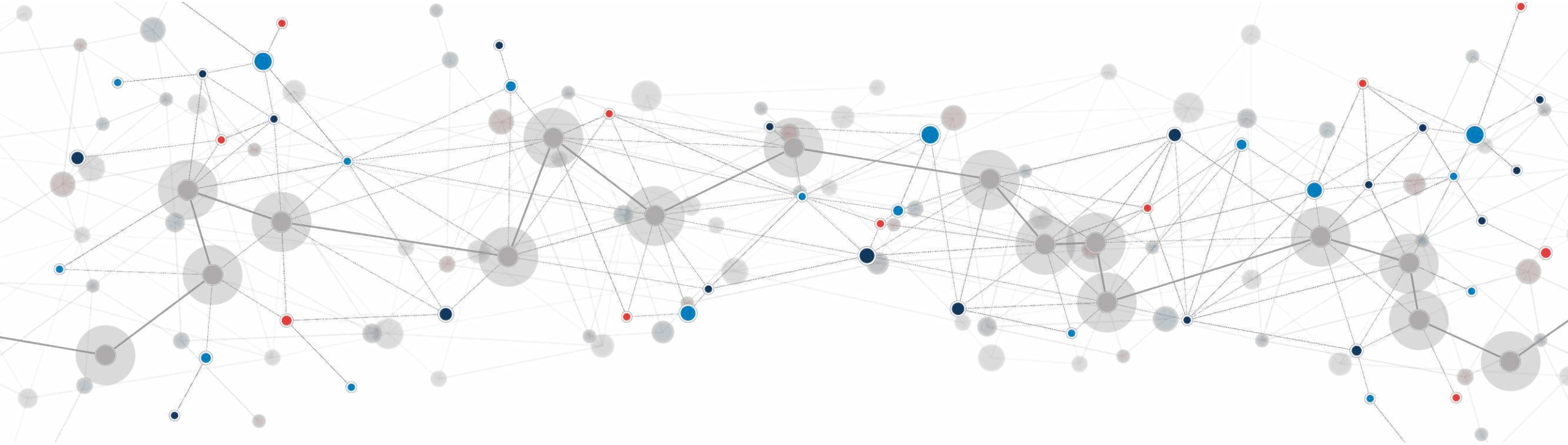

Assessment of potential impacts of regional virtual hubs on the forward markets

Final report

7 November 2024

COMPASS LEXECON

Context and objective of the report

- In application of Article 9 of the revised internal electricity market Regulation, the European Commission should carry out an **impact assessment to identify potential means among several options to improve the ability of market participants to hedge price risks in the internal electricity market**.
- This study focuses on one of those options, **regional virtual trading hubs for forward markets and the move from zone-to-zone to zone-to-hub long-term transmission rights** (LTTRs) in the CORE region and examined its extension to the Iberian countries and Italy (hereinafter referred to as "South").
- This impact assessment may result in amending Commission Regulation (EU) 2016/1719, establishing a guideline on forward capacity allocation (FCA Guideline).
- Throughout the EMD process, **Energy Traders Europe, Eurelectric and Europex (hereinafter referred to as "the associations") expressed concerns regarding the risks and difficulties associated with the implementation of virtual hubs and** asked for a **detailed and robust impact assessment.**
- Under this framework, between August and September 2024, **the European Commission held a targeted consultation aiming to seek stakeholders' views on how to improve the current functioning of the electricity forward markets**. This consultation, however, did not include the detailed impact assessment.

- In this context, the associations have asked Compass Lexecon to carry out **a study assessing some of the potential economic impacts of moving towards zone-to-hub LTTR allocation on forward electricity markets. The study is structured around 3 main steps:**
  - **Presentation of the context**
  - **Quantitative assessment of the potential impact of implementing a virtual hub**
  - **Conclusions**

Executive summary

Hedging on existing physical hubs vs. virtual hubs saves costs for consumers

- Price differences (spreads) between local zones and existing hubs in Germany or Hungary are less volatile than when using a VTH.
- Local zone prices move closer together (correlation) with existing hubs in Germany or Hungary than with a VTH.

→ **Proxy-hedging is generally safer and less costly in existing hubs of Germany or Hungary than it would be in a VTH.**

Liquidity split would make trading both on physical and virtual hubs less efficient than on today's forward market

- Hedging will mostly remain on local zones and existing physical hubs like Germany or Hungary: VTH liquidity development would likely be limited.
- Market participants from a few bidding zones may start hedging on a VTH: this would split liquidity between VTH and existing physical hubs, with efficiency losses compared to the existing setup.

→ **Likely, negative impact on liquidity would translate into higher transaction costs for market participants, and ultimately higher costs for consumers.**

Zone-to-hub LTTRs are unlikely to counterbalance less efficient hedging on virtual hubs

- Zone-to-hub LTTRs would be less adequate instruments as traders continue to proxy-hedge on existing hubs.
- TSOs would need to allocate higher volumes of zone-to-hub LTTRs to counterbalance less efficient hedging on virtual hubs, thereby increasing their financial exposure to LTTRs disconnected from physical cross-border lines.

→ **The key issue to investigate in the impact assessment is the design of zone-to-zone LTTRs to facilitate hedging on the more efficient physical hubs.**

Our assessment conclusions:

→ **Virtual hubs are no silver bullet to improve forward markets in the CORE (+ South) region.**

→ **Setting up virtual hubs in the CORE (+ South) region bears risks on hedging efficiency and liquidity.**

Glossary of terms

Term	Definition
BZ	Bidding Zone
CAL	Calendar product, a product with a delivery over a specified year with a fixed price
Churn factor	Defined as the overall volume traded through exchanges and brokers divided by physical electricity consumption. It is a mean to measure liquidity
FCA	Forward Capacity Allocation Guideline, establishing a framework for calculating and allocating interconnection capacities in the forward timeframe, as well as for cross-border trading in forward markets
FTR	Financial Transmission Right, can be an option or an obligation
Italian PUN price	National single price in Italy ("Prezzo Unico Nazionale"), calculated as the weighted average of prices from the Italian zones
LTTR	Long-Term Transmission Right: cross-border long-term spread derivative, used to hedge against price differences between electricity markets
MPs	Market Participants
Proxy-hedging	Use of a related asset to offset risk when a direct hedge is not available, relying on the correlation between the assets
PTR with UIOSI	Physical Transmission Right with Use-It-Or-Sell-It option: holder can nominate physically the electricity exchange or receive the market price difference if positive
TSO	Transmission System Operator
VTH	Virtual Trading Hub

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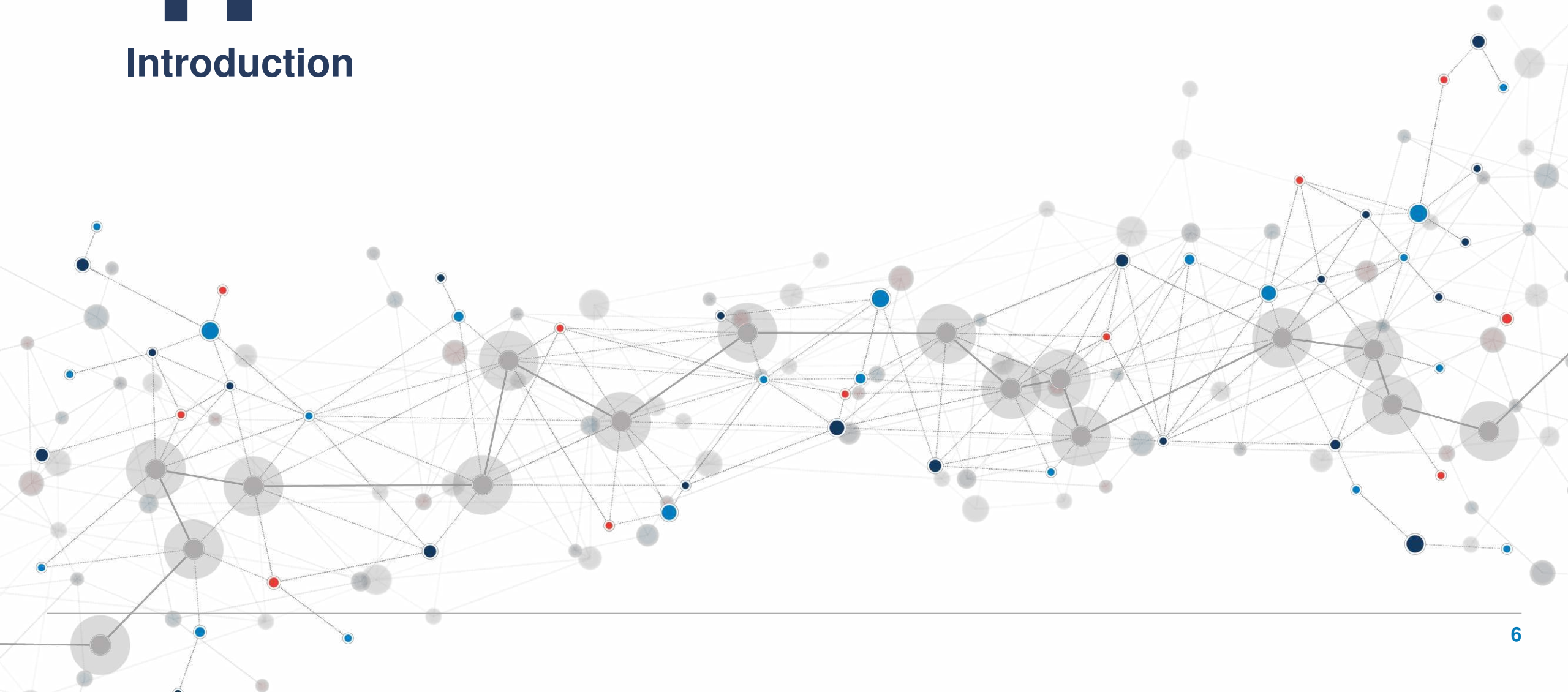
1.

Introduction



Overview of the forward market

Rationale and approach of forward trading

Forward markets are key to manage risks

- Forward markets are **fundamental for market participants** (MPs) **to manage risks**, in particular **market risks related to prices and available volumes**.
- Forward markets provide **price signals over a period long in advance** (from a few days to several years ahead of delivery). They therefore allow a price to be secured early, as a hedge against the volatility of shorter-term prices, both on the buy- and sell-side.
- Market participants, such as generators, traders, industrial consumers, and retail suppliers, can use a range of forward marketplaces and contracts to hedge and stabilize future revenue streams.
- MPs can hedge themselves over weeks, months or years; and against one zonal (often national) price or a combination of them.
- Trading could be done through energy **exchanges**, through **brokers** or purely **bilaterally**. In the two latter cases, trades can be registered with exchanges for clearing.
- For market participants to be well-hedged, they need access to products which (1) offer **effective protection against price movements** (i.e. where the underlying is closely correlated to the price that a market participant is exposed to) (2) at a **competitive price** (i.e. for which a liquid market exists).
- Whereas a **perfect hedge** refers to a forward contract where the underlying reflects the price the MP is exposed to, a **proxy-hedge** refers to a contract where the underlying is correlated to the price the MP is exposed to, e.g., from a neighbouring market. A proxy-hedge may be preferred if the neighbouring market is more liquid for example and can be complemented with a product that covers the remaining **locational (basis) risks**.

Overview of the forward market

Current framework for cross-zonal hedging

Locational (basis) risk and cross-zonal hedging

- Market participants who trade across borders or use other markets to proxy-hedge may also resort to specific products to hedge this locational / basis risk. These can either be:
  - **Market-based hedging products**, such as spread products (between the prices of two zones) or contracts for difference e.g. electricity price area differentials (i.e., EPADs – between the price of a zone and the price of a regional index).
  - **Hedging products allocated by TSOs**, the long-term transmission rights (LTTRs), including:
    - **LTTRs in the form of PTR/FTR options**: issued within the framework of the Single Allocation Platform (JAO) and the forward capacity allocation (FCA) Guideline,
    - **EPADs issued by TSOs (Svk pilot),**
    - **FTR obligations linked to a hub price**, e.g. the Italian PUN price (contracts covering the Risk of Volatility of the Fee for Assignment of Rights of Use of Transmission Capacity, 'CCCs').
- The **FCA Guideline** requires TSOs to issue LTTRs or equivalent measures to allow price risk hedging. Regulatory authorities can exempt TSOs from this obligation if an assessment proves there are sufficient other cross-zonal risk hedging opportunities **in the concerned bidding zones.**

Types of cross-zonal hedging instruments

Product	LTTRs	Spread	EPADs
Region	Continental	Europe	Nordic/Baltic
Issued by TSOs	Yes	No	No (Yes for Svk pilot)
Type of instrument	• Options (called PTR w/ UIOSI or FTR options) • Obligations* *(but not issued)	Combinations of futures (allows hedging on spread between price zones)	Futures (called differentials)
Underlying	Zone-to-zone spread (neighbouring BZs)	Zone-to-zone spread	Zone-to-hub (system price) spread
Timing of trade opportunities	Discrete auctions	Continuous trading	Continuous trading Svk: auctions

Source: ACER, Feb 2023, Further development of the EU electricity forward market, link. Neon energy, March 2024, Report on cross-border forward markets. FCA Guideline: link. Regulation (EU) 2019/943: link.

