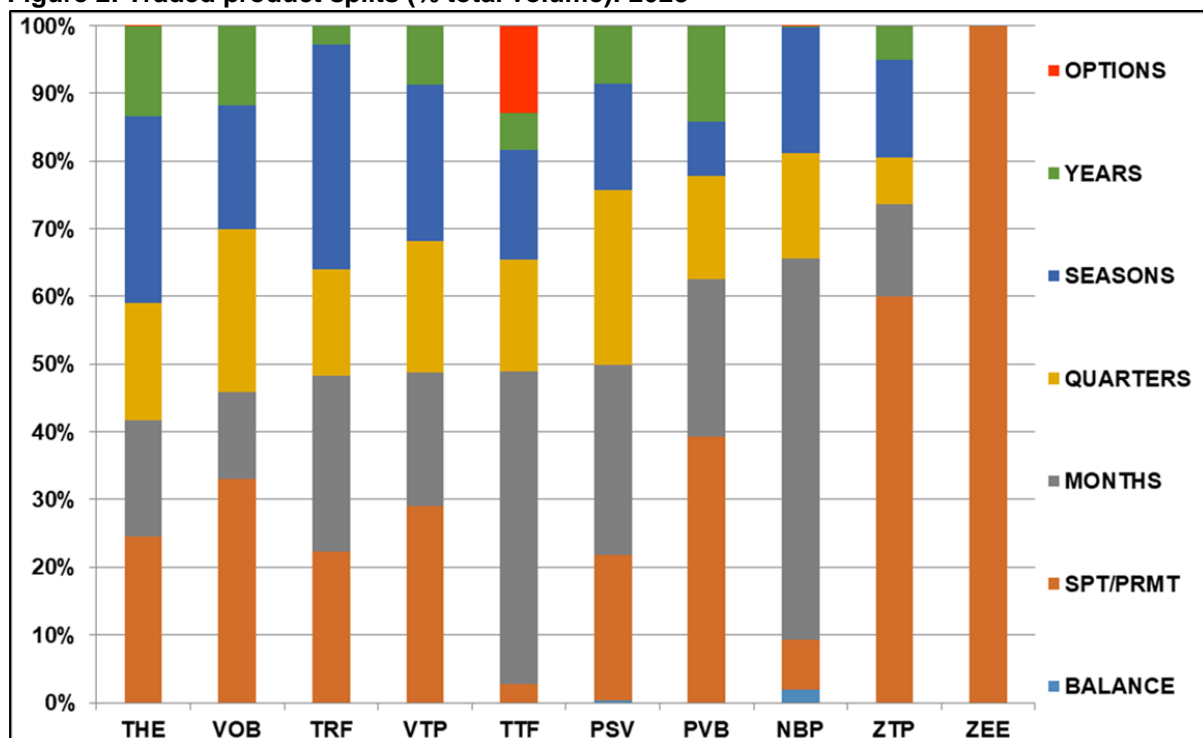


At a glance, it can be observed that in 2023, TTF is yet again top with a score of 49/56, the same as it has had for the last three years. Most of the individual products categories are shown as 'green', meaning that the OTC volume of that product is greater than 600TWh, and greater than 500TWh for the exchange volumes.

All of the remaining hubs stay in the same colour band as they have been since 2020; four hubs (NBP, THE, TRF, PSV) have a higher score in 2023 compared to the previous year, three hubs have a lower score (VTP, ZTP, ZEE), and two hubs remain the same (PVB, VOB).

This year the top five hubs (TTF, NBP, THE, TRF, PSV) have a score higher than the mean, with the VTP just below that number. The Spanish, Belgian ZTP, and Czech hubs are much lower and the Belgian ZEE had a score of just 4/56, reflecting the fact that it only traded spot products ahead of it ceasing to trade.

Figure 2: Traded product splits (% total volume): 2023



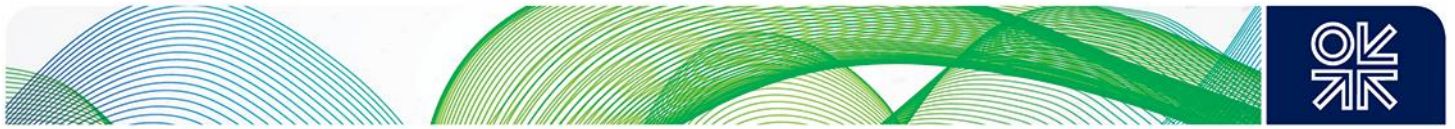
Sources: OTC: LEBA, ICIS; Exchange: ICE, ICE-Endex, EEX, CME, CEGH, GME; MIBGAS; P. Heather

There are some interesting product splits across the hubs, as shown in Figure 2, but it must be remembered that this figure shows the percentage split at each hub, not the actual volumes which need to be considered alongside the splits to be more meaningful.

Just two of the hubs saw a decrease in the proportion of spot/prompt/month trades compared to 2022: the Czech VOB from 69% to 46%, while the German THE saw a small decline from 48% to 42%. Three of the hubs saw an increase in the proportion of spot/prompt/months compared to 2022: the Belgian ZTP from 67% to 73%, the British NBP from 58% to 66% and the Belgian ZEE went to 100% ahead of it ceasing to trade at the end of Q3-2023. The remainder of the hubs had similar splits to the previous year.

However, when looking at the actual volumes traded, the result could appear rather different. For example, whereas the French TRF and German THE recorded the highest percentages of Seasons³⁵,

³⁵ 33.17% and 27.60% respectively, the highest percentages of all the hubs in this product.



as shown in Figure 2, the absolute volumes traded in the Seasons at the TRF was just 556TWh and at the THE was 1024TWh. By contrast, the Dutch TTF recorded a much lower percentage³⁶ of Seasons trading, but the actual traded volume was 10514TWh, some 10 times that of THE, and 19 times that of TRF.

Similarly, when looking at the Quarters, the Italian PSV recorded the highest percentage, followed by the Czech VOB, with the TTF recording the 5th highest percentage, as also shown in Figure 2. The absolute traded volumes however paint a different picture: TTF traded a total of 10735TWh, some 32 times that of PSV, and a massive 488 times that of VOB.³⁷

In the Years, TTF traded 3543TWh, some 4.4 times more than all the other hubs put together, despite in percentage terms the Spanish PVB, the German THE, the Czech VOB, the Austrian VTP, and the Italian PSV all recording higher splits than TTF.

Finally only three hubs, the Dutch TTF, the British NBP and for the first time the German THE recorded exchange financial options trading in 2023; the volumes were significantly higher than in 2022. The options contracts are listed on the ICE exchange and totalled 8406TWh on TTF, 6.9TWh on NBP and just 0.03TWh on THE, representing 14.73%, 0.15%, and 0% respectively of exchange trading.³⁸ In fact, there were more TTF options traded than the total trades at all of the Continental European hubs put together.³⁹

It is clear from the traded products table and the product splits that the Dutch TTF is the 'mature' risk management hub, with large volumes of MA reflecting LTC hedging, and large volumes of curve products reflecting portfolio risk management, including a large volume of options traded.

High absolute traded volumes are usually indicative of a liquid market with a large number and varied range of participants; depending on the size of the underlying physical market, this will likely also indicate a large churn rate. In Table 4, mature hubs are shown in green; the active hubs, with developing depth, liquidity and transparency in amber; the poor hubs, which cannot yet be considered as deep, transparent or liquid, in red; and the illiquid hubs in Brown.

Even from a summary glance at Table 4, it is evident that the Dutch TTF hub has by far the largest traded volumes, including as described above in all products across the whole curve. Despite having eased back in 2022, trading increased by 51% in 2023, which was the largest increase of any hub last year. As with the French hub, this is also partly due to the ever increasing levels of LNG imports⁴⁰ into the Netherlands. The TTF volumes are now over four times greater than all of the other hubs put together; they are over 10 times greater than the next most traded hub, the British NBP; over 17 times greater than the German THE hub, in Europe's largest gas consuming country; and nearly 40 times greater than the French TRF.

The Belgian ZTP hub had a phenomenal 138% increase in its traded volumes in 2022 but, in 2023, the volumes eased back by 16%, the second largest drop after the Belgian ZEE hub, which ceased trading in September 2023. There was a minor 2% fall in volumes at the British NBP, whereas all the other hubs improved to a greater or lesser extent.

³⁶ 16.18%.

³⁷ 331TWh and 22TWh respectively.

³⁸ Equivalent to 12.93%, 0.11%, and 0% respectively of total exchange and OTC trading.

³⁹ 8406TWh versus 8258TWh.

⁴⁰ A rise of 31% yr/yr, the only country of the five main LNG importers surveyed (see Chapter 4) to have had an increase.



Table 4:⁴¹ Key Element 3: Traded volumes: 2023

2023		TOTAL TRADED VOLUMES* (TWh)						
HUB		2008	2011	2021	Δ% =>	2022	Δ% =>	2023
TTF		560	6295	53430	-19	43135	+51	64980
NBP		10620	18000	6640	-5	6335	-2	6185
NCG	THE	EST.215	880	3155	+5	3305	+12	3710
GPL		EST.145	310					
TRF		PEG N 185	PEG N 430	855	+66	1415	+18	1675
PSV		160	185	1155	-19	940	+33	1275
VTP		CEGH 165	CEGH 170	920	-25	685	+0.5	690
ZTP		n/a	n/a	235	+138	560	-16	470
PVB		n/a	n/a	170	+61	260	+29	335
VOB		n/a	n/a	95	-5	90	+3	90
ZEE		500	870	80	-56	35	-86	5

*rounded to nearest 5TWh; not the same data sources in all years.

Sources: 2008: converted from bcm in IEA 2009 Natural Gas Review, p.30;
 2011: LEBA, ICIS, ICE, ICE-Endex, EEX, Powernext, CEGH, GME; P. Heather
 2021-2023: LEBA, ICIS, ICE, ICE-Endex, EEX, CME, CEGH, GME; MIBGAS; P. Heather

The figure clearly shows the wide variations between the European hubs with TTF firmly set at the top; the long gradual decline of NBP since 2016 (although still the second largest hub in Europe); the more or less steady performance of the German NCG through to 2021, with the GPL volumes adding to the increase in the merged THE volumes after October 2021; the slow but sure rise in the Italian PSV, despite a slight setback from 2020 to 2022; the slow but sure rise at the Austrian VTP, albeit from a much lower level, and also topping out since 2020; and the rather erratic performance of the French PEG Nord/TRF, before the increase seen in 2022 and 2023. France however remains behind Germany, and by about the same margin.

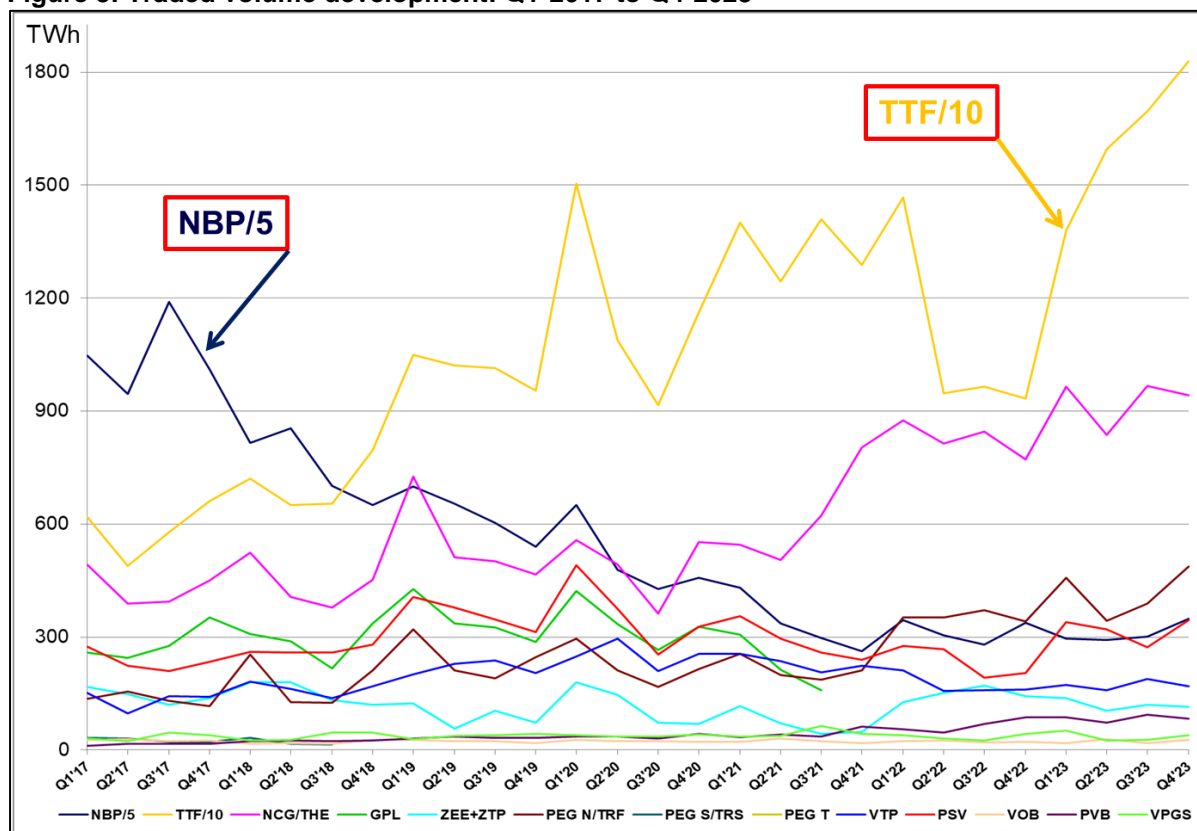
Finally in this section on traded volumes, Table 5 shows the total traded volumes at the 'emerging' hubs although, as can be seen in the second column, some of these have actually been operational for quite some years. The author has previously commented⁴² on the particular circumstances regarding the Polish VP GS and the Danish GTF/ETF hubs. At the VP GS in particular, although the total volumes there were a little higher in 2023, these are predominantly volumes traded between the incumbent supplier PGNiG and its distribution and retail subsidiaries; there were no OTC trades reported. Danish OTC (GTF) trades are primarily conducted by shippers adjusting or balancing their portfolios and none were recorded; at the exchange ETF there was no curve trading at all and again, the spot trading is primarily balancing operations, recording higher volumes likely on the back of the completion of the Baltic Pipe project.

⁴¹ The methodology used in this table is: (Volumes) Green: ≥5000; Amber: <5000; Red: <1000; Brown: <100TWh.

⁴² In particular, see: Heather (2015), Chapter 5.5.2.3 "Poland", pp. 44-46; also Heather (2019), paras. 5-6, p.16; and Chapter on "Emerging Hubs", pp. 18-19.



Figure 3: Traded volume development: Q1-2017 to Q4-2023



Sources: OTC: LEBA, ICIS; Exchange: ICE, ICE-Endex, EEX, CME, GME, MIBGAS, TGE; P. Heather

All of the hubs in the table had increased volumes in 2023, with the exception of the Romanian PVT, which fell for the second year in a row, by 40%⁴³ following the introduction in 2022 of a punitive 98% tax on wholesale electricity and gas transactions.⁴⁴ Of the remaining hubs in this table, the newly operational Portuguese PVN hub is still firmly at the bottom of the table but the very small volumes did rise slightly⁴⁵ in its second year of trading. The Greek gas hub showed strong growth in 2023, albeit from a very low first year start,⁴⁶ increasing threefold year-on-year to a total of 9.03TWh; however, there were still no OTC trades reported. The Slovakian SVOB is the only emerging hub to only trade OTC, and its volumes increased 148%, from 4.05TWh in 2022. Another strong increase was that of the Bulgarian VTT hub recording an increase of 225%, from 14.01TWh in 2022.

A major change in the traded gas markets over the past few years, and especially since 2021, has been the move away from OTC trading towards more exchange trading.⁴⁷ Figure 4 shows the relative shares of both OTC and exchange volumes at all of the main hubs listed in Table 4, and all but PVN shown in Table 5. The share of exchange trading now dominates and in 2023 attained a share of 82% of total European trades. Some of the emerging hubs do not have any OTC trading at all,⁴⁸ nor has Poland for a few years now; Denmark used to trade OTC but had no trades in 2023. The Hungarian MGP recorded a very small quantity of OTC trades.⁴⁹

⁴³ PVT traded volumes in 2022 were 30.79TWh.

⁴⁴ For more information, see Heather (2023), p.12, para. 2.

⁴⁵ PVN traded volumes in 2022 were just 0.06TWh.

⁴⁶ HTP traded volumes in 2022 were 2.87TWh.

⁴⁷ The shares of exchange trading went from 52% in 2020, to 65% in 2021, and to 77% in 2022.

⁴⁸ VTT, Baltic-Fi, HTP, PVT, and PVN.

⁴⁹ MGP OTC volumes in 2023 were just 0.249TWh.



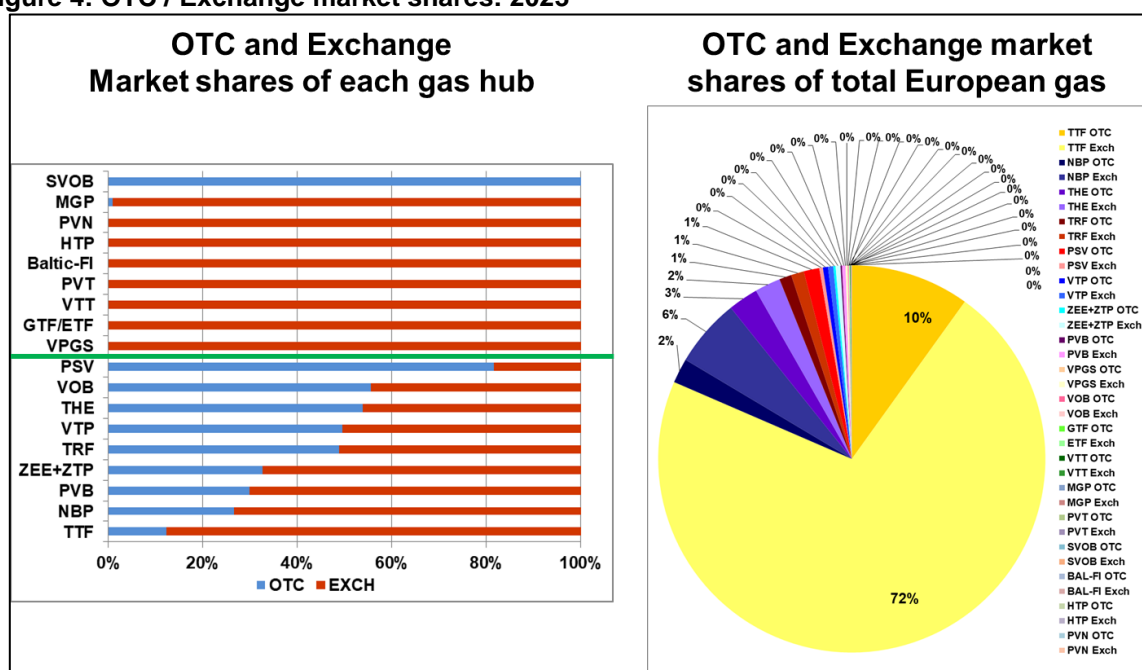
Table 5:⁵⁰ Traded volumes - emerging hubs: 2023

2023	HUB	Started	EMERGING HUBS TRADED VOLUMES (TWh)				
			OTC			EXCHANGE	
			PRMT	CURVE	TOTAL	SPOT	TOTAL
	VPGS	2014	No activity reported			20.75	143.62
	GTF/ETF	2004/08	No activity reported			52.78	52.78
	VTT	2020	No activity reported			14.98	45.50
	MGP	2010	n/a	n/a	0.25	29.66	29.71
	PVT [^]	2020	No activity reported			11.80	17.77
	SVOB	2016	n/a	n/a	10.05	no exchange trading	
	Baltic-FI [*]	2012-20	No activity reported			8.36	9.10
	HTP ^{**}	2018	No activity reported			9.03	9.03
	PVN	2021	No activity reported			Only WD,DA,ID	

[^]total physical trades transacted on the Romanian Commodity Exchange (BRM) but not necessarily conducted at the PVT.
^{*}the Baltic-Finland market area, as defined by the GET Baltic exchange, being the sum of the LT/LV-EE/FI Market Areas.
^{**}HEEnEx's Gas Trading Platform finally went live 21st March 2022; prior to this, all trades were 'balancing trades' on the Desfa platform.

Sources: ICIS, EEX, TGE, CEEGEX, HUDEX, BGH, GET Baltic, BRM, MIBGAS, HEEnEx; P. Heather

Figure 4: OTC / Exchange market shares: 2023



Sources: LEBA, ICIS, ICE, ICE-Endex, EEX, CME, GME; MIBGAS, TGE; HUDEX, CEEGEX, BGH, BRM, HEEnEx; P. Heather

⁵⁰ The methodology used in this table is: (Volumes) Green: ≥5000; Amber: <5000; Red: <1000; Brown: <100TWh.



When looking at individual hubs, the share of exchange trading is highest at TTF, NBP, and PVB,⁵¹ but still low at PSV.⁵² The remaining five hubs⁵³ are between 44% and 67%. The Slovak SVOB is the only hub without any exchange trading.

When looking at the pie chart on the right of Figure 4, it is very clear visually to see the dominance of TTF; as well as TTF accounting for 81.5% of all European gas trading, it accounts for 56% of OTC trading, and 81% of exchange trading. The total traded volumes from the top four hubs and the breakdown into the OTC and exchange volumes, along with the respective percentage shares are shown in Table 6.

Table 6:⁵⁴ Top 4 Hubs Total Traded, OTC, and Exchange volumes and shares: 2023

2023	TOP 4 HUBS TRADED VOLUMES AND OTC/EXCH SHARES					
HUB	Total Volume TWh	Share %	OTC Volume TWh	Share %	EXCH Volume TWh	Share %
TTF	64,982	81.49	7,913	56.25	57,069	86.90
NBP	6,185	7.76	1,642	11.67	4,543	6.92
THE	3,711	4.65	1,999	14.21	1,711	2.61
TRF	1,675	2.10	818	5.81	857	1.31

Sources: compiled by the Author from data behind other Tables and Figures; P. Heather

When adding the share of the top four hubs, TTF, NBP, THE and TRF, they together account for 96% of total European gas trading, made up of a total 88% of OTC trading, and 98% of exchange trading. These data clearly show how much bigger the TTF is compared to even its nearest rivals, with the fourth placed French TRF only registering 2.1% market share.

Moving on to Key Element 4, the author does not place much emphasis on the Tradability Index⁵⁵ but has always included it in the analysis of the hubs because it is sometimes quoted in various reports; it is not very meaningful as it does not record the depth of a market, only the bid/offer spread and must therefore be read alongside the other metrics.

Following a collapse in most hubs' scores in 2021, and remaining mostly low in 2022, all but 7 hubs recovered in 2023 but by only 1 point. Of the others, 3 hubs fell⁵⁶ and 4 remained the same.⁵⁷

Although this metric doesn't show the depth of a market, there is no doubt from the results that the Dutch TTF is far ahead of all the other hubs with a near 'perfect' score of 19/20, indicating that there are tight bid-offer spreads in all but one contract.⁵⁸

⁵¹ 88%, 73%, and 70% respectively.

⁵² 18.5%.

⁵³ VOB 44%, THE 46%, TRF 51%, VTP 51%, and ZEE+ZTP 67%.

⁵⁴ The methodology used in this table is: (Volumes Tw) Green: ≥ 5000 ; Amber: < 5000 ; Red: < 1000 ; Brown: < 100 TWh; (Shares %) Green: ≥ 25 ; Amber: < 25 ; Red: < 15 ; Brown: < 5 %.

⁵⁵ This is calculated by ICIS for 13 European hubs plus the Turkish UDN. The methodology consists of assessing the "bid-offer spread typically available every day to all interested counterparties", on 10 different contracts and for two bid-offer points of ≤ 0.5 €/MWh and ≤ 0.3 €/MWh, and then attributing 1 point if available, giving a score out of a maximum 20 points.

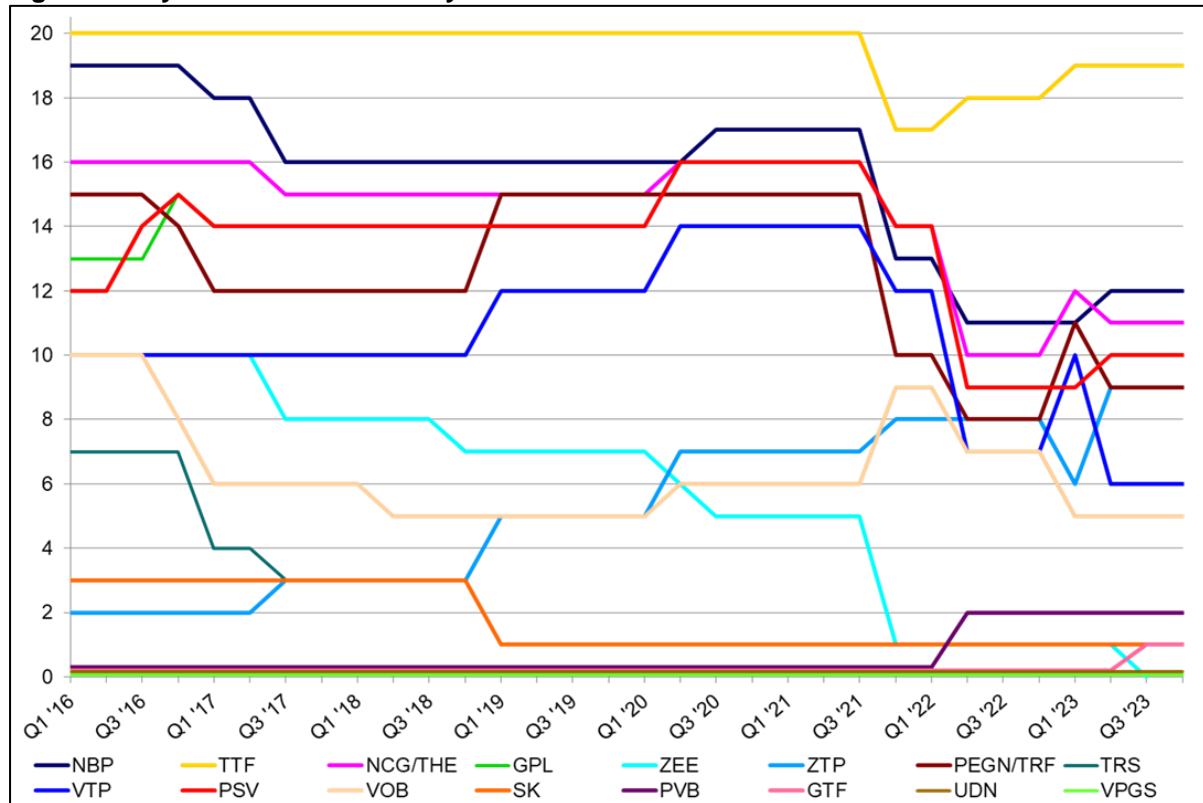
⁵⁶ VTP down 1 point, VOB down 2 points, and ZEE down from 1/20 to zero as it ceased trading.