Overview of the forward market

Liquidity may be improved in most forward markets in Europe, but market participants can proxy-hedge in more liquid markets

- Market participants will seek to hedge primarily in their local forward markets but their ability to do so is variable and liquidity could be improved in most markets.

- MPs anywhere in Europe can proxy-hedge positions on their market of choice.

- Germany is the most liquid hub in Europe, but several other markets can be used as hubs: the Nordic hub, France, Hungary, Italy, Netherlands, etc.

- The purpose of the analysis is to compare proxy-hedging under the current framework on such physical hubs and under a framework where a virtual hub would be introduced for the CORE (+ South) region.

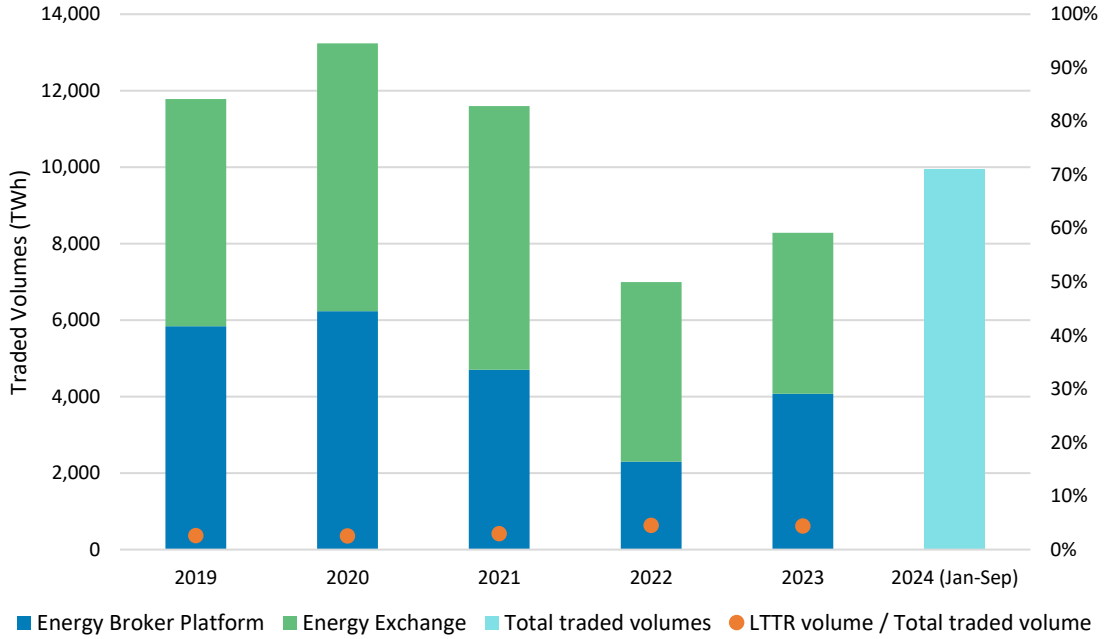
Source: EFET/Eurelectric workshop on forward market liquidity, May 2023

Overview of the forward market

The energy crisis temporarily affected the liquidity of forward markets

- Overall, liquidity decreased significantly in 2021 and 2022, to pick up again in 2023.
  - **This fall can be explained by the energy price crisis in 2022**, which both increased the costs of collaterals and eroded counterparty credit limits.
  - Market participants were **affected by state interventions, such as price caps or subsidies, which reduced incentives to hedge**.
  - **In 2023, liquidity increased compared to 2022, but is still below pre-crisis levels**. In the first 9 months of 2024, traded volumes on already exceeded those for the whole year 2023.
  - **The volume of LTTRs traded represents a small portion of the total forward market volume**, approximately 3%. This share remains constant over time, except for a 2-percentage point increase in 2022 due to a reduction in overall traded volume.
  - This shows that, while **LTTRs can bear significance for market participants, in particular to hedge locational basis risk**, **the larger part of hedging is channelled through other means.**

Evolution of brokered vs exchange trading in the EU (TWh)



Source: ACER report for data up to 2022, ACER database for Apr-Dec 2023, REMIT Quarterly report for Q1 2023 and 2024, and JAO.

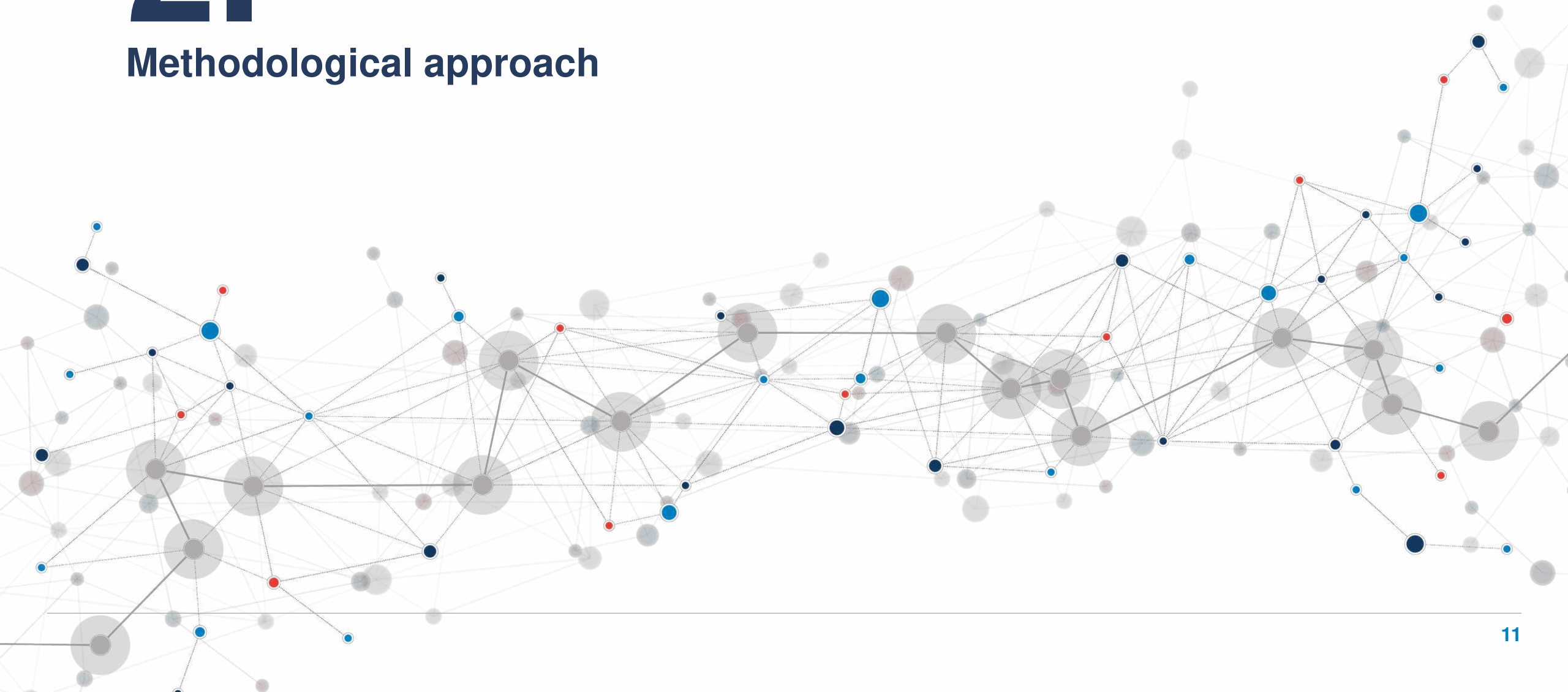
Note: Data for 2023 contains a 3rd category (Traded via Brokers and cleared on Exchanges), which we have included it in the Energy Broker Platform category for consistency with past data. The split between categories is missing for Q1 2023, so we applied the ratio calculated from the 9 remaining months. The distinction is not available in 2024.

Traded volumes represented are the volumes traded in the EU forward markets, whether peak or base load and with monthly, quarterly and yearly maturities. The LTTR volume/Total traded volume indicator is calculated as the ratio of the volume of LTTRs auctioned through JAO (only ATC volumes, excluding resale) to the total traded volumes reported by ACER. The LTTRs considered were traded in the EU, GB and CH, except the Nordics and the Baltics. Dutch and German borders are considered, as well as the border EE-LV.

Source: ACER Monitoring Report of July 2024, March 2024 and November 2023

2.

Methodological approach



Methodology – We have followed a three-step approach based on an ex-post construction of a virtual hub price

1 Virtual hub price construction

- Build ex-post estimation of what could have been the virtual hub price.
- Look at different approaches and geographies.

2 Compare virtual hub price with proxy-hedging markets

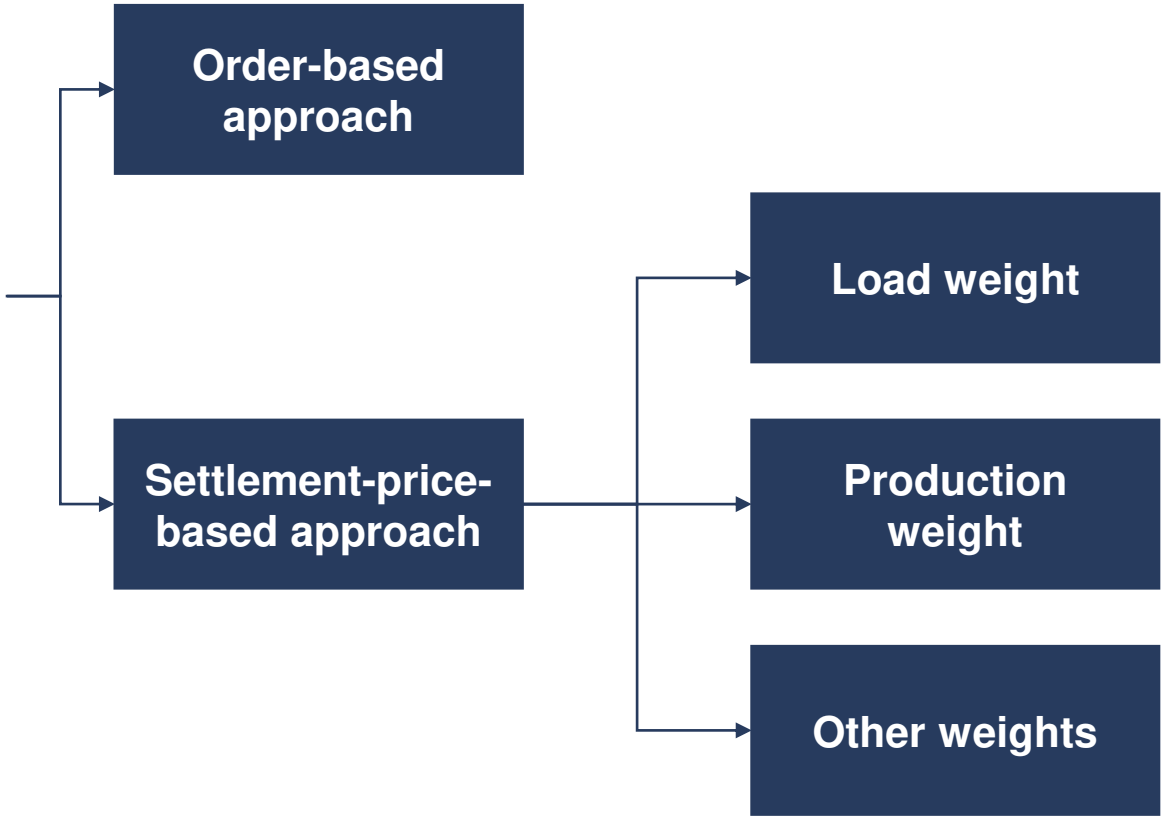
- Compare different forward markets that could be used for proxy-hedging: virtual hub vs. Germany or Hungary.
- To do so, look at different indicators to assess hedging "quality".

3 Assess impacts of the creation of a virtual hub

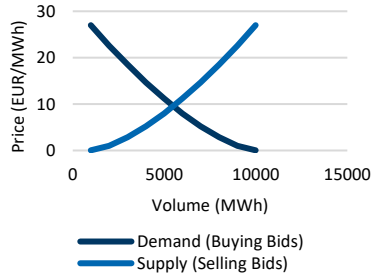
- Assess interactions with long-term transmission rights' allocation.
- Assess potential impacts on liquidity and forward market functioning in general.

Methodology – How to determine the virtual trading hub price?

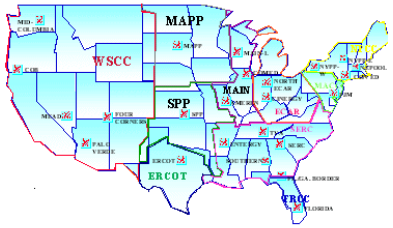
Different methodologies to calculate the virtual trading hub prices



- In the Nordic setting, this involves aggregating all bids for buying and selling electricity for each hour of the next day across the Nordic and Baltic regions and clearing the market assuming no transmission constraints between bidding zones.