⁵⁷ SVOB and GTF at 1/20, UDN and VPGS at zero.

⁵⁸ According to the ICIS European Gas Hub Report, Q4-2023, p.8, the only contract to not have a bid-offer spread of less than ≤ 0.3 €/MWh was the Balance of Month.



Figure 5: Key Element 4: Tradability Index: 2023



Sources: ICIS European Gas Hub Reports 2016-2023; P. Heather

Another important metric is Key Element 5, the traded gas hubs churn rate.⁵⁹ In this one metric all others are, necessarily, reflected: if there are many participants, trading many different products in large quantities, then the churn rate is likely to be high. The churn rate is used by traders as a 'snapshot' of a market's liquidity; some traders will not participate in markets with a churn of less than 10 and many financial players will only participate when the churn is above 12. In his analysis the author has determined that a hub is 'mature' when the churn rate is 10 times or more.

Since 2020 the author has calculated and shown both the hubs' net⁶⁰ market churn rates for the last three years as well as the gross⁶¹ churn. Using a net churn methodology can be appropriate in the early stages of the development of a hub, as it is initially more focused on the Market Area (in most cases, national) balancing requirements. However, to judge the growing liquidity and maturity of a hub, as it trades further down the curve and attracts risk management volumes, the gross churn methodology is more accurate as it shows a given hub's ability to be a pricing benchmark beyond its own market area. This is because there are many various reasons for the amount of trading effected at a given hub: trading of actual physical gas or trading to hedge and risk manage gas, both destined for consumption in that hub area; but also, trading in relation to quantities of gas destined for export to neighbouring market areas.

Table 7 shows the net and gross churn rates for the 10 main hubs⁶² studied in this paper. The results for 2023 show that there is only one European benchmark hub, the Dutch TTF standing far ahead of all the others and the only hub considered as 'mature', and one regional Sterling marker price, the British

⁵⁹ For an explanation, see: Heather (July 2019), p 11.

⁶⁰ The net churn is the total traded volumes at a given hub, divided by its consumption, as defined and used by the EU.

⁶¹ The gross churn is the total traded volumes at a given hub, divided by its physical demand or throughput.

⁶² With the two Belgian hubs together, using total physical data for Belgium as a whole, as it is very difficult to get accurate physical data for the ZEE area alone. The 2023 figure is for ZTP alone.



NBP. Although no longer⁶³ considered a 'mature' hub, the NBP is nevertheless still the only hub in the 'active' category in terms of gross churn. The only other hub that in 2023 got close to the author's threshold of 5 times for 'active' hubs, is the Austrian VTP (and on a net churn basis its score is a quite high 9.3); the German THE and French TRF hubs both improved but are firmly in the 'poor' category, in both gross and net churn results. The Italian PSV improved to 1.9 but this is only coming back to where it was in 2020, the Czech VOB saw large increase in its gross churn but this is due to the large fall in 'transit' gas rather than an increase in traded volumes; the remaining hubs are under 1 times churn making them 'illiquid'.

Table 7:⁶⁴ Key Element 5: Churn rates 2022

2023	TRADED GAS HUBS CHURN RATES					
	Net Churn* basis			Gross Churn** basis		
HUB	2021	2022	2023	2021	2022	2023
TTF	136.7	142.1	223.8	67.5	63.0	100.9
NBP	8.0	8.2	8.9	7.3	6.1	7.1
VTP	9.3	8.0	9.3	1.9	2.4	4.2
THE	3.2	3.9	4.6	1.8	2.4	3.6
TRF	1.9	3.4	4.7	1.6	2.4	3.2
PSV	1.4	1.3	2.0	1.4	1.2	1.9
VOB	0.9	1.1	1.3	0.2	0.3	1.1
ZEE+ZTP [^]	1.6	3.6	3.1	0.7	0.9	0.9
PVB	0.5	0.7	1.0	0.4	0.6	0.8

* Total traded volume / Consumption in hub area.
 ** Total traded volume / Demand in hub area (= Total Physical Throughput = Consumption + Exports).
[^] Physical volumes are for Belgium as a whole; 2023 figure is for ZTP.

Sources: 2021-2023: LEBA, ICIS, ICE, ICE-Endex, PEGAS, EEX, CME, CEGH, GME; MIBGAS; P. Heather

The author has heard it said that it is not realistic to place such emphasis on the TTF churn, as the Netherlands has relatively low gas consumption. This is indeed true and, if using the EU definition of churn, using the physical consumption as the denominator, the churn is a staggering 224 times; the author agrees that this figure is meaningless. He further agrees that even using the physical demand as the denominator could be seen as unrealistic but, if you compare that demand figure to that of Germany, it is under two thirds.⁶⁵ That would imply that, if both country's traded gas markets were similarly 'mature', then the TTF gross churn would be about one and a half times that of the German gross churn. In fact, the Dutch TTF gross churn is over 28 times greater than that of the German THE hub.

To try to achieve a more realistic indication of the TTF's gross churn, and the real maturity, importance, and relevance of this hub as a benchmark, or reference price for physical contracts beyond its national

⁶³ The NBP gross churn in 2020 was 11.2, the last year that it was considered as 'mature'.

⁶⁴ The methodology used in this table is: Green: ≥ 10 ; Amber: < 10 ; Red: < 5 ; Brown: < 1

⁶⁵ Physical demand in the Netherlands in 2022 was 644.34TWh; for Germany it was 1028.20TWh. Source: JODI Gas World.



borders, the Author has since 2019 calculated the churn rates for the global benchmarks.⁶⁶ In those calculations, the TTF's churn rate using the physical consumption data from the surrounding countries⁶⁷ comes out at an impressive, mature and indeed liquid, 36.8 times. There is no doubt in the author's mind that TTF is a reliable benchmark that can and does in practice, offer accurate price signals of the gas flowing in the (north-west) European gas grids, that is used by shippers from many European countries to price physical contracts, and to hedge their portfolio exposures.

4. The LNG effect on trading activity in 2023

In the author's paper covering the results of 2022 trading, he concluded there was indeed an 'LNG effect' on traded volumes at those hubs that saw large volumes of extra LNG being imported; namely, Belgium (ZTP), France (TRF) and Spain (PVB).

From all the above analysis of the 5 Key Elements for 2023, and the summary table 9 below, the results are less clear than for 2022. However, there was a large increase in traded volumes and churn rate at the Dutch TTF and the Netherlands was the only country⁶⁸ with an increase in LNG sendout in 2023 compared to 2022.

The relative changes are shown in Figure 6, which shows the LNG sendout volumes in the five European countries which recorded the greatest increases from 2021 to 2022 when Europe was 'crying out' for additional gas supplies to replace the dramatically reduced Russian pipeline volumes. These additional volumes, many signed under new supply contracts, as well as a number of spot cargoes diverted from other destinations in order to profit from high European gas prices, initially went to those countries with established LNG import terminals.

However, when looking at the relative changes in sendout over the past two years, 2023 compared to 2021, all five countries saw an increase from between +31% in the UK and Spain, to an impressive +182% in the Netherlands. The detailed changes for each country and the associated absolute volumes are shown in Table 8.

Although deliveries and sendout volumes in 2023 were almost unchanged in Belgium and lower in three of those five countries, with the exception being the Netherlands, these extra LNG volumes helped sustain or even increase trading volumes in those countries, through the need of both LNG suppliers and gas buyers to actually sell most⁶⁹ of the liquefied LNG into the hub and buy the gas from the hub. This would be the case regardless of contractual pricing terms: an LNG contract into France could still have, say, TTF as a reference marker price, which would entail extra risk management trading at the TTF hub, as well as potentially extra trading at the TRF hub.

Table 8: Relative sendout volumes in BE,FR, NL,UK,ES, and percentage changes: 2021/2023

GWh	BE	FR	NL	UK	ES
2021	44,064	182,063	81,839	154,760	189,369
2023	119,988	313,097	230,590	203,390	247,576
2023/2021	172%	72%	182%	31%	31%

Sources : Kpler; J. Sharples, P. Heather

⁶⁶ See Chapter 8 for more detail.

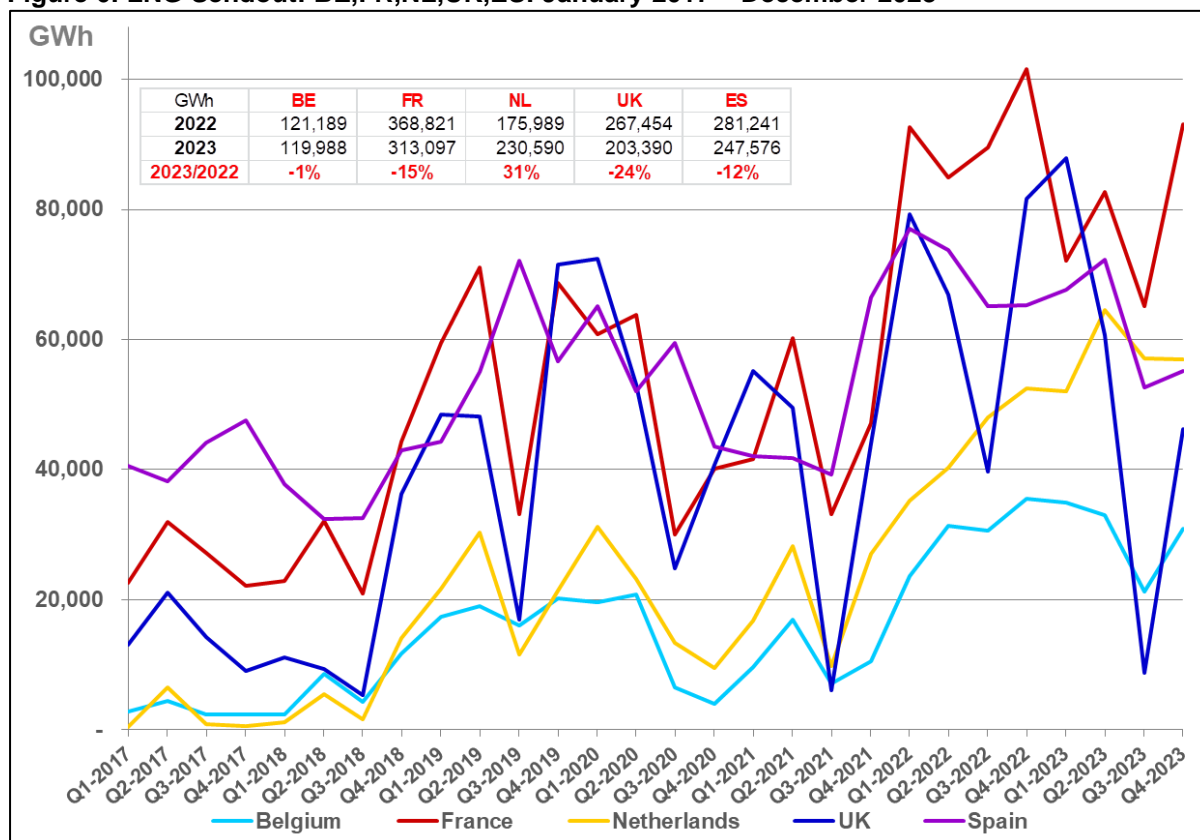
⁶⁷ The countries used in the analysis are France, BeNeLux, Germany, Austria, and the Czech Republic.

⁶⁸ Of the five surveyed: NL, UK, FR, BE, ES.

⁶⁹ However, if the importer is a portfolio player/aggregator, it would simply bring the liquefied gas into its portfolio, without the need for an explicit sell/buy trade at the national hub.



Figure 6: LNG Sendout: BE,FR,NL,UK,ES: January 2017 – December 2023



Sources : Kpler; J. Sharples, P. Heather

As can be seen in Figure 6, the sendout volumes in all five countries were quite erratic during 2023. The UK had a massive drop in Q2 and Q3, only to retrace about half the fall in Q4; the Belgian volumes also fell in Q2 and Q3 before recovering in Q4; however, in France, Spain, and the Netherlands there was initially a rise in Q2, a greater fall in Q3 (except in the Netherlands which had a lesser set back), before having in Q4 a sharp recovery in France, a slight recovery in Spain and staying about the same in the Netherlands.

The additional sendout volumes throughout the year in the Netherlands, and in the last quarter in the four other countries, must have had a positive impact on the total traded volumes at the respective national hubs. They would also therefore account for some of the significant increase in traded volumes at the TTF, the sustained volumes at NBP in a market that has seen gradual decline over the past 6 years, and the smaller increase in traded volumes at the TRF and PVB.

Figure 6 additionally shows that in Q123, the LNG sendout volumes in Britain and Spain continued to increase, whereas in the Netherlands and Belgium there was a slight dip and in France there was a sharp decline from 2022 levels. This was primarily due to the ongoing strikes in France against pension reforms which brought the terminals, among other parts of the economy, to a standstill.⁷⁰ Many cargoes were diverted to other terminals in the UK, Belgium, or further afield.

Since the massive rise in hub prices and the need to continue the move away from Russian gas, there have been many projects⁷¹ to bring more gas into Europe, including a number of new LNG terminals

⁷⁰ For more detail, see: Platts, 2th March 2023, "European LNG cargo glut looms amid French strike action": <https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/lng/032823-european-lng-cargo-glut-looms-amid-french-strike-action>

⁷¹ For more detail, see Heather (2023), Chapter 4, p. 18.



and FSRUs⁷² in particular in the Netherlands and Germany. Many of these projects have already been delivered and more will be during the course of 2024, especially in Germany; as the author predicted in last year's paper, this has already led to greater traded volumes at the Dutch and German hubs.