- In several **US electricity markets** (PJM, ERCOT ISO-NE), locational marginal prices (LMPs) from a set of physical nodes/locations (selected based on specific criteria, such as geographic proximity, historical price correlations, or other operational characteristics) are aggregated (weighted average, different weights such as load, generation, traded volume) in virtual trading hubs where market participants can trade energy contracts.



Methodology – Our methodology to estimate the virtual hub price on the forward market is a load or production weighted approach

1 Market design assumption: Virtual price is computed day-ahead based on weighted average defined ex-ante (load or production)

- **Virtual price is computed day-ahead based on weighted average**.
- This is **a common approach**, used in other markets, **simple and easy to replicate**, testing weights based on consumption and production levels.
- **We excluded approaches based on weights known ex-post.** These would create incompletely-defined contracts as the underlying would only be known ex-post.
- **We also excluded unconstrained price**, such as in the Nordics, because we **lack access to adequate data** to replicate this.

2 Modelling assumption: Forward prices on the virtual hub equal the (same) weighted average of the forward prices

- We assume forward market prices on the virtual hub equal the **weighted averages of the zonal forward prices**, using EEX, TGE and OMIP data.
  - This implicitly assumes that MPs will trade in the virtual hub forward market with regard to the day-ahead virtual hub in the same way as they do on other forward markets.
  - MPs thus take into account their **perspectives of each individual market when they trade**, rather than ex-post.
- **We compare hedging using the simulated virtual hub forward price with proxy-hedging on the German** (and Hungarian) **forward markets.**
- Beyond **different weights**, we also look at **different geographical scopes** for the calculation of the virtual hub price (Core or Core + South, i.e. IT, ES, PT).

Methodology – Our analysis concentrates on indicators assessing the quality of proxy-hedging using the virtual hub vs. reference markets

When proxy-hedging, market participants mainly consider liquidity, hedging quality and transaction costs. Our quantitative analysis focuses on the hedging quality.

	Calculation approach	Rationale
1 **Correlation between zone and hub prices**	▪ **Static correlation** between the log differences of the country price and hub price over the entire sample period for multiple forward products presented by delivery year. ▪ **Rolling correlation** based on log differences between the country price and hub price using a rolling window of 20 trading days for a single calendar product.	▪ Correlation is a proper measure of dependence between two price variables: ***does my proxy/hub price move with my home market price?***
2 **Volatility of price spreads between zone and hub**	▪ **Ratio of two standard deviations** of price spreads between country and hub A, and the same country and another hub, e.g. std(BE-VTH) / std(BE-DE).	▪ Represents the relative risks of hedging against the virtual hub or another proxy-hub**: *how strong are the price divergences between the proxy/hub price and my home market price?***
3 **Distribution of price spreads between zone and hub (Kurtosis)**	▪ **Kurtosis** of price spreads (country – hub) measures the shape of the distribution's tails and how sharply peaked or flat the distribution is. The measure indicates whether extreme values (outliers) are more or less common than in a normal distribution.	▪ Represents the shape of the distribution tails of differences between price spreads***: how likely is the proxy/VTH price to be very far off my home market price?***

- For efficient hedging, other aspects would be the liquidity of the hub and the bid-ask spreads. We do not have any simulation on the potential liquidity of the VTH and how this would affect zones' liquidity, nor of the resulting bid-ask spreads of the VTH.
- If hedging on the VTH tends to be better for one zone, it should attract liquidity to the detriment of the historical proxy-hub. Conversely, if it is not better, liquidity should remain in the proxy-hub.

Source: Compass Lexecon analysis

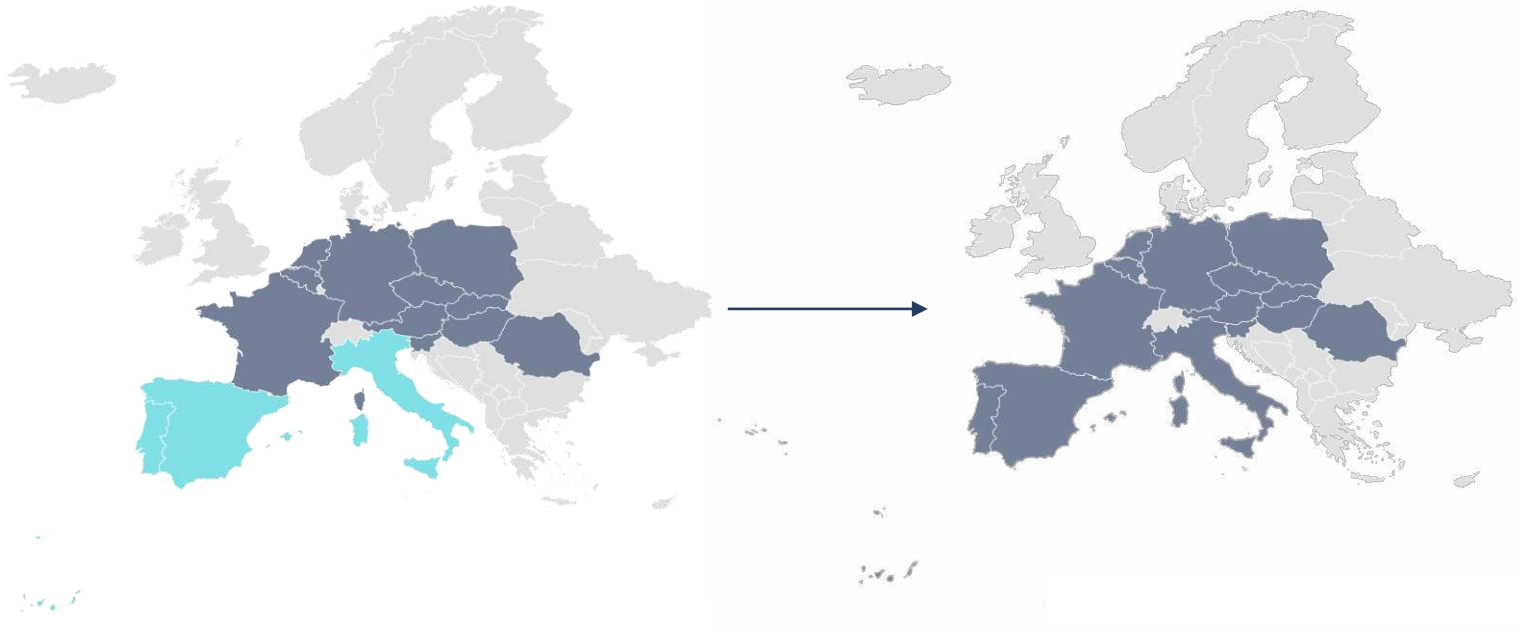
Methodology – Scope definition

CORE and CORE + South regions

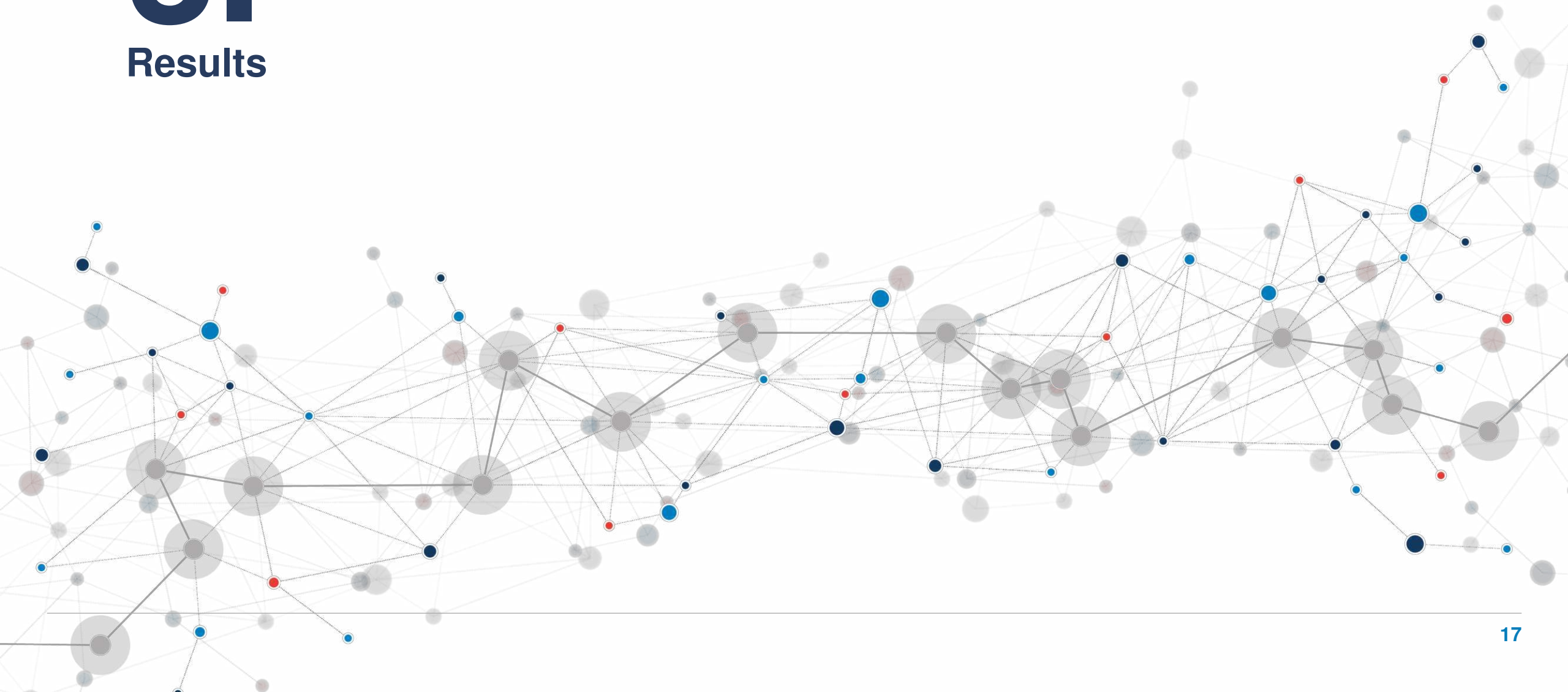
- The original hub of the analysis is composed of the CORE countries. We computed an extension of this hub by incorporating Southern Europe (ES, PT and IT), called CORE + South.
- We are also interested in measuring the impacts of incorporating Southern Europe into the VTH as well as the relationship between Southern Europe and the CORE VTH on CORE countries. Hence results will be presented for all countries, but when “CORE” is mentioned, the VTH is calculated using only CORE countries.

CORE	CORE + South
Austria	Austria
Belgium	Belgium
Czech Republic	Czech Republic
France	France
Germany	Germany
Hungary	Hungary
	Italy
Netherlands	Netherlands
Poland	Poland
	Portugal
Romania	Romania
Slovakia	Slovakia
Slovenia	Slovenia
	Spain

Geographical scope considered in the calculation of the VTH
(in dark blue – CORE on the left ; CORE + South on the right)