5. A summary of traded gas hubs in 2023

Table 9 summarises the 5 Key Elements in 2023 for the 9⁷³ main traded gas hubs in Europe. The combination of each of the Key Elements and their respective scores is what determines the overall rankings of the hubs, as can be easily observed by the colour coding, used in the table and in Map 1.

Table 9:⁷⁴ Summary of the 5 Key Elements 2023

2023	5 KEY ELEMENTS					
HUB	Active Market Participants*	Traded Products**	Traded Volumes	Tradability Index (Q4)	Churn Rate***	Score /15****
TTF	200	49	64980	19	100.9	15
NBP	135	40	6185	12	7.1	11
THE	90	35	3710	11	3.6	8
TRF	75	26	1675	9	3.2	8
PSV	58	25	1275	10	1.9	8
VTP	68	21	690	6	4.2	7
ZTP	55	14	470	9	0.9	5
PVB	46	15	335	1	0.8	4
VOB	44	12	90	5	1.1	4

* Hub Score in the OTC Active Traders table.
 ** Score /56 derived from the OTC and Exchange product categories in the Traded Products Table.
 *** Gross churn basis.
 **** Score based on each of the Key Elements scoring zero for Brown; 1 point for Red; 2 points for Amber; 3 points for Green.

Source: Calculated from previous tables

TTF is now the only Mature 'tier one' hub, scoring a maximum 15/15. All the 5 Key Elements are shown as green and all of those results are the best/highest of all the hubs.

NBP went from Mature to an Active 'tier two' hub in 2021 and has remained there since. This is due to a fall in its Tradability Index score and, especially, a lower churn rate from 11.2 in 2020, to 7.1 in 2023.

There are three more 'active' hubs, all scoring 8/15. The German THE and French TRF both eased back one point from 9/15 in 2022. The last 'active' hub, the Italian PSV moved up one point to move from a 'poor' hub in 2022; last year the Austrian VTP scored 8/15 but that moved down one point in 2023 to 7/15.

The remaining three 'poor' hubs are the Belgian ZTP, down one point to 4/15, and the Spanish PVB and Czech VOB, both also on 4/15 as they were in 2022.

Having examined each of the 5 Key Elements in detail it is clear that the Dutch TTF is far and away the leading European traded gas hub, used by many more market participants than any other hub, has a

⁷² Floating Storage and Regasification Units.

⁷³ Now that ZEE has ceased trading it is no longer included in this summary table.

⁷⁴ The methodologies used in this table are: (Tradability Index): Green: ≥ 18 ; Amber: ≥ 16 ; Red: < 16 ; Brown < 5 ; (Hub rankings): Green/Mature: 12-15 Orange/Active: 8-11 Amber/Poor: 4-7 Red/Inactive: 1-3.



very high traded products score, with far greater total traded volumes than all the other put together: TTF also accounts for 81.5% of all European gas trading, for 56% of all OTC trading, and 87% of all exchange trading. TTF also has the highest Tradability Index score, only missing one point on one of the 'balance of month' contracts, and finally, by far the greatest churn rate.

6. The 3 Main Indicators

There are 3 Main Indicators⁷⁵ that reveal the level of liberalisation and market development of traded gas hubs: the political will to create the necessary framework to get the process off the ground; the cultural attitudes to trading and change that drive success in a trading environment; and these in turn dictate the level of commercial acceptance needed to allow the market to grow organically.

These 3 Main Indicators are the basis of creating successful traded gas markets. They are somewhat subjective but are essential to allowing a traded gas market to develop. They do not however in themselves guarantee that a market will succeed and become mature.

The European Federation of Energy Traders (EFET) has been publishing a Gas Hub Development Study since 2014 and this is a good proxy for evaluating the three Main Indicators across all countries, as it assesses 5 regulatory conditions, 6 TSO conditions and 7 market conditions. Initially it surveyed the so-called 'established' hubs plus a few newly-formed but not yet necessarily trading 'emerging' hubs. In 2017, they added Ukraine; in 2018 they added Portugal and removed the Belgian ZEE.

EFET stopped assessing the so-called 'established' older NW European hubs in 2019, and decided to focus on the 'emerging' hubs as well as adding Croatia and Slovenia to the countries surveyed, adding the Irish IBP in 2020. No study was published in 2020 and, for 2021, EFET refined the hub scoring criteria in order to better reflect these hubs and their particular difficulties in establishing themselves and/or developing trading. In particular, it was decided to remove from the criteria the measure of volumes of trades in the longer term products which was no longer useful since the study focussed on the less mature markets. It was replaced with an assessment of market interference. Where an authority imposes conditions or obligations which constitute a barrier to entry or trade, then a lower score is given.

EFET did not publish a Study in 2022 but, in 2023 they added Moldova and Serbia, so that the Study now covers 18 hubs, all 'emerging'.

The results of the 2023 Study are given in Table 10, enhanced by a four colour coding.⁷⁶ The Table shows that these 'emerging' hubs have mostly been steadily improving with, in the last year compared to 2021, eight hubs improving further, six remaining the same, and two falling: the Turkish UDN and the Bulgarian VTT.

The following comments are taken from the EFET Press Release⁷⁷ for the 2023 Study. The biggest improvers were Greece, where balancing has improved and the exchange is more established, and Ireland where EFET recognised better market-based balancing and where the index is increasingly referenced. There were also improvements in the Baltic states, attributable to transparency and balancing, especially in Lithuania thanks to the gas release programme. Slovenia has nudged ahead of Croatia in terms of market design, though Croatia is more widely traded. Poland sees a technical increase in the score, though trading remains challenging.

⁷⁵ See Heather (2015) for a full description of the 3 Main Indicators. This Paper gives the situation in 2023.

⁷⁶ The methodology for the rankings is: Mature/Green: =>18; Active/Orange: <18; Poor/Amber: <15; Inactive/Red: <9. However, this methodology was established when the Study covered the 'established' hubs so that this year the table only has countries/hubs in the bottom two categories.

⁷⁷ <https://www.efet.org/files/documents/231106%20GC%20PR%20Hub%20Scores%202023.pdf>.



Table 10: EFET Hub scores categorised as mature, active, poor and inactive: 2014–2022

HUB	Score 2016	Score 2017	Score 2018	Score 2019	Score 2020	Score 2021	Score 2023
MGP	9	12½	11½	12½	13½	14	14
IBP	n/a	n/a	n/a	n/a	9½	12	14
HTP	5½	6½	8½	10	10½	12	13½
Lithuania	n/a	n/a	n/a	n/a	8½	11	13
Finland	n/a	n/a	n/a	n/a	9	11½	12½
Estonia	n/a	n/a	n/a	n/a	8½	11½	12½
Latvia	n/a	n/a	n/a	n/a	8	11½	12½
SVOB	8	8½	9½	10	10½	12	12
Ukraine	n/a	3½	3½	7	9	11	11
VPGS	9½	10	9½	9½	10	10½	11
Slovenia	n/a	n/a	n/a	6	6½	9½	10
Croatia	n/a	n/a	n/a	7½	8	9½	9½
Portugal	n/a	n/a	4½	5½	5½	9½	9½
UDN	4	5½	6	9½	10½	11½	9
Romania	2	3	3	4½	6½	8½	8½
Bulgaria	1½	1	4½	5	7½	9	7½
Moldova	n/a	n/a	n/a	n/a	n/a	n/a	3½
Serbia	n/a	n/a	n/a	n/a	n/a	n/a	3½

Source: 2020 EFET Review of Gas Hubs Assessments; 2022 scores derived from discussions; P. Heather

Of those countries remaining unchanged, Ukraine has preserved its trading despite the challenges it faces and Hungary remains constant at equal top of the table, but below the level at which EFET would describe the hub as mature. Lower down the table, progress is stalled in Slovakia and Romania.

Scores are reduced in Turkey where transparency has become worse and trading activity more difficult, and in Bulgaria where, despite recognised improvements in transparency and progress in establishing the exchange, balancing is less market-based, trading obligations are more onerous, and market intervention exacerbates concentration issues rather than facilitates competition and liquidity.

Moldova and Serbia have been added, but scores indicate still only a basic hub design, reflecting part-implementation of EU rules, rather than genuine reform that will lead to wholesale trading.

7. Long term market trends

As well as reviewing the European traded gas hubs data for 2023, this paper seeks to review the longer term trends to see whether or not the traded gas markets have continued to trade erratically into 2023, or whether there is an emerging pattern to suggest that they have ‘rebalanced’.

This chapter will therefore focus on the ‘established’ hubs (selected hubs)⁷⁸ and review the longer term traded volumes development, as well as the relative spreads between the main trading ‘pairs’ of hubs, and in particular the French TRF to Dutch TTF spread as this was the one that widened the most in

⁷⁸ British NBP, Dutch TTF, German NCG/THE, Belgian ZEE/ZTP, French TRF, Austrian VTP, and Italian PSV.



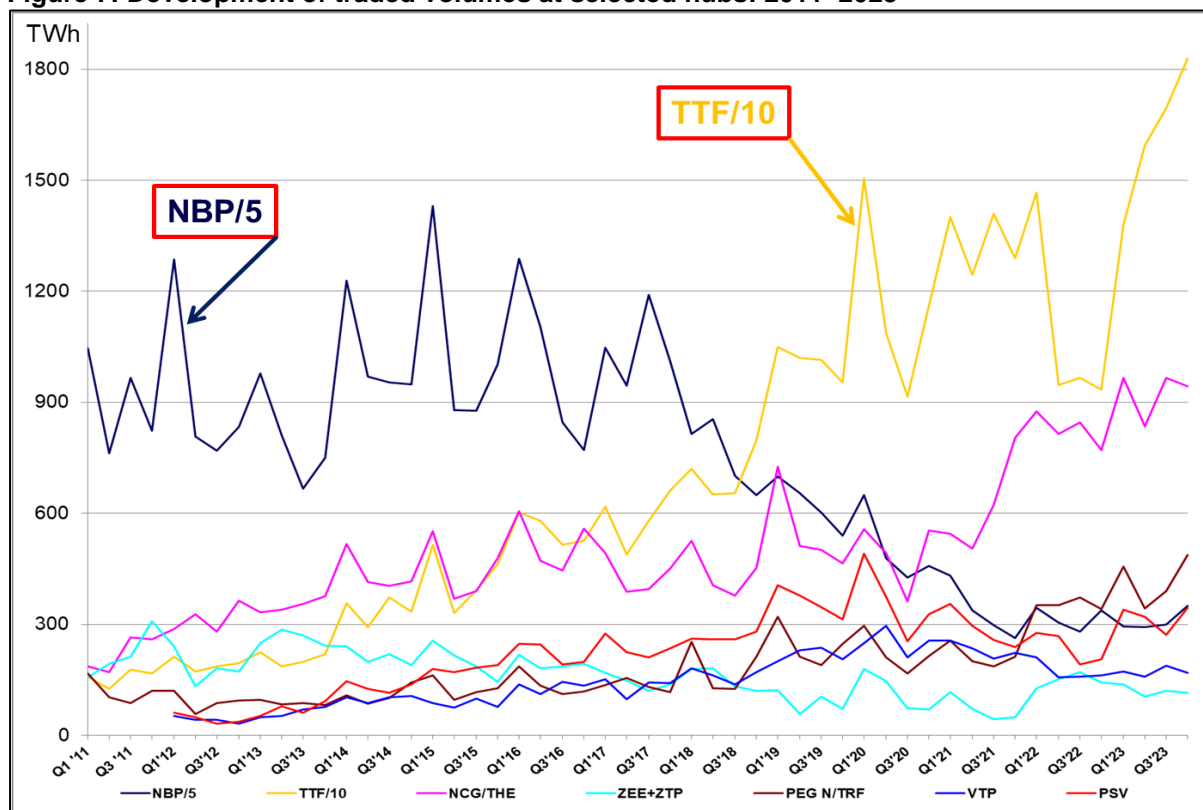
2022. It will furthermore review the overall price correlation and convergence at selected hubs and review their volatility.

The review and analysis will enable a subjective judgement on the markets have indeed ‘rebalanced’.

7.1 Development of traded volumes in selected hubs

The recent development of traded volumes was shown in Figure 3, whereas Figure 7 shows the development over the past thirteen years starting in 2011. This shows more clearly how NBP was then the leading and dominant market, remaining steady until late 2017; since then it lost the participation of many Continental European shippers who used to risk manage their portfolios at the most liquid hub. As TTF overtook NBP in 2016, more and more of those shippers migrated their hedging and risk management trading over to the Dutch market, thereby foregoing the additional currency risk associated with NBP trading. NBP continued to lose volumes until the end of 2020, when it stabilised and traded volumes have held steady.

Figure 7: Development of traded volumes at selected hubs: 2011–2023



Sources : OTC: LEBA, ICIS; Exchange: ICE, ICE-Endex, EEX, CME, GME; P. Heather

As mentioned, TTF overtook NBP in 2016 but it was growing strongly from as far back as 2014. As with most of the hubs, it too recorded a sharp fall in traded volumes during 2020 and, after recovering from that during 2021, a second sharp fall throughout 2022 only to rebound very sharply in every quarter of 2023, attaining new record highs to end the year over 50% up on the previous year's trading.

Of the remaining five hubs, the Belgian ZEE/ZTP hubs and the French TRF appeared to go against the trend in 2022, starting the year with three, albeit relatively small, successive quarterly rises; the French hub then had a 'seesaw' 5 quarters to the end of 2023 but did eventually finish at slightly higher levels. As explained in Chapter 4, a link has been observed between French traded volumes and the LNG imports into the country, and this is confirmed by comparing figures 6 and 7. The Belgian hubs' traded volumes followed TRF in 2022 and again very much in line with higher LNG imports but on the other



hand then eased in the five quarters after Q3-2022. However they remain much in line with those recorded in the years 2017 to 2020.