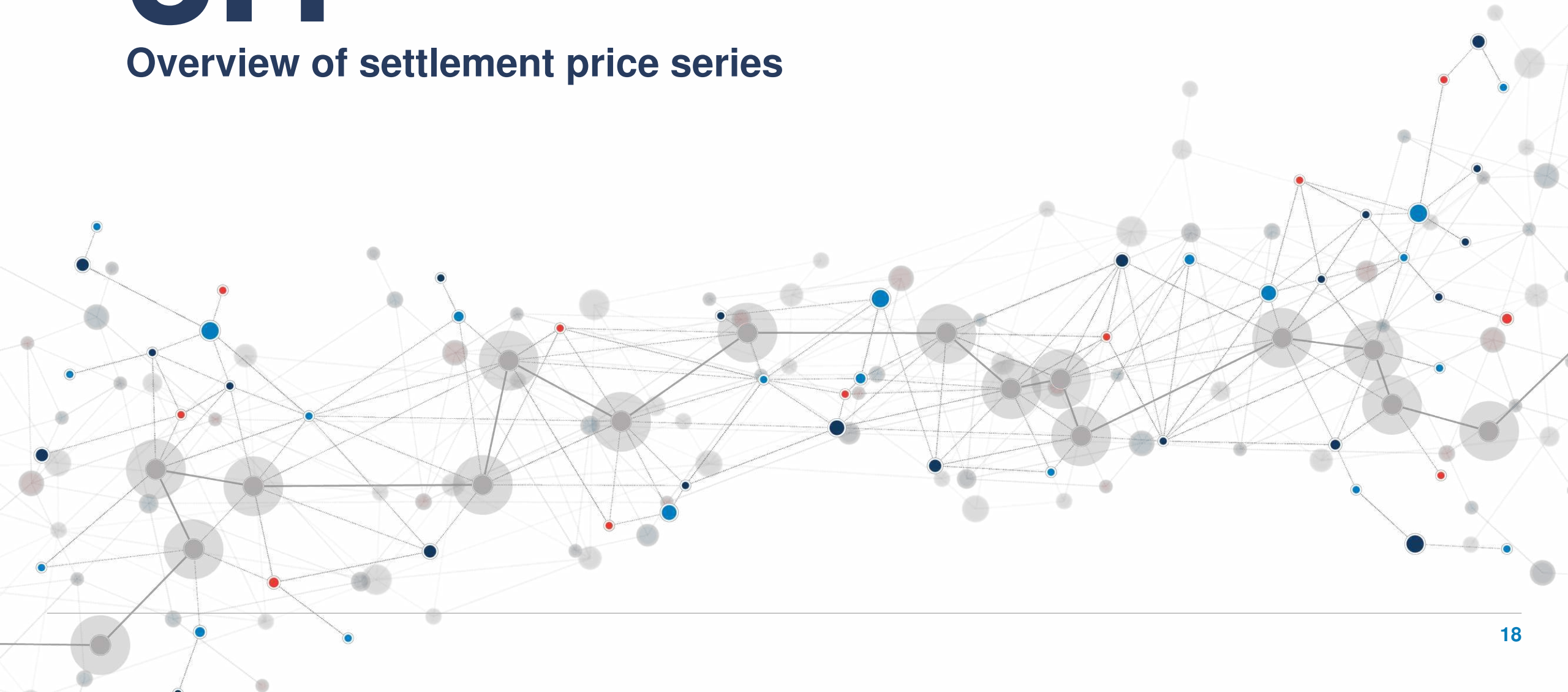


3.
Results



3.1

Overview of settlement price series

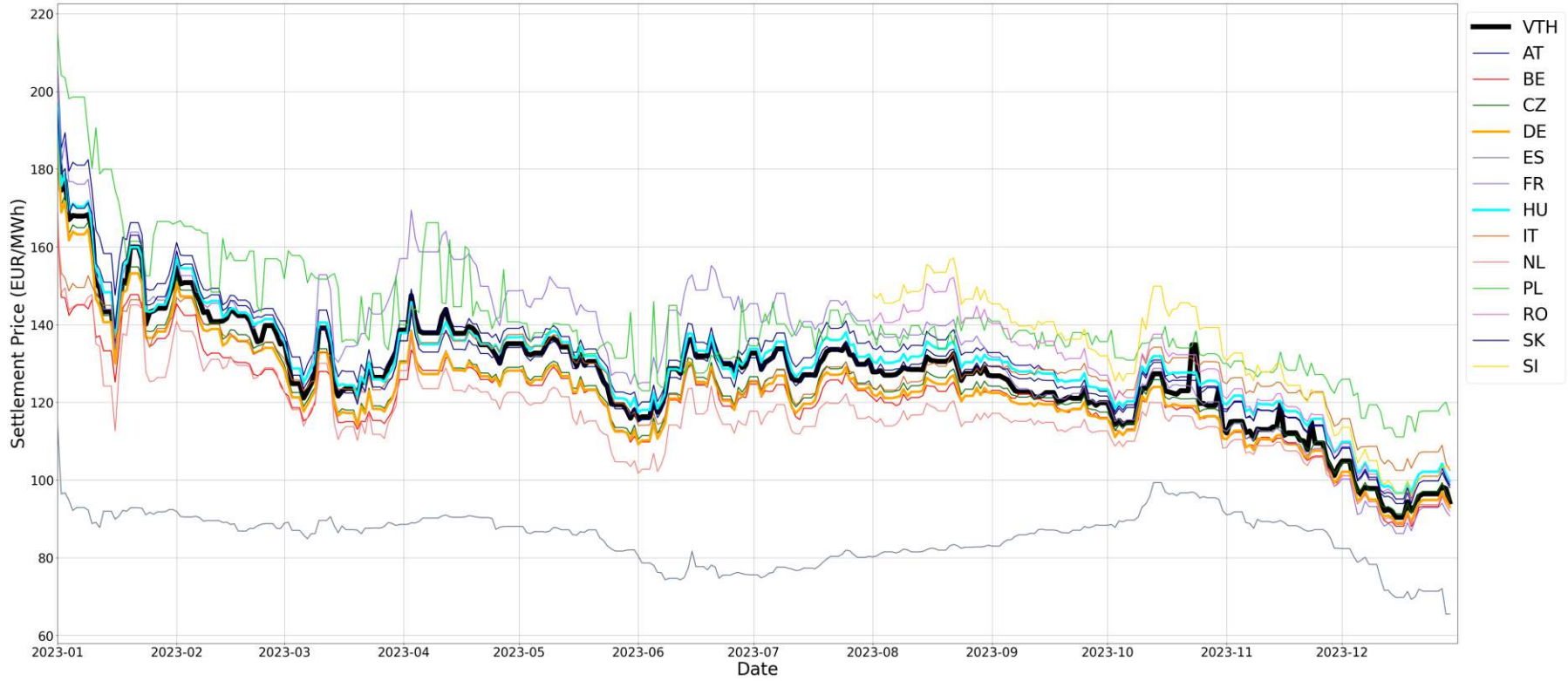


VTH price dynamics in CORE are driven mainly by France and Germany who share around 60% weight* in the VTH price index

Quotations in 2023 for the CAL2024 – CORE region

- This graph illustrates the **price volatility observed in the 2023 trading period** – especially in France mainly due to nuclear outages – but also the **high correlation between most forward markets**.

CAL+1 products traded in 2023 for delivery in 2024, consumption-weighted, CORE region**



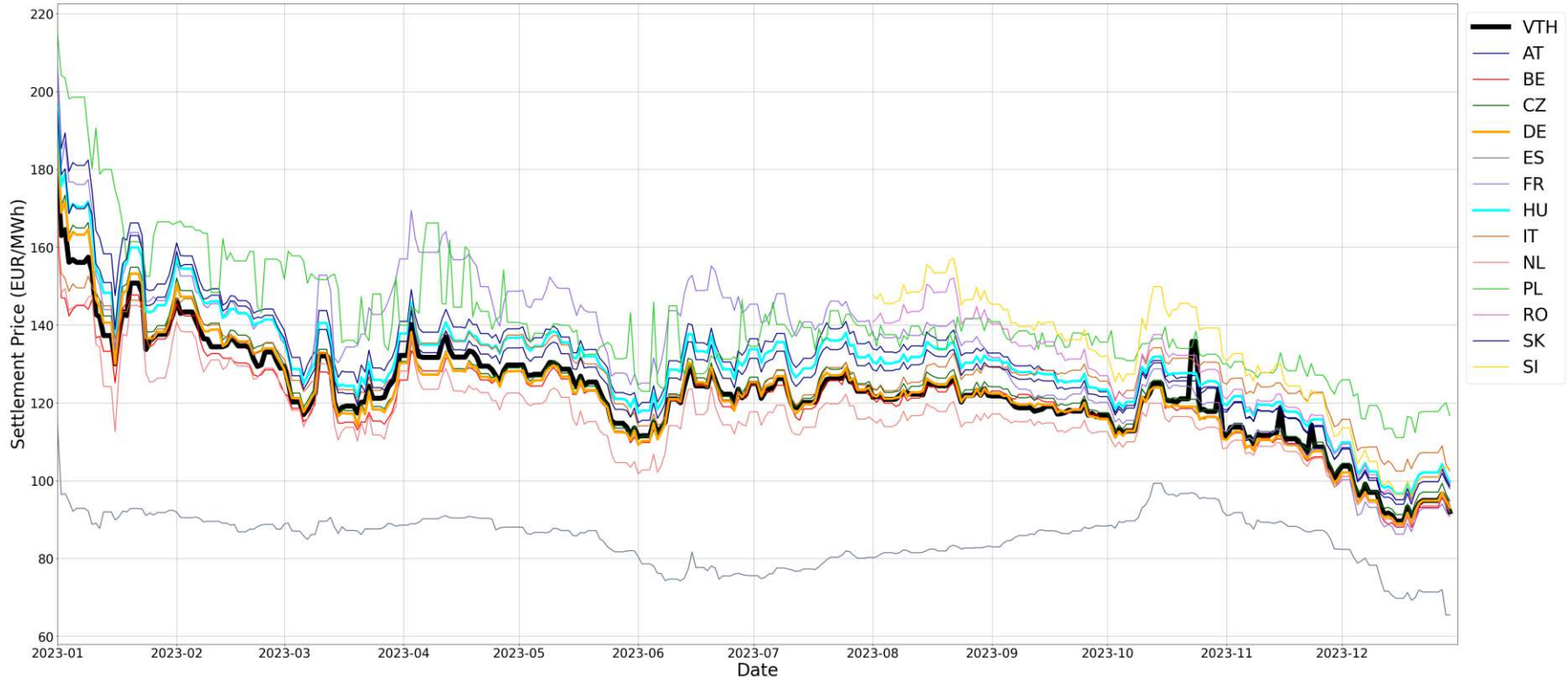
Notes: * Detailed weights by country, region, and weighting approach are presented in the Appendix.
** Portugal is not represented in the following graphs for confidentiality reasons; however, it is included in the calculation of the weights and the VTH price.
Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

VTH price in CORE + South is based on less concentrated country weights but includes more diversified price dynamics, such as Spain

Quotations in 2023 for the CAL2024 – CORE + South region

- The settlement price in the VTH based on CORE + South gets pulled down by Spain compared to the VTH based on CORE-only, as Spain has both a non-negligible weight in the VTH index and significantly lower price due to governmental interventions.

CAL+1 products traded in 2023 for delivery in 2024, consumption-weighted, CORE + South region*



Notes: * Portugal is not represented in the following graphs for confidentiality reasons; however, it is included in the calculation of the weights and the VTH price.
Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

The difference in VTH price between the CORE region and CORE + South region becomes particularly evident during periods of volatility

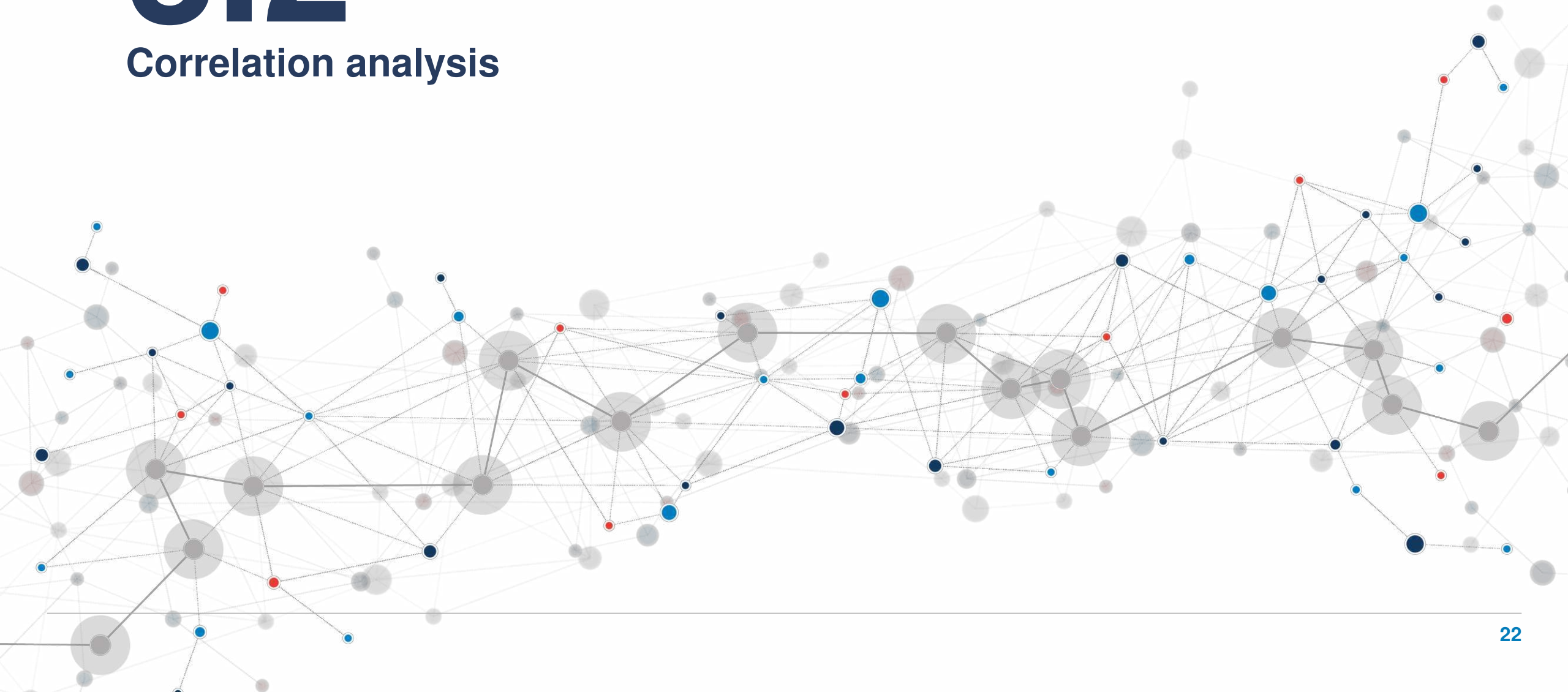
Difference in quotations in 2023 for the CAL2024 – CORE vs. CORE + South region

- Settlement price in the VTH specified on **CORE-only is systematically higher than the one in a VTH specified on CORE + South** throughout most of 2023 because of France's significant price premium against all other CORE countries and its large weight in the VTH index. This drives VTH up until end of 2023.