The German THE and Italian PSV broadly followed the same pattern as TTF, albeit at much lower volumes. After the 2022 dip in volumes, THE has regained its trend of slow but steady upward traded volumes, whereas PSV has also recovered from the dip but to a lesser extent. This echoes the pattern of weaker traded volumes from the highs of Q4-2019. Finally, the Austrian VTP has stabilised after the slow decline in its traded volumes since mid-2020.

7.2 Month Ahead price spreads

The Month Ahead spreads are commonly traded in the European gas markets, principally because the MA contract is most used in pricing underlying physical contracts and therefore, it is the MA contracts, OTC and especially exchange futures, that are most used in the risk management of physical gas portfolios, in particular as those physical contracts approach maturity/delivery. As the shippers/traders will have most often placed their hedging on Europe's most liquid gas market, the Dutch TTF, this would invariably involve an amount of spread trading between their local hub and TTF; they then need to 'bring back' that hedge to their local market ahead of physical delivery.

The ICIS European Gas Hub Report (EGHR) publishes graphs in its quarterly reports of the basis prices (spreads) between the main European hubs and the benchmark TTF hub. As mentioned previously, it is the French TRF versus Dutch TTF spread that recorded the highest differential during the turbulent trading period of 2022, but the other main European hubs also saw wide variations in their basis prices to TTF.

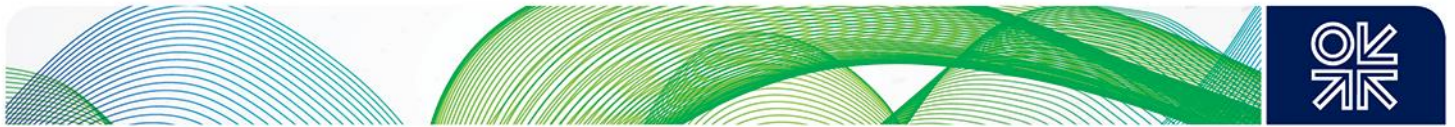
Figure 8: ICIS TTF/TRF (and PVB/TRF) MA spreads H2-2020 to Q1-2024



Source: ICIS EGHR Q1-2024

The very wide disjoint in the TRF/TTF spread in 2022 was due to the 'LNG effect', as described in Chapter 4. The need in Europe to replace Russian pipeline gas supplies led to a massive increase in LNG imports but, due to a lack of west to east transportation and cross-border capacities, this led to unusual price anomalies and to the very wide TRF/TTF spread over the whole of 2022, especially in the summer, as seen in figure 8.

The TTF/TRF spread has over time been marginally negative but in 2022 went positive due to the large quantities of LNG imported into France. As shown in the graph, the positive spread started from March 2022 and reached a maximum in early September and again in early October 2022, and since then the TTF premium fell quite sharply, and even went a touch negative in early January 2023, before stabilising over the course of the year. Although there was a brief small increase in Q4-2023, it fell back again in early 2024.



This means that French traders who may have had difficulty in managing their gas portfolios during 2022, will no longer in 2024 have any difficulty or any potential additional costs in trading locational TTF/TRF spreads as part of their risk management strategy.

Figure 9: ICIS TTF/THE, TTF/PSV, TTF/VTP MA spreads H2-2020 to Q1-2024



Source: ICIS EGHR Q1-2024

Spreads between TTF and the THE, PSV and VTP hubs are shown in figure 9. They had some small fluctuations in 2020 and 2021, but those became quite wide variations during 2022, although in absolute terms far less than those of TRF. The most extreme of these three hubs was the Austrian VTP and although that hub's spread against TTF has rebalanced from 2023, there have still been some variations, both positive and negative, to the benchmark TTF. The THE and PSV have mostly settled back down to a similar pattern as pre-2022.

7.3 Price convergence and correlations

Turning to the convergence of the main European hub prices and their correlation, some interesting points emerge. For most of the 2010s the markets were well correlated and increasingly had good price convergence also, with the possible exception of the Italian PSV, which was typically well correlated but at slightly higher prices, mainly due to border capacity limitations.

However during the very turbulent trading of 2022, both correlation and convergence widened significantly at some of the hubs and, with the selected hubs in focus here, there were some large anomalies. In particular the NBP and Belgian hubs lost their otherwise good correlation, particularly in early Q2-2022 and again in August of that year, along with the French TRF. All three of those hubs diverged to quite a large extent from the other five hubs for most of the period April to September 2022, and to a lesser and gradually decreasing extent through to the end of the year.

These points can clearly be observed in figure 10 and also show how all the hubs continued to be well correlated during the price shock of H2-2021 and kept very good convergence too. The main reasons for the disjointed markets in 2022 were the large volumes of additional LNG imports into France, Great Britain and Belgium and the lack of onward transportation and cross border capacity to ship the gas eastwards to where it was desperately needed.

The figure does show though how the markets started to rebalance from as early as Q4-2022, albeit with some price divergence still, through to about May 2023. After that point, the selected hubs became well correlated and had good price convergence, and certainly these are now broadly as good as prior to April 2022.

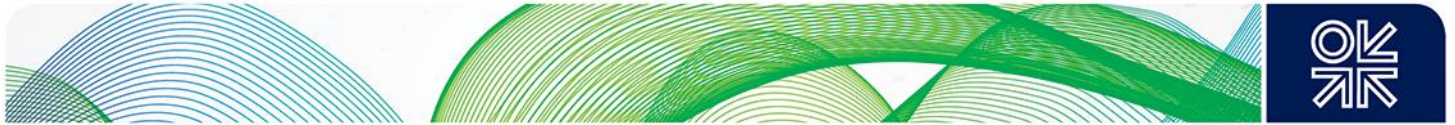
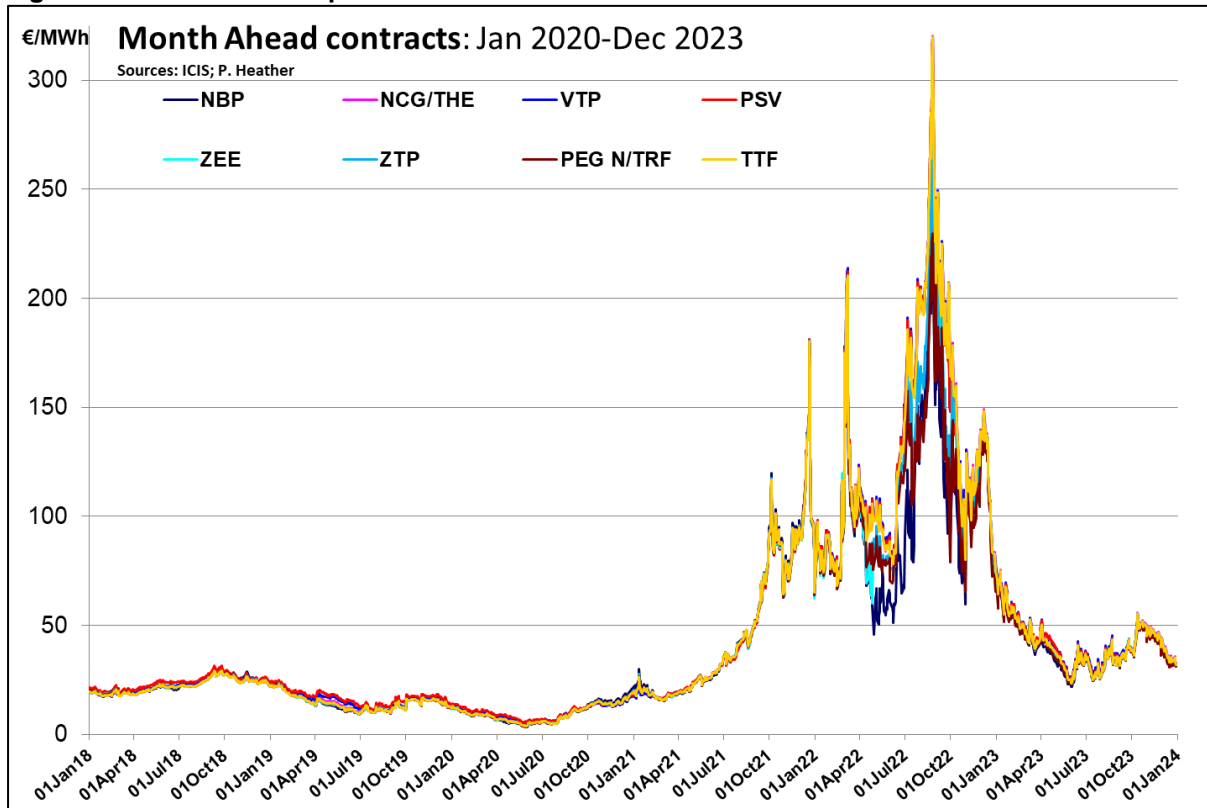


Figure 10: Selected hubs price correlation: 2018 to 2023



Source: ICIS; P.Heather

The actual correlation coefficients of some of the main 'pairs' of hubs show how the three large NWE LNG importers⁷⁹ have very similar correlation patterns as each other against the benchmark TTF, which although also an LNG importer was not as restricted in being able to export south and east. These correlation coefficients are shown in figure 11.

All three pairs show near perfect correlation to TTF before and since the extraordinary market conditions in 2022; even in 2022 the worst coefficient for France in Q3 was slightly above 70% and for Belgium just under 70%; Britain though did 'disconnect' from TTF in Q2 of that year with a coefficient of just above 50%. However, all three had recovered by Q1-2023 to almost perfect correlation and have remained at those high levels since.

⁷⁹ Britain, France, and Belgium, whose actual LNG import volumes for 2021 and 2022 are shown in table 8 and figure 6.



Figure 11: DA Correlation coefficients for TTF/NBP, TTF/TRF, TTF/BE⁸⁰: 2020 to Q1-2024



Source: ICIS EGHR Q1-2024; P.Heather

The other three sets of correlation coefficients between TTF and the German THE, Austrian VTP and Italian PSV, did show greater correlation throughout the whole four year period,⁸¹ at a perfect 100% for THE, about 91% to >99% for VTP and slightly wider range on the PSV from >84% to >99%. These are all shown in figure 12.

All three figures, the absolute price correlations and the correlation coefficients all show that the markets in these six selected NWE hubs did rebalance and have remained pretty much in line to this day with the markets prior to 2022 and before.

⁸⁰ ICIS recorded the data for ZEE up to September 2023, ZTP thereafter.

⁸¹ ICIS only show the correlation coefficients for the German THE from 2020.



Figure 12: DA Correlation coefficients for TTF/THE, TTF/VTP, TTF/PSV: 2020 to Q1-2024



Source: ICIS EGHR Q1-2024; P.Heather

NOTE: ICIS have not used the same scales on the VTP and PSV bar charts as each other, or as the other hubs.

7.4 Price volatility

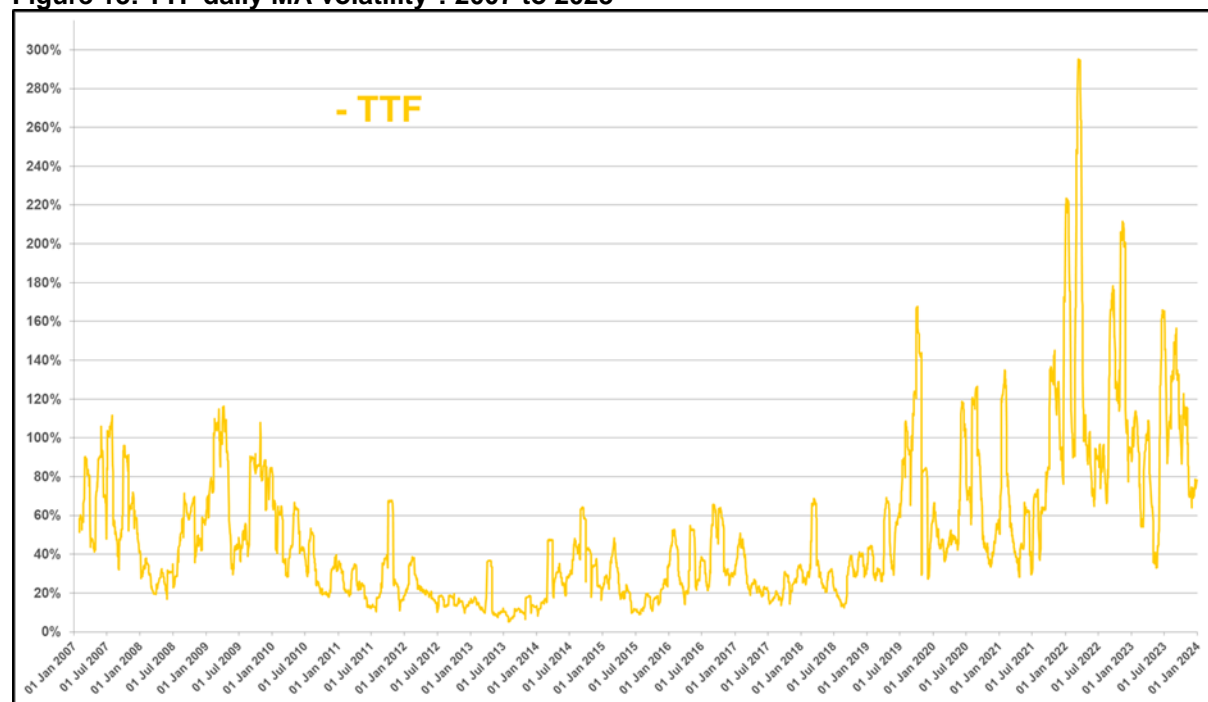
The final important comparison to make is that of the volatility at the selected hubs and to see how they compared over the six year period from 2018 to 2023 and whether they have rebalanced or not after the extreme moves of 2021 and 2022. For the sake of clarity, figure 14 doesn't go further back than 2018 but, in order to show the longer term trend, figure 13 first shows the volatility graph for TTF alone from 2007 to 2023.