VTH price difference for CAL2024 product traded in 2023 (CORE vs. CORE + South)

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

3.2
Correlation analysis



Correlation is a crucial quantity in the valuation of many energy derivatives and assets

Why correlation matters

- Correlation is the **proper measure of dependence between two random variables,** in this case hub and country prices.
- Correlation is **crucial in multi-commodity derivatives** because it affects pricing, risk management, and portfolio optimization.
- **Correlation changes over time** and it is important to apply adequate methodology to correctly measure it.
  - Correlation is time-dependent **due to several factors:** the relationship may depend on a specific time period, the interaction between the two processes can fluctuate, the relationship might be complex (non-linear), and errors in measuring it can cause apparent changes.

Methodology

- Applying a standard practice from financial markets, we study **correlations between logarithmic returns** (return correlations). This approach addresses non-stationarity because price-time series in financial markets are not stationary, meaning they do not follow a consistent pattern over time.
- We look at two versions of correlations:

1) **Static correlation** between pairs of power prices (hub and country) in log differences representing the average relationship.
2) **Rolling correlation** between pairs of power prices (hub and country) in log differences based on 20 trading days. This dynamic indicator **captures changes between prices over time**, dynamically showing **changes in market conditions**, such as supply shocks, geopolitical events, or changes in demand.

Static correlation shows that VTH calculated on CORE is noisier and less correlated than DE for all but 3 countries

Methodological interpretation

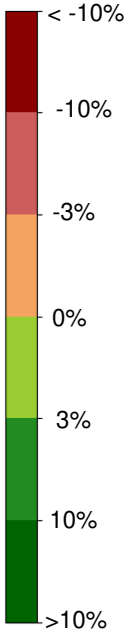
- The static correlation represents **the average relationship** between the prices of a hub (DE or VTH) and a country.
- The correlation here is presented on differences between logarithms, which focus mainly on the short-term co-movements between the hub and country prices.

Results

- In the **CORE** hub configuration, **price correlation between Germany and other zones is generally higher than with the VTH.** This indicates that **proxy-hedging with Germany could provide higher quality of hedging than with the simulated VTH**.
- **Exceptions are Spain, France and Poland**, where the correlation is mainly neutral or better with VTH compared to DE.

Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1/2/3, VTH based on demand-weighted **CORE region**

Year	2022		2023		2024		2025	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country								
AT	100%	94%	100%	94%	99%	90%	99%	89%
BE	96%	92%	90%	86%	82%	77%	77%	78%
CZ	100%	94%	100%	94%	100%	91%	100%	90%
DE	100%	94%	100%	94%	100%	91%	100%	90%
FR	97%	94%	94%	94%	88%	89%	85%	90%
HU	98%	93%	99%	94%	99%	90%	100%	90%
NL	97%	92%	93%	88%	94%	87%	79%	78%
PL	60%	63%	52%	58%	28%	35%	8%	26%
RO	98%	93%	99%	93%	100%	97%	99%	95%
SI	98%	95%	100%	95%	100%	97%		
SK	99%	93%	100%	94%	100%	91%	100%	90%
Countries outside the VTH calculation area								
ES	85%	82%	65%	65%	46%	46%	35%	42%
IT	94%	89%	88%	83%	87%	82%	62%	54%



Note: The colour code compares VTH to DE. It is based on the difference of correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to show how they would be impacted by the VTH.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data
Notes: * Hedge effectiveness represents the percentage of risk that is reduced through hedging.

Lower static correlation of the VTH translates into lower hedge effectiveness and higher financial risk exposure compared to proxy-hedging in DE

Hedge effectiveness and financial impacts

- **Hedge effectiveness** can be defined as **the proportion of the risk** (variance) that is **eliminated by hedging**.[1]
- Lower correlation with a hub implies a lower hedge effectiveness.
- In the table on the right:
  - **A negative VTH-DE %** implies that the VTH has **lower hedge effectiveness** and therefore higher risk, compared to DE.
  - **A positive VTH-DE %** implies that the VTH has **higher hedge effectiveness** and therefore lower risk, compared to DE.
- A lower hedge effectiveness translates into unhedged risks and therefore costs. In the right column of the table, we present the financial impact for a trader with €1,000,000 total exposure to the power price fluctuations:
  - The example shows that in most of the cases using **VTH decreases the hedge effectiveness between 1.5 % to 11.6 %.** This means that the trader would face additional unhedged risk of €15,000 to €116,000.
  - Poland and Spain are **exceptions, where VTH improves hedge effectiveness by 1% to 7%** due to better correlations than DE.

From a hedge effectiveness perspective, DE provides a better proxy-hedge than VTH for most countries. This is due to DE's higher correlation which allows to better offset the risks associated with the underlying country price risk exposures.

Correlation difference, hedge effectiveness of hubs and the residual financial impact of using VTH instead of DE

Delivery year 2023 for CAL+1/2/3, VTH based on demand-weighted **CORE region**

Year	2023		
Zone	**Correlation difference** VTH-DE	**Hedge effectiveness*** Difference VTH-DE	**Financial impact** residual difference
Country			
AT	-6%	-11.1%	-111 k€
BE	-4%	-7.5%	-75 k€
CZ	-6%	-11.6%	-116 k€
DE	-6%	-11.6%	-116 k€
FR	-1%	-1.5%	-15 k€
HU	-6%	-11.1%	-111 k€
NL	-4%	-7.8%	-79 k€
PL	6%	7.1%	71 k€
RO	-6%	-11.1%	-111 k€
SI	-5%	-9.5%	-95 k€
SK	-6%	-11.2%	-112 k€
Countries outside the VTH calculation area			
ES	1%	0.9%	9 k€
IT	-5%	-8.1%	-81 k€

Note: * Hedge effectiveness represents the percentage of risk that is reduced through hedging. It is equal to correlaiton^2. The table displays correlation and hedge effectiveness difference between hubs (VTH-DE) for each country and the associated financial impact.

The colour code compares VTH to DE. It is based on the difference of correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to show how they would be impacted by the VTH.

Sources: 1. Hull, 2021, Options, Futures, and other Derivatives. Eleventh Edition; CL analysis based on EEX, TGE, OMIP and ENTSO-E data.

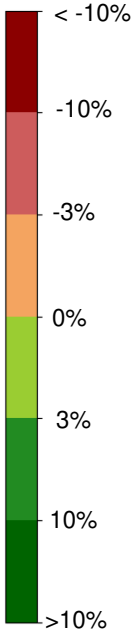
Static correlation shows that VTH calculated on CORE + South region is better correlated than on CORE only, but remains less correlated than DE for all but 3 countries

Results

- In the **CORE + South** hub configuration, **price correlation between Germany and other zones is generally higher than with the VTH.** This indicates that **proxy-hedging with Germany could provide higher quality of hedging than with the simulated VTH**.
  - For example, for a trader proxy-hedging Austrian (AT) CAL2023 with VTH the hedge effectiveness is **7.6% lower** compared to the almost perfect hedge effectiveness of DE. For an exposure of €1M, there is **€76k** higher residual risk for the VTH proxy hedge compared to DE.
  - This holds true even for Italy, which is part of the CORE + South VTH weighting. Despite that, we still observe similar correlation than with DE.
- **Exceptions are Spain and Poland**, where the correlation is mainly neutral or better with the VTH than with DE.
  - Correlation between Spain and the VTH increases since its weight contributes to VTH calculation in the CORE + South hub configuration.
- Compared to a VTH based on CORE, the VTH based on CORE + South region **tends to be a bit better correlated** with country prices.
  - A possible explanation is the bigger weight attributed to France in the CORE setup: as France had higher prices than the rest of the sample, including Spain and Italy may balance them down. The VTH then becomes better correlated with several countries esp. in the first years.

Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1/2/3, VTH based on demand-weighted **CORE + South region**

Year	2022		2023		2024		2025	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country								
AT	100%	96%	100%	96%	99%	92%	99%	87%
BE	96%	93%	90%	89%	82%	79%	77%	77%
CZ	100%	96%	100%	96%	100%	93%	100%	87%
DE	100%	96%	100%	96%	100%	93%	100%	87%
ES	85%	87%	65%	71%	46%	53%	35%	48%
FR	97%	96%	94%	95%	88%	90%	85%	85%
HU	98%	95%	99%	95%	99%	92%	100%	87%
IT	94%	93%	88%	88%	87%	87%	62%	63%
NL	97%	94%	93%	91%	94%	88%	79%	76%
PL	60%	63%	52%	57%	28%	34%	8%	26%
RO	98%	95%	99%	95%	100%	97%	99%	93%
SI	98%	97%	100%	97%	100%	97%		
SK	99%	95%	100%	96%	100%	93%	100%	87%



Note: The colour code compares VTH to DE. It is based on the difference of correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to sh how they would be impacted by the VTH.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data
Notes: * Hedge effectiveness represents the percentage of risk that is reduced through hedging.

Rolling correlation provides a dynamic view on correlation over the trading time, illustrating declining correlation in times of high volatility

Methodological interpretation

- Rolling correlation between two power prices (hub and country) based on 20 trading days log differences is a statistical measure that captures the **strength and direction of the relationship** between the log returns of these two prices over a moving window of 20 trading days.
- **Positive rolling correlation** indicates that when the log return of one power price increases, the other tends to increase as well.

Results

- Rolling correlation generally shows an **improvement of the correlation between both DE/VTH and other markets between 2019 and 2022**.

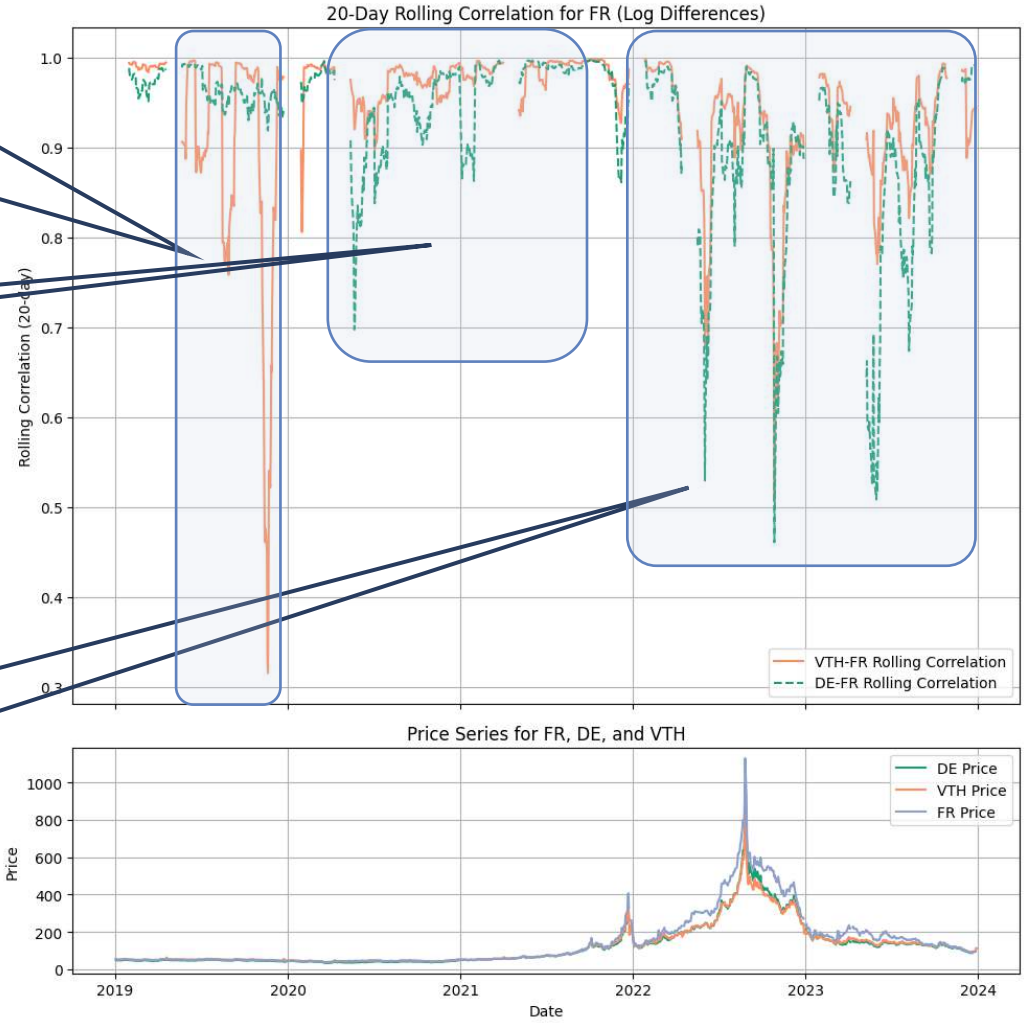
The correlation with the VTH is negatively affected at the end of 2019 due to few events of diverging prices (e.g. FR price flat while VTH drops by few euros) which impact rolling correlation for 20 days.