This figure gives an overview of the long term volatility of what has become Europe's benchmark gas hub: the first four years show a range of about 20% to 120%, then gradually declining into and throughout the 2010s in a narrower band of about 5% to 65%. From the summer of 2019, the volatility



became more erratic and at the same time started to show a series of ever greater peaks, followed by sharp falls; this continued until May 2023 and a low of 33%,⁸² then a sharp rise to 166% in June,⁸³ before appearing to stabilise to slightly lower levels thereafter, finishing the year at 33% at the end of November, finally up to 78% at the end of December. The average TTF volatility for the whole period from January 2007 to the end of December 2023 was 51.38%.

Figure 13: TTF daily MA volatility*: 2007 to 2023



Source: ICIS; P. Heather

* annualised 20 day rolling volatility levels, expressed as a percentage.

To put these latter figures into perspective, the average TTF volatility in the two year period⁸⁴ before the first big rise in gas prices in the summer of 2021 was 68.28%; the average TTF volatility in the most volatile 13 months from Q4-2021 to Q4-2022,⁸⁵ both in terms of extremely high absolute levels and steep rises and sharp dips, was 137.36%; and the average TTF volatility in December 2023 was 73.75%. For now at least it appears that to a large extent the market has also rebalanced in terms of volatility.

Looking at the selected hubs as a whole, figure 14 shows that most of the time the eight hubs do follow each other with regards to the timing of the moves, but that there are some significant differences as to the actual extent of those rises and falls. However, during the last three quarters of 2022⁸⁶ there were some significant opposites with volatility at the British NBP, the Belgian ZEE and ZTP and the French TRF indicated in the figure as the “period of extreme divergence”.

These significant opposites of increased volatility broadly coincide with the large additional volumes of LNG imports and the resultant lower hub prices, especially so at TRF. These opposites are quite staggering: when looking at the four main periods, the relative volatility of the NBP, ZEE/ZTP, TRF, and TTF show how disjointed those markets were: on 17th May 2022, TTF volatility was 103%, ZTP 133%,

⁸² On 19th May 2023 TTF volatility was 33.01%.

⁸³ On 22nd June 2023 TTF volatility was 165.92%.

⁸⁴ September 2019 to August 2021.

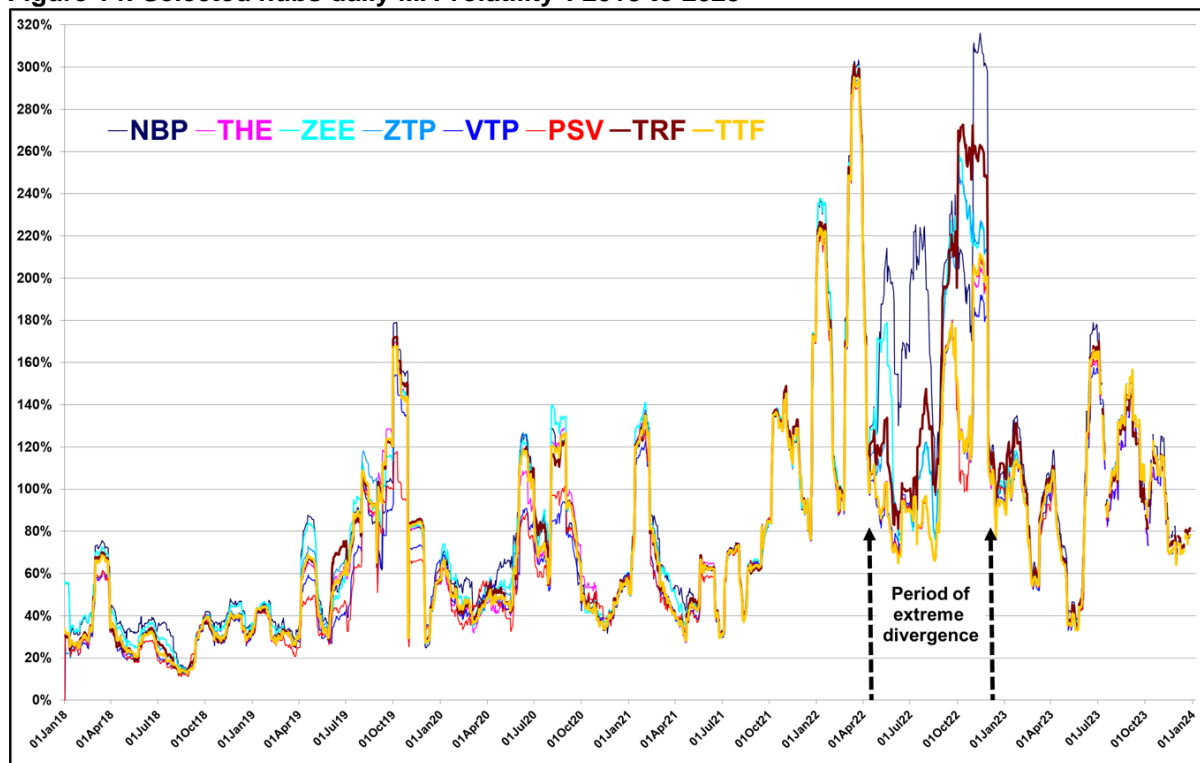
⁸⁵ 1st November 2021 to 30th November 2022.

⁸⁶ From mid-April to end-November 2022.



TRF 134%, ZEE, 179%, and NBP 214%; in July 2022 there were four spikes with the greatest on 29th July when TTF volatility was 96%, ZEE 121%, ZTP 122%, TRF 143%, and NBP 224%; in early October 2022 the British, Belgian and French hubs saw a rise in volatility, whereas at TTF they fell. On the 12th October TTF volatility was 124%, NBP 208%, ZEE and ZTP 244%, and TRF 273%; by November the levels of volatility were starting to ease - with the exception of NBP which had a last spike of 314% on the 14th – so that by the 21st November the last large divergence was the TTF at 207%, Zee 222%, ZTP 223%, TRF 259%, and NBP at 306%.

Figure 14: Selected hubs daily MA volatility*: 2018 to 2023



Source: ICIS; P. Heather

* annualised 20 day rolling volatility levels, expressed as a percentage.

The British NBP had the highest average volatility by far during 2022 but, leaving NBP aside as it is priced in Sterling and serves a slightly different purpose to the continental hubs priced in euros, it is the French TRF that had the highest average volatility in H2-2021, 2022, and 2023; and the Belgian hubs also had very high average volatility, especially the ZEE hub.

The actual average volatility for the selected hubs are shown in Table 10, which is colour coded with green, being the lowest volatility and red being the highest. It is apparent that in each of the three periods recorded, the French TRF always has the highest continental hub volatility and only in 2022 is that of NBP higher; NBP actually has the lowest average volatility in both H2-2021 and 2023. At the other Continental European hubs, TTF has the lowest volatility in H2-2021 and is middling in both 2022 and 2023, when VTP was lowest.

Traders do not generally mind volatile markets, so long as they are deep and liquid such as the Dutch TTF and this is why that hub has attracted an ever greater number of market participants amid ever greater trading volumes; what they do not like is markets that are 'difficult' or unpredictable to trade, especially in the large volumes necessary for hedging and risk management, whether they are volatile or not.

However, when looking at the actual percentages, it is clear how much of a difference in the volatility rates there is between TRF and the benchmark TTF. Not only was TRF the most volatile market on



average throughout the turbulent period from H2-2021 through 2022 and into early 2023 but it appears to have remained so in the latter part of 2023 as well. Having fewer market participants than TTF, less deep and liquid products to trade and much lower volumes over a shorter time horizon, means that the French hub is not conducive to effective and efficient risk management. On the other hand, TTF is the most liquid market with the most market participants, most traded products and highest volumes. As such, liquidity begets liquidity and that in turn helps to generally keep the volatility lower than at less liquid hubs.

Table 10: Comparative volatility at selected hubs: H2-2021, 2022, 2023

H2-2021	NBP	VTP	PSV	THE	TTF	ZTP	ZEE	TRF	HIGHEST
Ave Volatility	66.26%	66.74%	67.04%	66.62%	66.46%	66.84%	66.62%	67.05%	HIGH
2022	NBP	VTP	PSV	THE	TTF	ZTP	ZEE	TRF	MID HIGH
Ave Volatility	132.44%	93.30%	93.65%	94.36%	94.71%	108.80%	113.69%	115.95%	MIDDLE
2023	NBP	VTP	PSV	THE	TTF	ZTP	ZEE	TRF	MID LOW
Ave Volatility	72.50%	74.18%	75.10%	75.59%	76.62%	88.00%	88.72%	94.58%	LOW
H2-21 - 23 Ave	90.40%	78.07%	78.60%	78.86%	79.26%	87.88%	89.68%	92.53%	LOWEST

Source: Taken from data behind figure 14; P. Heather

After a period of very high volatility for the whole of 2022, levels have both come back down and stabilised somewhat with a broad convergence across the four lowest hubs by the end of 2023, albeit less so with the Belgian and French hubs.

7.5 Markets have rebalanced

This chapter focused on the long term market trends at the selected hubs with a view to determining whether the markets had ‘rebalanced’ or not. From the above analysis of the traded volumes development, the relative spreads between the main trading ‘pairs’ of hubs, the overall price correlation and convergence of the hubs, and finally their volatility, it is indeed apparent that the markets have certainly for the most part rebalanced.

8. TTF remains a global gas price benchmark

The author has been following the development of gas trading activity in the Asia-Pacific region for a number of years and since 2019, has developed a methodology to try to compare the churn rates⁸⁷ of the main representative gas markets around the world.

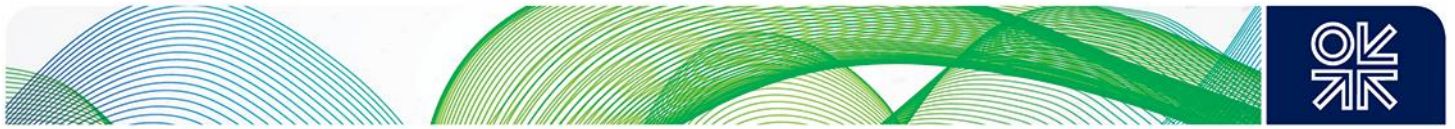
The Dutch TTF is truly *the* leading pricing benchmark for North-West Europe and indeed many other European countries also, as well as increasingly being used to price spot LNG cargoes. It has become an investment asset class⁸⁸ in its own right and there are signs that it is becoming a global benchmark too. Not only have the TTF total traded volumes grown to such an extent that they represent 81.5% of total European traded gas volumes, but its churn rate calculated against the much greater physical consumption figure of the countries including and surrounding the Netherlands,⁸⁹ and whose shippers are known to be using TTF for their risk management, has now grown to nearly 37 times.

This section looks at TTF in the global context, alongside the other European benchmark NBP and against the US Henry Hub (HH). Finally, these are also compared to the nascent LNG pricing

⁸⁷ Note that these are calculated using consumption as the denominator and so for TTF and NBP the results are different to the gross churn rates in Table 3. For JKM, the denominator is LNG imports.

⁸⁸ Part of the Futures asset class of investments.

⁸⁹ See Footnote 67.



benchmark JKM⁹⁰ using the ICE and CME exchange-traded JKM options and futures contracts as the numerator and the LNG imports into China, Japan, Korea, and Taiwan.

Henry Hub is *the* pricing benchmark in North America,⁹¹ with most of the other Market Centers (or hubs) being priced by differential against it. HH is used to price physical gas contracts in North America, and is also used to price some LNG cargoes destined for South America, Asia and Europe. It is extensively used for risk management of physical gas portfolios and is an investment asset class in its own right.

The British NBP was the North West European (NWE) benchmark hub for over a decade but has since lost that mantle to TTF; it remains *the* pricing benchmark for the British Isles and is also used to price most LNG cargoes destined for the British Isles.

Finally and although not strictly a 'hub', the JKM has become the pricing benchmark for some LNG cargoes delivered into Asia, although it has also been used to price LNG cargoes to other parts of the world. Futures and options contracts based on the S&P Global Platts marker price have increased considerably over the past few years.

For the purposes of calculating churn rates, the relevant denominators used are the gas consumption in the United States, Canada and Mexico for HH; the gas consumption in France, Germany, Austria, Czech Republic, and Benelux for TTF; the gas consumption in the United Kingdom and the Republic of Ireland for NBP; and the LNG imports into China, Japan, Korea, and Taiwan for JKM.

Table 11 shows the results of this global comparison and uses a similar colour coding⁹² to the author's European hubs analyses. It shows which benchmarks are illiquid, mature, liquid and very liquid. The results clearly show that HH remains the premier global gas benchmark with an impressive churn of 59.6 (up from 49.7 times last year) when compared to US consumption alone. This is the first year that the HH churn has risen again after falling for two consecutive years,⁹³ and shows that this market also has rebalanced after the volatile energy markets of 2021 and 2022. There is no doubt that this hub is a very mature and very liquid gas pricing benchmark and remains so even after Mexican consumption⁹⁴ is added (the churn is a little lower at 56.9 times) and after including Canadian consumption⁹⁵ (the churn is a little lower still at 50.1 times).

TTF, when compared to the consumption in the five countries of its main sphere of influence, has a risen considerably from the previous year (in 2022 it was 22.6 times) and is now 36.8 times, just short of becoming a 'very liquid benchmark hub. There is no doubt that this is a mature and liquid gas pricing benchmark.