Improving correlation for both DE and VTH.

Correlation is deteriorating with the crisis and higher volatility is observed in 2022 and 2023. Over that period, correlation with DE/VTH appears relatively similar.

France: Rolling correlation of VTH-FR and DE-FR prices

In log differences, CAL+1, VTH based on demand-weighted **CORE + South region**

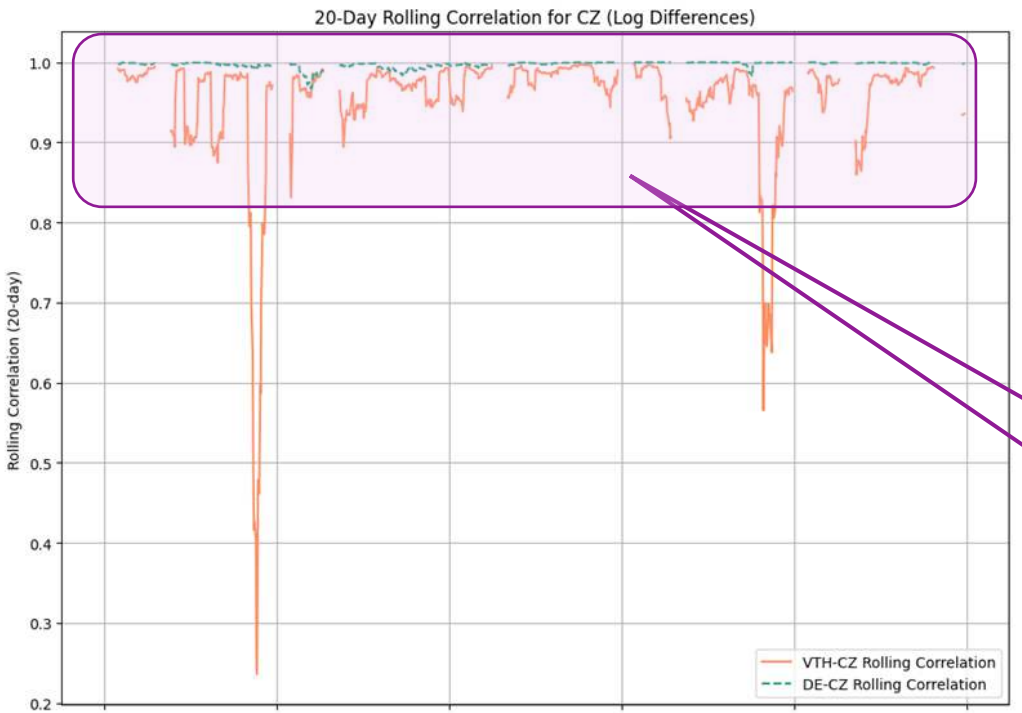


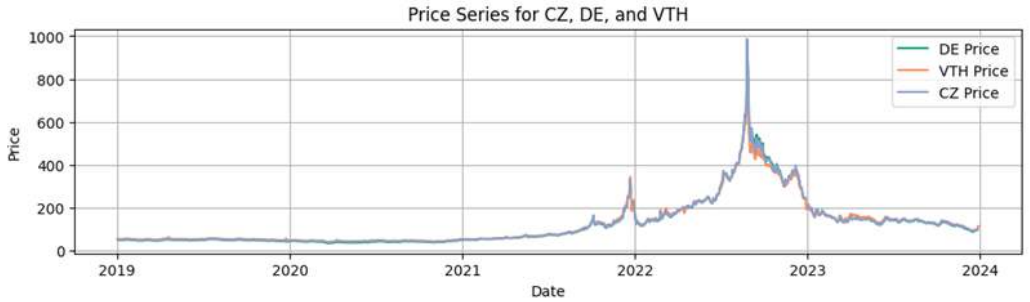
Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

Rolling correlation provides a dynamic view on correlation over the trading time, illustrating declining correlation in times of high volatility

Czechia: Rolling correlation of VTH-CZ and DE-CZ prices

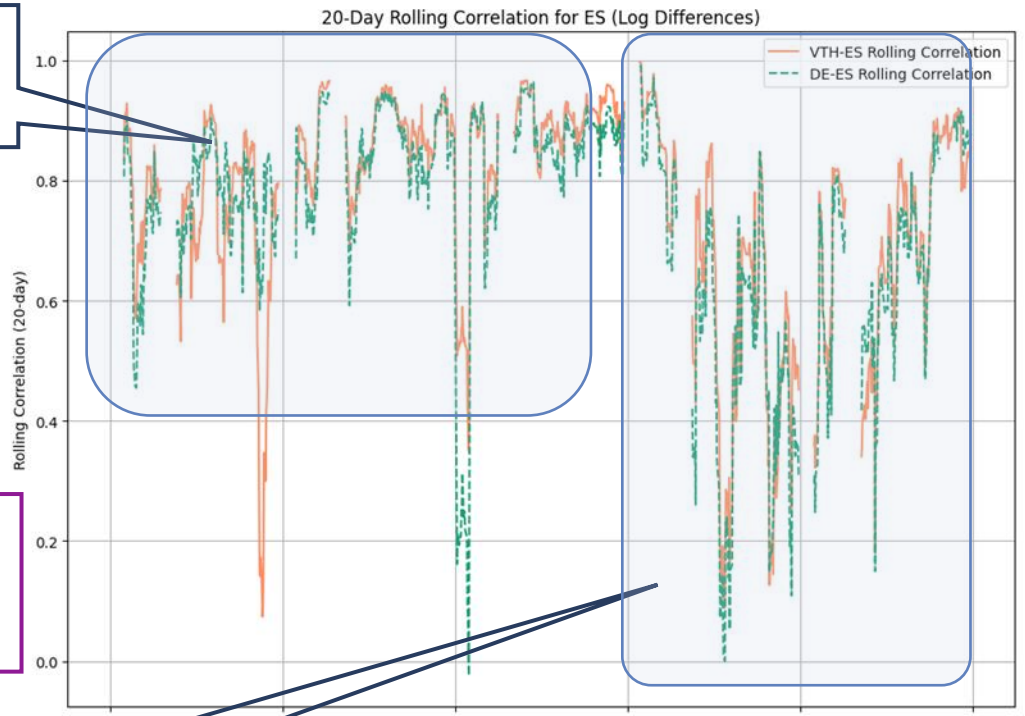
In log differences, CAL+1, VTH based on demand-weighted **CORE + South region**

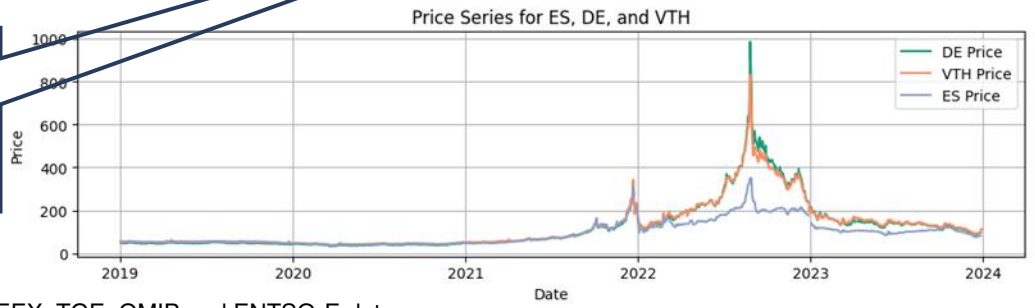




Spain: Rolling correlation of VTH-ES and DE-ES prices

In log differences, CAL+1, VTH based on demand-weighted **CORE + South region**





Improving correlation of DE and VTH with ES between 2019 and 2022.

Systematically higher correlation of DE with CZ throughout the entire horizon.

Dip and subsequent return in correlation of VTH and DE with ES during high volatility period.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

Rolling correlation provides a dynamic view on correlation over the trading time, illustrating declining correlation in times of high volatility

Results

- Rolling correlation generally shows an **improvement of the correlation between both HU/VTH and Romania between 2019 and 2022**.
- Overall, the correlation with DE is systematically higher than the correlation with VTH.

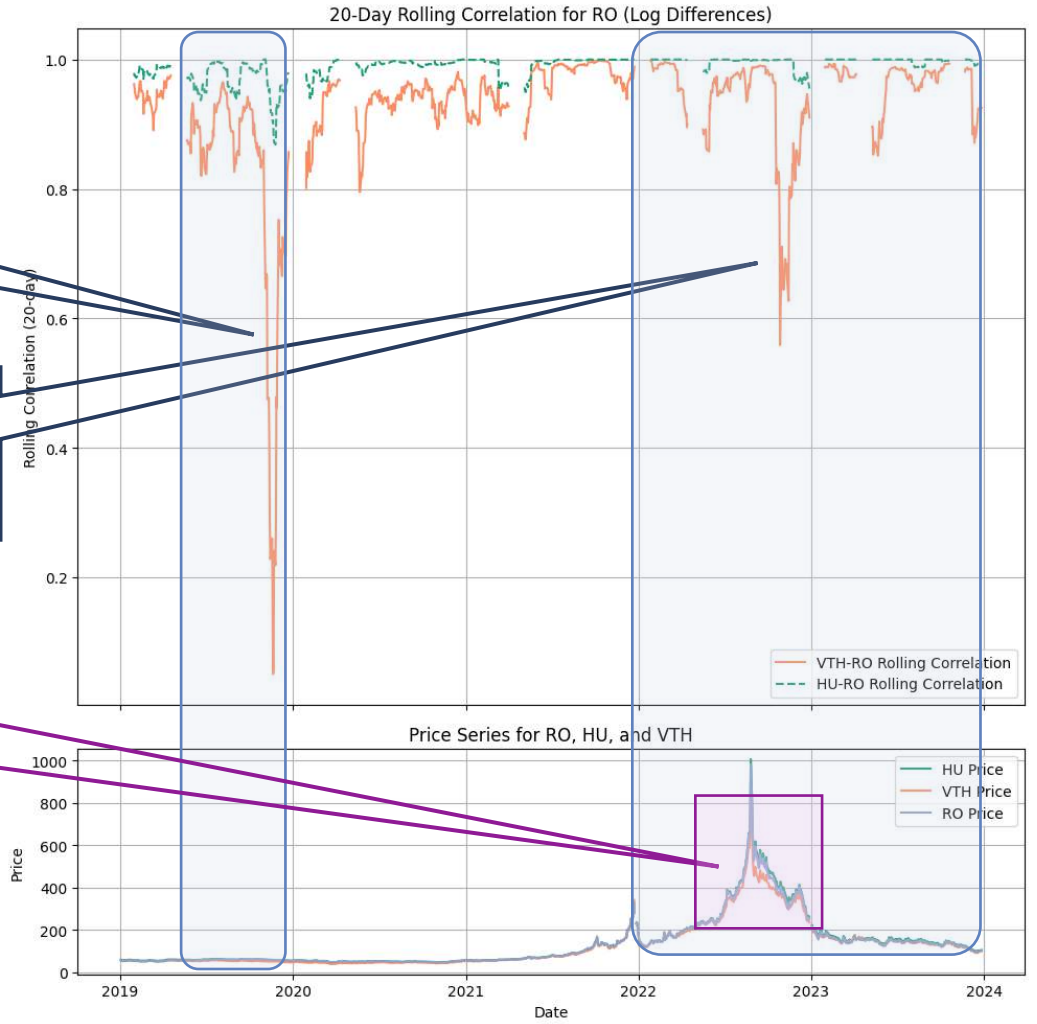
Romania: Rolling correlation of VTH-RO and HU-RO prices

In log differences, CAL+1, VTH based on demand-weighted **CORE + South region**

The correlation with the VTH is negatively affected at the end of 2019 due to few events of diverging prices and such events being carried forward for 20 days.

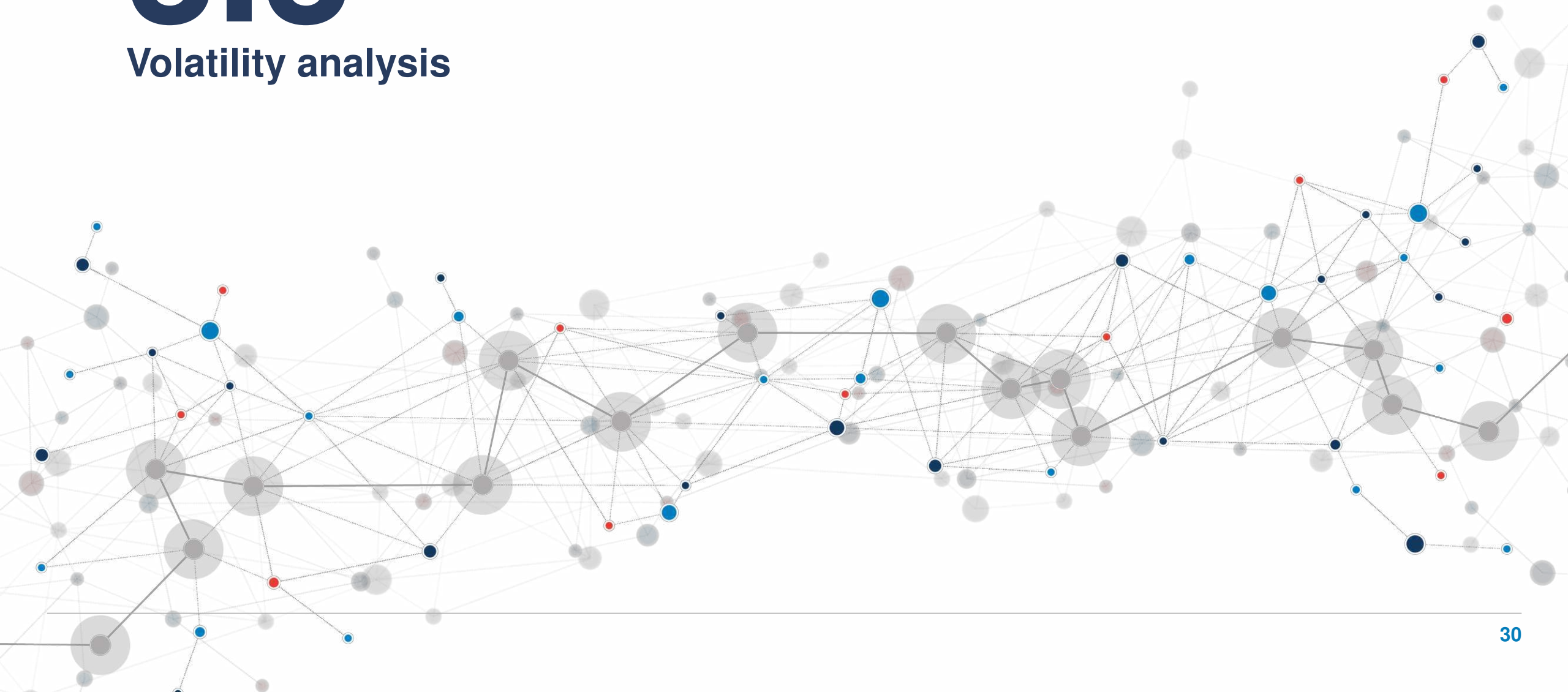
Correlation is deteriorating with the crisis and higher volatility is observed in 2022 and 2023. Over that period, however, RO prices are still better correlated with HU prices than VTH prices.

During the period of high volatility (second half of 2022), VTH prices are decoupling from HU and RO prices, the latter keeping a very similar evolution.



Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

3.3
Volatility analysis



As spreads with the VTH are, in most cases, more volatile, proxy-hedging in the VTH appears riskier than in the DE hub

Methodological interpretation

- The standard deviations of the spreads between VTH/DE and the different zones show the **volatility of these spreads**, and therefore the **risks associated with proxy-hedging in the VTH/DE.**
  - A ratio greater than 1 indicates that the price spreads with VTH are more volatile than with DE, suggesting that VTH has a higher risk of price swings relative to the DE.
  - Conversely, a ratio less than 1 indicates that the price spreads with DE have higher volatility.

Results

- For most of the countries, **proxy-hedging in the virtual hub appears riskier than proxy-hedging in Germany**.
  - For most of the countries, incl. Spain or Italy (not incl. in VTH calculation), the ratio of the standard deviations (VTH/DE) is significantly higher than 1. This indicates that the volatility of the spreads compared to the reference markets is higher in the VTH configuration.
  - For several countries, the ratio can be very high, such as CZ, RO, SK or HU at least in some years.
- **Only for France, the VTH may offer less volatility** across the 4 years, thanks to their weight in the calculation of the VTH prices.
- Poland-VTH spread volatility improves gradually compared to DE, becoming lower in 2024 and 2025.

Ratio of standard deviations of spreads (VTH/DE) by country and delivery year, consumption-weighted

CORE region

Note: liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

The results are more contrasted when the VTH scope is extended to South: the majority of countries would still be better off proxy-hedging using DE

Results

- The **geographical scope extension of the VTH leads to lower volatility with the VTH for 5 countries except for 2022** (BE, ES, IT, NL and PL).
- The geographical scope extension of the VTH **improves the ratio for half of the countries**, whereas the other half would be worse off:
  - **Italy and Spain's spreads with VTH have lower volatility than with DE when integrated in the VTH calculation** (except in 2022);
  - Belgium and the Netherlands see a reduced volatility with the VTH compared to DE;
  - Conversely, **France's price loses influence in the VTH calculation** since its weight is dissolved by additional countries, resulting in riskier proxy-hedging with VTH compared to DE.
- As shown in the appendix, volatility with the VTH remains higher for most Eastern countries, where market participants are likely to continue to proxy-hedge in Hungary.

➢ **The analysis may also indicate that traders (from many countries) will likely continue to proxy-hedge in Germany (and potentially in Hungary for Eastern-based parties), with the risk of splitting liquidity, resulting in lower liquidity on the VTH than desired. Conversely, the move to VTH for some may negatively affect liquidity in Germany (/ Hungary).**

Ratio of standard deviations of spreads (VTH/DE) by country and delivery year, consumption-weighted

CORE + South region

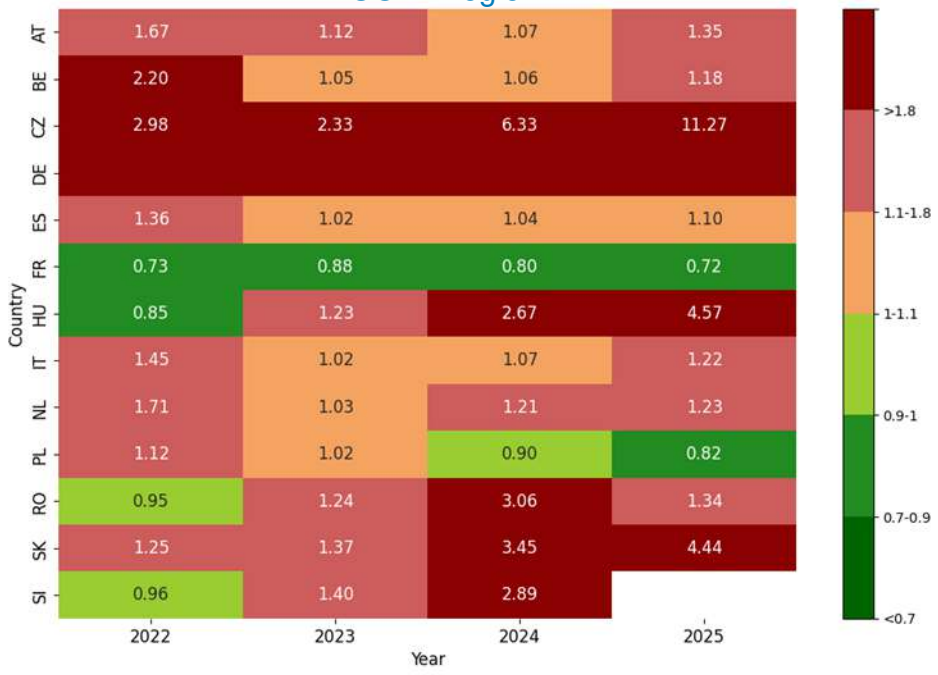
Note: liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

The results are more contrasted when the VTH scope is extended to South: volatility of the spreads increases for half of the countries and conversely for the rest

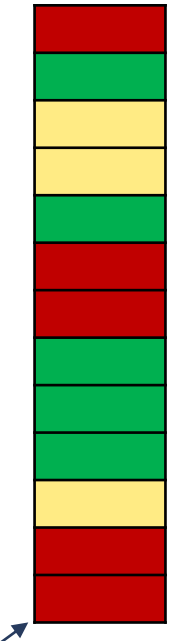
Ratio of standard deviations of spreads (VTH/DE) by country and delivery year, consumption-weighted

CORE region



CORE + South region

Comparison between regions*



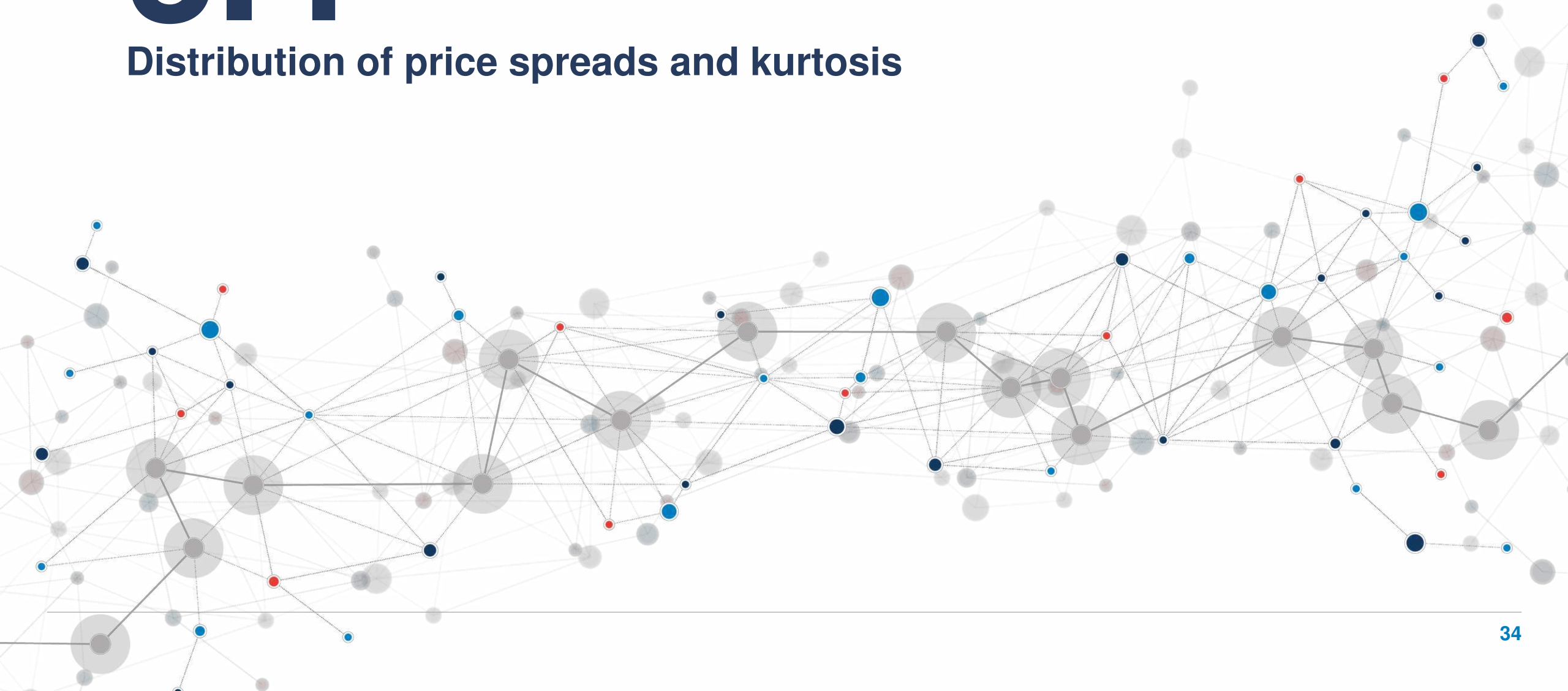
Note: liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3.

Note: * The colour ladder indicates if CORE + South specification is better (green), worse (red) or neutral (yellow) compared to the CORE-only specification.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

3.4

Distribution of price spreads and kurtosis



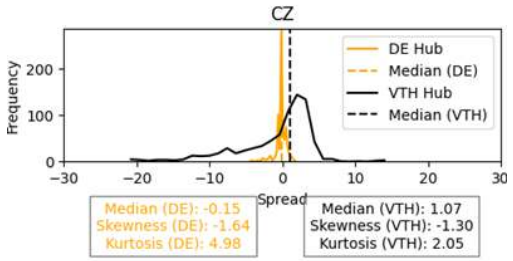
Distributions of spreads with VTH/DE show contrasting and inconclusive results

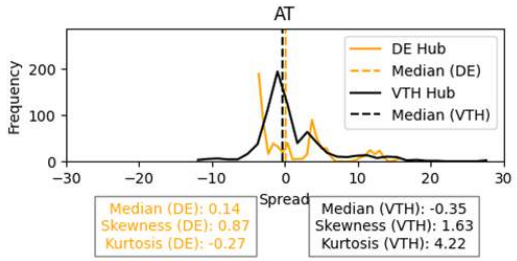
- Distributions of spreads with Germany and VTH show contrasting results for different countries.
- Some countries show “good-looking” distributions around the German price, such as the Czech Republic (CZ), which has very tight and relatively evenly distributed spreads, irrespective of the regional configuration.
- Others, such as Austria (AT), have a more balanced distribution with VTH, although broader than with DE. It may look much better in the CORE configuration (closer to and more evenly distributed around zero) compared to the broader CORE + South configuration.
- Others have difficult-to-read results, such as Spain (ES), whose distribution of spreads is far off a normal one, irrespective of regional configuration.