NBP, when compared to the consumption across the United Kingdom and the Republic of Ireland, has a churn of 8.3 times (up from 7.6 last year); this is despite a slight fall in traded volumes, the underlying physical consumption in the UK and Ireland fell more.⁹⁶ It can still, however, be considered a regional Sterling gas pricing benchmark.

There is no doubt that the Asian JKM marker price is gaining support from the LNG industry, with producers, aggregators and buyers using it more each year. There are two exchanges offering JKM

⁹⁰ Japan Korea Marker, a price marker published daily by S&P Global Platts.

⁹¹ It is the most used benchmark in the US and Mexico, although less so in Canada where AECO ('Alberta') is the main pricing hub; see: <https://www.capp.ca/wp-content/uploads/2024/03/Natural-Gas-Market-Fundamentals.pdf>, slide 3. The Alberta Energy Company (AECO), located in Alberta Canada, is one of the largest gas distribution hubs in North America; it's the most widely used Canadian benchmark for natural gas and is quoted in CAD/Gigajoules.

⁹² Dark Green/Very Liquid: ≥ 40 ; Mid Green/Liquid: $15 < 40$; Light Green/Mature: $10 < 15$; Amber/Poor: $5 < 10$; Red/Illiquid: < 5 . The calorific value conversion factors are those stated by the IEA for each country.

⁹³ The HH churn in 2020 was 57.0, in 2021 was 50.1, and in 2022 was 49.7.

⁹⁴ All of Mexico's gas is priced against HH.

⁹⁵ Although realistically, HH is only used to price a proportion of Canadian contracts, the remainder being against Canadian hubs, especially Alberta; see footnote 91.

⁹⁶ Total NBP traded volumes fell by 2.4% year/year; physical consumption in the stated countries fell by 10.5%.



futures and options derivative contracts,⁹⁷ the ICE and CME. Despite the turbulent global energy markets of 2021 and 2022 causing the traded volumes to fall, they rose significantly in 2023, set against slightly lower LNG imports.

Table 11: Global Gas Benchmarks Churn Ratios - 2023⁹⁸

Global Benchmark churn rates 2023 (HH, TTF, NBP: trading/consumption; JKM: trading/LNG imports)			
	Country/Region	Hub	Churn
VERY LIQUID	United States	HH	59.6
	US + Mexico	HH	56.9
	US + Mexico + Canada	HH	50.1
LIQUID	FR-DE-AT-CZ-BeNeLux	TTF	36.8
POOR	Britain	NBP	8.9
	UK-IE	NBP	8.3
ILLIQUID		No hubs yet but increasing spot trading	
	CN-JP-KR-TW	JKM	0.69

Sources: JODI, ICE, CME, LEBA, ICIS, ICE, ICE-Endex, EEX; P. Heather

Asia has started to liberalise its gas markets but has a long way to go. Increased short term and spot LNG trades and the use of the JKM are helping the transition. The JKM, when compared to its main sphere of influence, has a churn of 0.69 times in 2023 (up from 0.59 in 2022). This is an illiquid market but is clearly showing some signs of growth.

9. Summary and Conclusion

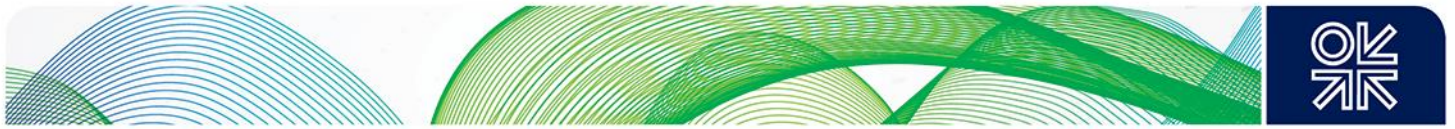
The main purpose of this paper has been to analyse the results of the trading data in 2023 for the European traded gas hubs, in order to be able to assess whether the traded gas markets have rebalanced after the three very turbulent years in the energy markets.

The European gas markets have experienced a rough ride since 2020 when demand for gas was greatly reduced by the global Covid-19 pandemic. However, more major disruption to the energy markets was to follow in 2021 and 2022 resulting in a severe readjustment of the European traded gas markets.

Map 1 showed all the European gas hubs that were operational at the end of 2023. All of Europe now has a gas hub of sorts, ranging from the very small 'nascent' balancing and spot trading hubs; to the 'inactive' hubs that might have a little more spot and prompt trading but often very little or no curve trading; to the medium 'poor' hubs in Belgium, Czech Republic, and Spain that trade more products but

⁹⁷ JKM derivatives trading was launched in 2012.

⁹⁸ All the data behind this table can be seen in Appendices: "Global gas hubs: Net market churns: 2022, 2023".



still in relatively low volumes; to the larger 'active' hubs in Britain, France, and Germany that trade reasonable volumes and also in more types of products but that are simply dwarfed by the only 'mature' benchmark hub in Europe, the Dutch TTF.

Despite the extreme trading conditions over the past few years, trading across all the European hubs remained relatively buoyant and very much in line with the underlying physical volumes in each country. However, in 2023 trading picked up significantly, set against a general fall in physical volumes. When comparing the 2022/23 year-on-year difference, Europe as a whole had a 40% rise in traded volumes, whilst physical demand fell by -18%. All countries had higher traded volumes except Belgium, Britain, and Romania and all had lower physical demand, except Bulgaria, Denmark and Romania.

9.1 Review of the 5 Key Elements in 2023

Trading activity continued to increase in 2023, attracting more participants and liquidity. The Dutch TTF is by far the leading gas hub in Europe and attracts not only physical traders but financial, institutional and speculative traders also.

A good measure of a hub's maturity is the types of products available to trade and their traded volumes, which are a good indication of whether a given hub is used mainly for balancing purposes, or for hedging and risk management. Here too the Dutch TTF is yet again top of the table, with all but the balancing and spot individual products categories shown as 'green'.

It is clear from the traded products table and the product splits that the Dutch TTF is the 'mature' risk management hub, with large volumes of MA reflecting LTC hedging and large volumes of curve products reflecting portfolio risk management, including a large volume of options traded.

High absolute traded volumes are usually indicative of a liquid market with a large number and varied range of participants; here too the Dutch TTF hub has by far the largest traded volumes, including as described above, in all products across the whole curve.

A major change in the traded gas markets over the past few years and especially since 2021, has been the move away from OTC trading towards more exchange trading. The share of exchange trading now dominates and in 2023 attained a share of 82% of total European trades. The share of exchange trading is highest at TTF, NBP and PVB, but still low at PSV.

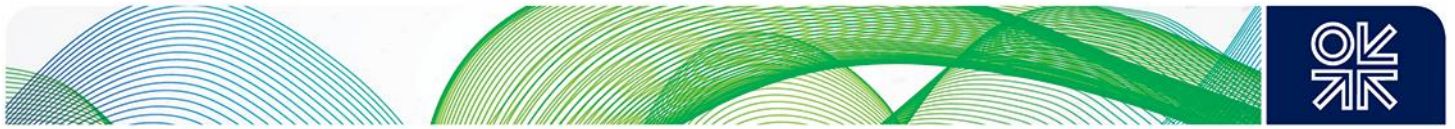
When adding the share of the top four hubs, TTF, NBP, THE and TRF, they together account for 96% of total European gas trading, made up of a total 88% of OTC trading and 98% of exchange trading. These data clearly show how much bigger the TTF is compared to even its nearest rivals, with the fourth placed French TRF only registering 2.1% market share.

Although the Tradability Index doesn't show the depth of a market, there is still no doubt from the results that the Dutch TTF is far ahead of all the other hubs with a near 'perfect' score of 19/20, indicating that there are tight bid-offer spreads in all but the tightest <€0.3/MWh contract.

The most important metric is the traded gas hubs' churn rate as, in this one metric all others are, necessarily, reflected: if there are many participants, trading many different products in large quantities, then the churn rate is likely to be high. The net and gross churn rates for the 10 main hubs were studied in this paper and the results for 2023 show that there is only one European benchmark hub, the Dutch TTF, standing far ahead of all the others and the only hub considered as 'mature', plus one regional Sterling marker price, the British NBP.

The author concluded in the 2022 paper that there was indeed an 'LNG effect' on the traded volumes at those hubs that saw large volumes of extra LNG being imported; in 2023 there was a large increase in traded volumes and churn rate at the Dutch TTF and the Netherlands was the only country with an increase in LNG sendout compared to 2022.

The urgent need since 2022 to bring additional volumes of LNG into Europe resulted in an expansion of LNG terminals and FSRU projects, in particular in the Netherlands and in Germany, and this has already led to greater traded volumes at the Dutch and German hubs.



Having examined each of the 5 Key Elements in detail, as well as several complimentary analyses, it is clear that the Dutch TTF is far and away the leading European traded gas hub, used by many more market participants than any other hub, has a very high traded products score, with far greater total traded volumes than all the other put together: TTF also accounts for 81.5% of all European gas trading, for 56% of all OTC trading, and 87% of all exchange trading. TTF also has the highest Tradability Index score, only missing one point on one of the 'balance of month' contracts, and finally, by far the greatest churn rate.

9.2 The long term trends

This paper reviewed the longer term trends at eight selected hubs, namely the British NBP, the Dutch TTF, the Belgian ZEE and ZTP, the German THE, the Austrian VTP, the French TRF, and the Italian PSV, to determine whether or not the traded gas markets have continued to trade erratically into 2023, or whether there is an emerging pattern to suggest that they have 'rebalanced'.

This comprised looking at the development of traded volumes since 2011, the Month Ahead price spreads, the correlation coefficients and their volatilities.

The development of traded volumes shows that the British NBP remained fairly steady (despite quite violent summer/winter variations) all the way through to 2017, since when its traded volumes eased back somewhat, stabilising in 2023; it is still the second largest hub in Europe.

Dutch TTF made steady and often strong progress over the whole period, overtaking NBP in 2016. However, as with most of the hubs, it recorded a sharp fall in traded volumes during 2020 and after recovering from that during 2021, a second sharp fall throughout 2022 only to rebound very sharply in every quarter of 2023, attaining new record highs to end the year over 50% up on the previous year's trading.

The French hub made slow progress over the whole period with a 'seesaw' 5 quarters to the end of 2023 but did eventually finish at slightly higher levels.

The Belgian hubs' traded volumes had their peak in 2011 since when they have made a long slow decline; despite further falls in the five quarters after Q3-2022, they broadly remained much in line with those levels recorded in the years 2017 to 2020.

The German THE made slow progress up to 2019 and the Italian PSV saw steady progress up to 2019, albeit from a lower start in 2012. Since 2019, both hubs eased back into 2021 although THE then regained its trend of slow but steady upward traded volumes, whereas PSV continued to dip lower, recovering slightly in 2023.

After a long slow increase in volumes from 2011 to mid-2020, the Austrian VTP started to ease lower, although this appears to have stabilised in 2023.

The graphs in this paper show that it was the French TRF versus Dutch TTF spread that recorded the highest differential during the turbulent trading period of 2022 with TTF at a wide premium. The other main European hubs also saw wide variations in their basis prices to TTF.

However, from early October 2022 the TTF premium to TRF fell quite sharply, and even went a touch negative against TRF in early January 2023, before stabilising over the course of the year. Although there was a brief small increase in Q4-2023, it fell back again in early 2024.

This means that French traders who may have had difficulty in managing their gas portfolios during 2022, will no longer in 2024 have any difficulty or any potential additional costs in trading locational TTF/TRF spreads as part of their risk management strategy.

With regards the spreads between TTF and the THE, PSV and VTP hubs, the most extreme of these three hubs was the Austrian VTP and although that hub's spread against TTF has rebalanced from 2023, there have still been some variations, both positive and negative, to the benchmark TTF. The THE and PSV have mostly settled back down to a similar pattern as pre-2022.



For most of the 2010s the markets were well correlated and, increasingly had good price convergence also, with the possible exception of the Italian PSV, which was typically well correlated but at slightly higher prices, mainly due to border capacity limitations.

During the very turbulent trading of 2022 both correlation and convergence widened significantly at some of the hubs and there were some large anomalies: in particular the NBP and Belgian hubs lost their otherwise good correlation, along with the French TRF. All three of those hubs diverged to quite a large extent from the other selected hubs.

The main reasons for the disjointed markets in 2022 were the large volumes of additional LNG imports into France, Great Britain and Belgium and the lack of onward transportation and cross border capacities to ship the gas eastwards to where it was needed.

The actual correlation coefficients of some of the main 'pairs' of hubs show near perfect correlation of the three large NWE LNG importers to the benchmark TTF before and since the extraordinary market conditions in 2022. The three other sets of correlation coefficients between TTF and the German THE, Austrian VTP, and Italian PSV, showed greater correlation throughout the whole four year period. The absolute price correlations and the correlation coefficients all show that the markets in these six selected NWE hubs did rebalance and have remained pretty much in line to this day with the markets prior to 2022 and before.

The volatility graph for the benchmark TTF alone from 2007 to 2023 shows that during the most extreme 13 months from Q4-2021 to Q4-2022, both in terms of extremely high absolute levels and steep rises and sharp dips, average volatility was 137.36%. This dropped sharply and in December 2023 average volatility was 73.75%. For now at least it appears that to a large extent the TTF market has also rebalanced in terms of volatility.

For the selected hubs as a whole, most of the time the eight hubs do follow each other with regards to the timing of the moves but there were some significant differences as to the actual extent of those rises and falls, especially in the last three quarters of 2022, when there were some significant opposites with the volatilities at the British NBP, the Belgian ZEE and ZTP and the French TRF.

NBP aside, volatility at the continental hubs was always highest at the French TRF, whereas the TTF had the lowest volatility in H2-2021 and was middling in both 2022 and 2023, when VTP was lowest. Not only was the TRF the most volatile market on average throughout the turbulent period from H2-2021 through 2022 and into early 2023 but it appears to have remained so in the latter part of 2023 as well.

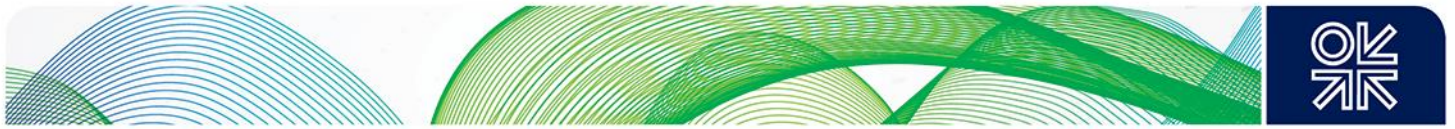
Having fewer market participants than TTF, less deep and liquid products to trade and much lower volumes over a shorter time horizon means that the French hub is not conducive to effective and efficient risk management. On the other hand, TTF is the most liquid market with the most market participants, most traded products, and highest volumes: liquidity begets liquidity and that in turn helps to generally keep the volatility lower than at less liquid hubs.

After a period of very high volatility for the whole of 2022, levels have both come back down and stabilised somewhat and with a broad convergence across the four lowest hubs by the end of 2023, but less so with the Belgian and French hubs.

9.3 TTF as a global pricing benchmark

On a global level, the analysis shows that the TTF is truly *the* leading pricing benchmark for North-West Europe and indeed many other European countries also, as well as being used to price some LNG cargoes destined for Europe. It has become an investment asset class in its own right and there are signs that it has become a global benchmark too.

Henry Hub is *the* pricing benchmark in North America, with most of the other Market Centers (or hubs) being priced by differential against it. HH is used to price physical gas contracts in North America, and is also used to price some LNG cargoes destined for South America, Asia and Europe. It is extensively used for risk management of physical gas portfolios and is an investment asset class in its own right.



The British NBP was the North West European benchmark hub for over a decade but has since lost that mantle to TTF; it remains *the* pricing benchmark for the British Isles and is also used to price most LNG cargoes destined for the British Isles.

Finally, and although not strictly a 'hub', the JKM has become the pricing benchmark for LNG cargoes delivered into Asia, although it has also been used to price LNG cargoes to other parts of the world.

9.4 Final Conclusion

This paper set out to determine whether the traded European gas hubs had rebalanced after the turbulent years from 2020 to 2022. Having reviewed each of the 5 Key Elements in detail, as well as several complimentary analyses, it is clear that the benchmark Dutch TTF is far and away the leading European traded gas hub, used by many more market participants than any other hub, has a very high traded products score, with far greater total traded volumes than all the other put together; it also has the highest Tradability Index score and finally, by far the greatest churn rate.

On a global scale, HH is the North American benchmark hub and remains a leading global gas benchmark, used to price LNG cargoes to Asia and Europe. It is now closely followed by TTF which is not only the benchmark for its immediate sphere of influence but increasingly so for all of Europe and globally and NBP remains a regional benchmark hub for the British Isles and some LNG pricing. The JKM is currently the only feasible price marker in Asia, but is very far from being an active and reliable one.

The actual results also show that the trading at TTF has rebalanced and indeed, gone from strength to strength. The other European hubs can also be said to have rebalanced on the whole, with some exceptions, particularly at some emerging hubs. With regards the analysis on the long term trends, the price spreads, price correlation, and prices volatilities these also show to a large degree that the markets have rebalanced. Finally, Henry Hub and JKM trading has also rebounded.



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Appendices

The European traded gas hubs in 2023

NBP	- National Balancing Point; GB; 1996
ZEE and ZTP	- Zeebrugge Hub / Zeebrugge Trading Point; BE; 2000/2012
PSV	- Punto di Scambio Virtuale; IT; 2003
TTF	- Title Transfer Facility; NL; 2003
(AOC) PVB 2004/2015	- Almacenamiento Operativo Comercial / Punto Virtual de Balance; ES;
GTF and ETF	- Gas Transfer Facility and Exchange Transfer Facility; DK; 2004 and 2008
(PEGs) TRF	- Points d'Échange de Gaz (Nord, Ouest, Est, Sud, TIGF) / PEG Nord (merger of PEGs N,O,E); FR ; 2004/2009
	- Trading Region South (merger of PEGs S, TIGF); FR; 2015
	- Trading Region France (merger of PEG N, TRS); FR; 2018
(CEGH) VTP	- (Central European Gas Hub; AT; 2005) Virtual Trading Point; AT; 2013
(GPL/NCG)THE	- Gaspool and NetConnect Germany; DE; 2009 to September 2021
	- Trading Hub Europe; DE; 2021
MGP	- Magyar Gázkiegyenlítési Ponton; HU; 2010
UDN	- Ulusal Dengeleme Noktası; TR; 2011
VOB	- Virtuální Obchodní Bod; CZ; 2011
VPGS	- Virtual Point Gaz-System; PL; 2014
NIBP	- Northern Ireland Balancing Point; NI; 2015
SVOB	- Slovenskom Virtuálnom Obchodnom Bode; SK; 2016
IBP	- Irish Balancing Point; IE; 2017
HTP	- Hellenic Trading Point; GR; 2018
PVT	- Punctul Virtual de Tranzactionare; RO; 2020
VTT	- Virtualna Türgovska Tochka; BG; 2020
PVN	- Ponto Virtual de Negociação; PT; 2021
Croatia, Serbia, and Slovenia	- nascent hubs with little or no trading



Churn rates: 2021 to 2023 – Top 6 Hubs

Volumes in TWh	Σ OTC (less cleared)	Σ Exch. Fut/Opt	Σ Exch. spot	Σ Traded	Σ NET Physical	Net market churn	Σ GROSS Physical	Gross market churn
TTF 2021	16,512.34	36,172.40	767.12	53,451.85	390.86	136.8	791.65	67.52
TTF 2022	7,217.58	34,463.24	1453.15	43,133.97	303.50	142.1	684.38	63.03
TTF 2023	7,912.94	55,681.50	1387.09	64,981.53	290.41	223.8	644.34	100.85
Δ Holland	10%	62%	-5%	50.7%			-5.9%	60.0%
NBP 2021	1,957.43	4,595.28	93.25	6,645.96	832.05	8.0	907.09	7.33
NBP 2022	1,884.26	4,322.59	127.12	6,333.98	775.58	8.2	1,034.14	6.12
NBP 2023	1,641.69	4,416.87	125.97	6,184.53	692.36	8.9	866.85	7.13
Δ Britain	-13%	2%	-1%	-2.4%			-16.2%	16.5%
VTP 2021	686.19	100.99	133.28	920.46	99.14	9.3	488.72	1.88
VTP 2022	263.72	228.11	194.56	686.39	86.15	8.0	288.93	2.38
VTP 2023	340.04	171.43	176.68	688.15	74.35	9.3	162.23	4.24
Δ Austria	29%	-25%	-9%	0.3%			-43.9%	78.6%
THE 2021	2,437.27	117.01	598.33	3,152.62	993.76	3.2	1,754.38	1.80
THE 2022	1,562.72	734.28	1009.65	3,306.65	845.38	3.9	1,373.52	2.41
THE 2023	1,999.32	882.06	829.20	3,710.59	812.99	4.6	1,028.20	3.61
Δ Germany	28%	20%	-18%	12.2%			-25.1%	49.9%
TRF 2021	619.18	34.85	199.52	853.55	457.61	1.9	534.70	1.60
TRF 2022	865.39	258.92	292.52	1,416.84	419.52	3.4	592.91	2.39
TRF 2023	817.95	506.10	351.25	1,675.29	356.44	4.7	525.53	3.19
Δ France	-5%	95%	20%	18.2%			-11.4%	33.4%
PSV 2021	1004.26	54.73	94.57	1,153.56	805.45	1.4	821.80	1.40
PSV 2022	719.61	121.33	121.31	962.25	725.42	1.3	774.02	1.24
PSV 2023	1039.99	110.03	126.40	1,276.42	653.12	2.0	679.48	1.88
Δ Italy	45%	-9%	4%	32.7%			-12.2%	51.1%



Churn rates: 2021 to 2023 – the remaining hubs, all under 1.0 gross churn

VOB 2021	61.43	9.47	23.46	94.36	100.58	0.9	493.29	0.19
VOB 2022	37.44	16.40	35.52	89.36	80.90	1.1	277.26	0.32
VOB 2023	51.15	17.02	23.90	92.06	72.64	1.3	83.53	1.10
Δ Czech	37%	4%	-33%	3.0%			-69.9%	241.9%
ZEE+ZTP/L'21	159.55	1.76	150.88	312.18	190.99	1.6	422.71	0.74
ZEE+ZTP/L'22	269.70	52.84	269.90	592.44	164.18	3.6	635.32	0.93
ZEE+ZTP/L'23	155.56	46.39	274.16	476.11	153.97	3.1	539.52	0.88
Δ Belgium	-42%	-12%	2%	-19.6%			-15.1%	-5.4%
PVB 2021	74.28	32.99	53.07	160.34	381.49	0.4	415.29	0.39
PVB 2022	63.42	90.56	104.43	258.41	365.78	0.7	433.42	0.60
PVB 2023	99.62	108.55	126.14	334.31	327.02	1.0	401.29	0.83
Δ Spain	57%	20%	21%	29.4%			-7.4%	39.7%
VPGS 2021	0.00	148.90	31.63	180.53	230.23	0.8	437.45	0.41
VPGS 2022	0.00	116.58	21.94	138.53	191.32	0.7	198.32	0.70
VPGS 2023	0.00	122.86	20.75	143.62	159.34	0.9	166.09	0.86
Δ Poland	n/a	5%	-5%	3.7%			-16.3%	23.8%
GTF/ETF 2021	32.11	0.01	17.57	49.69	27.65	1.8	47.76	1.04
GTF/ETF 2022	17.99	0.04	17.58	35.60	20.11	1.8	46.67	0.76
GTF/ETF 2023	0.00	0.00	52.78	52.78	17.87	3.0	114.80	0.46
Δ Denmark	-100%	-100%	200%	48.2%			146.0%	-39.7%
VTT 2021	0.00	10.09	2.39	12.48	36.47	0.3	137.88	0.09
VTT 2022	0.00	9.98	4.03	14.01	29.22	0.5	162.38	0.09
VTT 2023	0.00	30.51	14.98	45.50	27.19	1.7	169.47	0.27
Δ Bulgaria	n/a	206%	272%	224.8%			4.4%	211.2%
MGP 2021	2.29	0.88	30.42	33.59	118.55	0.3	128.79	0.26
MGP 2022	1.27	0.00	26.01	27.28	100.78	0.3	117.44	0.23
MGP 2023	0.25	0.05	29.66	29.96	89.72	0.3	112.01	0.27
Δ Hungary	-80%	n/a	14%	9.8%			-4.6%	15.1%
PVT 2021	0.00	50.86	13.34	64.20	123.72	0.5	131.09	0.49
PVT 2022	0.00	15.73	16.59	32.32	104.46	0.3	114.00	0.28
PVT 2023	0.00	5.97	11.80	17.77	97.85	0.2	120.14	0.15
Δ Romania	n/a	-62%	-29%	-45.0%			5.4%	-47.8%
SVOB 2021	26.52	n/a	n/a	26.52	58.47	0.5	450.38	0.06
SVOB 2022	4.05	n/a	n/a	4.05	56.61	0.1	262.87	0.02
SVOB 2023	10.05	n/a	n/a	10.05	45.75	0.2	157.83	0.06
Δ Slovakia	148%	n/a	n/a	148.4%			-40.0%	313.6%
Σ Europe 2022	12907.15	40430.60	3694.31	57,032.07	4,268.92	13.4	6,995.59	8.15
Σ Europe 2023	14068.55	62099.36	3550.77	79,718.67	3,870.99	20.6	5,771.32	13.81
Δ Europe	9%	54%	-4%	40%	-9%		-18%	69%



Global gas hubs: Net market churns: 2022, 2023

Volumes in TWh	Benchmark Hub	Σ Traded Volumes	Σ NET Physical / Asia Net LNG Imports	Net market churn
Britain 2022	NBP	6,333.98	775.58	8.2
Britain 2023	NBP	6,184.53	692.36	8.9
Δ Britain		-2.4%	-10.7%	9.4%
UK + IE 2022	NBP	6,333.98	833.29	7.6
UK + IE 2023	NBP	6,184.53	745.52	8.3
Δ UK + IE		-2.4%	-10.5%	9.1%
Holland 2022	TTF	43,133.97	303.50	142.1
Holland 2023	TTF	64,981.53	290.41	223.8
Δ Holland		50.7%	-4.3%	57.4%
NW Europe 2022	TTF	43,133.97	1,906.27	22.6
NW Europe 2023	TTF	64,981.53	1,767.00	36.8
Δ NW Europe		50.7%	-7.3%	62.5%
United States 2022	HH	456,242.50	10,010.24	45.6
United States 2023	HH	537,109.00	9,004.67	59.6
Δ United States		17.7%	-10.0%	30.9%
US + Mexico 2022	HH	456,242.50	10,415.45	43.8
US + Mexico 2023	HH	537,109.00	9,439.00	56.9
Δ US + Mexico		17.7%	-9.4%	29.9%
US + MX + CA 2022	HH	456,242.50	11,700.65	39.0
US + MX + CA 2023	HH	537,109.00	10,724.31	50.1
Δ US + MX + CA		17.7%	-8.3%	28.4%
NW Asia 2022	JKM	1,761.40	2,991.99	0.59
NW Asia 2023	JKM	2,042.92	2,948.59	0.69
Δ Asia	JKM	16.0%	-1.5%	17.7%