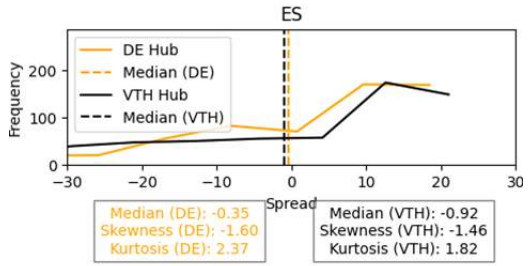
➢ **No clear general conclusion on the best hub and configuration can be drawn visually.**

Price spread distributions (area - hub) for DE and VTH hubs, CAL2024 product, consumption-weighted

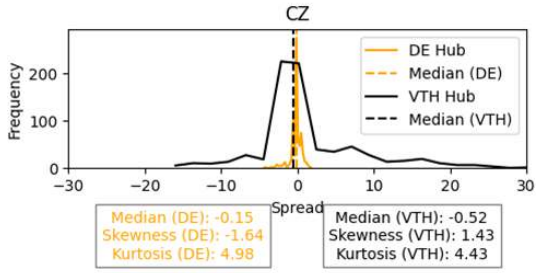
CORE region

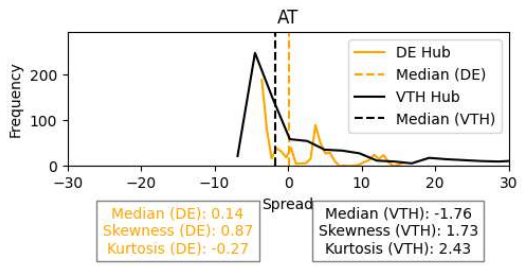


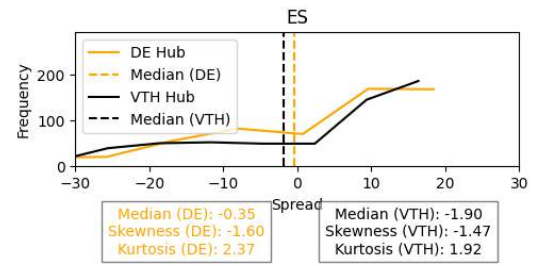




CORE + South region







Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data
Note: All distribution figures have a mean value of 0 (de-meaned); the x-axis has a fixed range of+-30.

Especially with a narrower geographical scope, the distribution of spreads with VTH generally has a lower kurtosis, i.e. lower risks of outliers

Methodological interpretation

- The kurtosis is a metric **looking at the probability of outliers,** measuring "tailed-ness" of the distribution**.** High kurtosis (>3) indicates higher probability of extreme price differences (outliers), whereas <3 indicates the opposite. Values close to 3 correspond to a normal distribution.
- Although volatility and correlation appear to be tier-1 indicators for the hedging quality, looking at **kurtosis is still interesting to assess risks of large deviations**, i.e. of inadequate hedging.
- It is worth noting however that, **when such large deviations occur, traders may decide not to trade / proxy-hedge and wait to see whether things normalise**.

Results

- Even though correlation and volatility indicators tend to be better with Germany, the **distribution of spreads for many countries show higher kurtosis with Germany than with the VTH, especially with the CORE VTH**.
- This can be explained by the fact that using a VTH smoothens the impact of specific occasional events affecting the DE price and may also reflect in the VTH price specific occasional events affecting the considered countries along with others.
- The extension of the geographical scope of the VTH tends to increase kurtosis for a majority of countries, especially for Eastern countries.

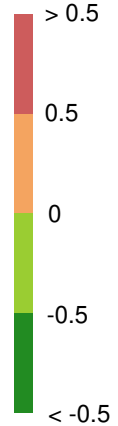
Overview of summary statistics for the distribution of spreads (area - hub) for CAL2024 products and consumption weighted VTH

CORE region

Country	DE	VTH
AT	-0.27	4.22
BE	1.53	0.81
CZ	4.98	2.05
ES	2.37	1.82
FR	-0.11	-0.16
HU	-0.54	2.01
IT	1.99	1.23
NL	1.38	0.28
PL	5.18	4.81
SK	0.06	1.61
DE		1.59
VTH	1.59	

CORE + South region

Country	DE	VTH
AT	-0.27	2.43
BE	1.53	1.55
CZ	4.98	4.43
ES	2.37	1.92
FR	-0.11	-0.11
HU	-0.54	4.95
IT	1.99	1.31
NL	1.38	2.40
PL	5.18	4.25
SK	0.06	5.27
DE		4.86
VTH	4.86	

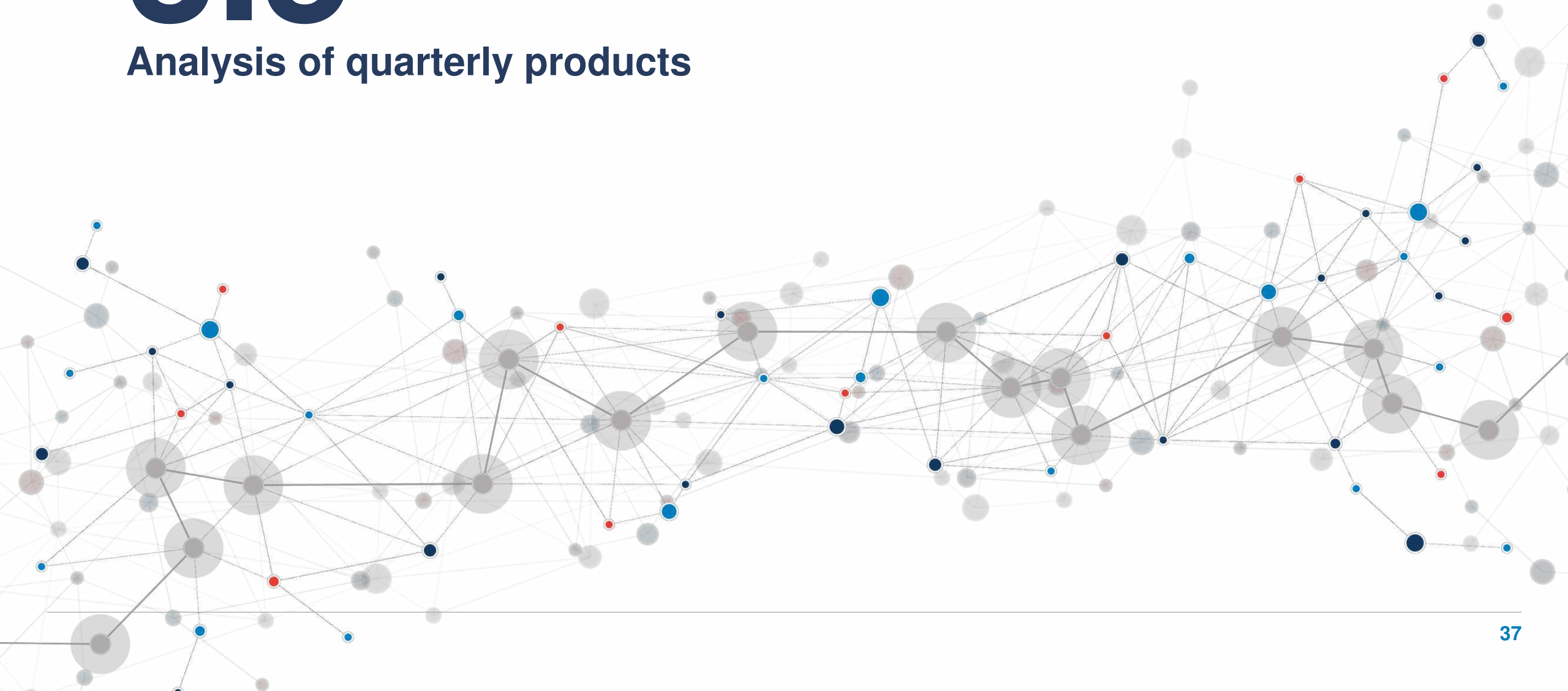


Note: The colour indicators show whether using VTH is better (green) or worse (red) compared to DE. Values lower than 3 indicate lower likelihood of outliers (compared to normal distribution) and above 3 indicate higher likelihood of extreme outliers. The colour coding is based on the difference of kurtosis between VTH and DE: $kurt_{VTH} - kurt_{DE}$.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

3.5

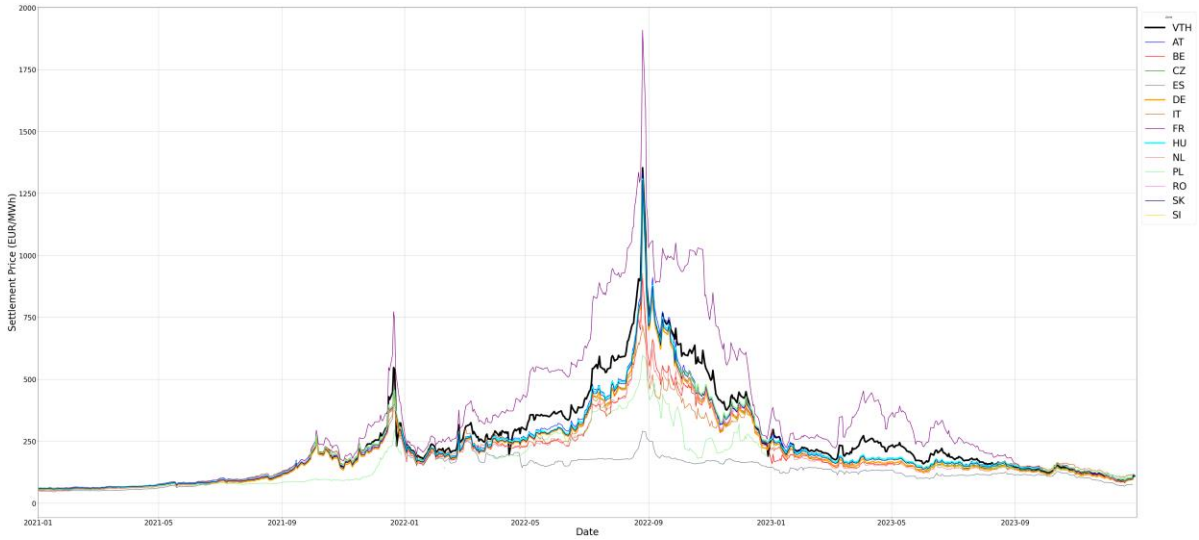
Analysis of quarterly products



For Q1 +1 products, the settlement price of the VTH for the CORE region is strongly influenced by higher and more volatile prices in France

The graphs show the evolution of settlement prices over the period for Q1 + 1 products, i.e. quarterly products for the first quarter and for which the delivery year is the year N+1 (similar to CAL+1 products) over 2022-2023 and in 2023. During these periods, French prices were particularly high and volatile, bringing up the VTH price.

Evolution of settlement prices for Q1 +1 product
CORE region, demand-weighted



Evolution of settlement prices for Q1 +1 product traded in 2023
CORE region, demand-weighted

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

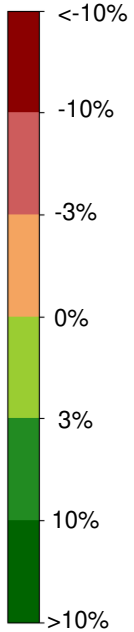
Static correlation shows that, also for quarterly products, VTH calculated on CORE is noisier and less correlated than DE for most countries

Results

- The results indicate **that, also for quarterly products, VTH based on demand-weighted CORE region tends to be noisier than DE** for most of the delivery years and country pairs.
- This indicates that **proxy-hedging with Germany could provide higher quality hedging than with the simulated VTH for quarterly products, as for yearly**.
- The **correlation does not improve for the CORE countries** when Southern Europe is not included in the VTH calculation.
  - Only France, given its weight in the VTH calculation and its relatively low correlation with Germany when compared to other CORE countries, shows higher correlation with VTH.

Price correlation (in log differences) between hub and country pairs, by delivery year for Q1+1, VTH based on demand-weighted **CORE region**

Year	2020		2021		2022		2023		2024	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country										
AT	98%	93%	99%	94%	100%	97%	100%	89%	98%	85%
BE	72%	78%	88%	88%	97%	95%	89%	84%	74%	67%
CZ	99%	94%	100%	94%	100%	97%	100%	89%	100%	87%
DE	100%	94%	100%	94%	100%	97%	100%	89%	100%	87%
FR	88%	94%	81%	93%	92%	97%	80%	88%	71%	92%
HU	82%	78%	87%	83%	99%	97%	100%	89%	100%	87%
NL	92%	90%	95%	91%	95%	93%	86%	79%	88%	80%
PL	39%	19%	64%	64%	45%	44%	32%	37%	47%	45%
RO	77%	74%	84%	83%	99%	97%	99%	68%	97%	97%
SI	69%	65%	88%	88%	100%	97%	100%	68%	99%	98%
SK	97%	92%	96%	91%	100%	97%	100%	89%	100%	87%
Countries outside the VTH calculation area										
ES	71%	75%	78%	75%	87%	86%	61%	59%	58%	48%
IT	91%	90%	93%	90%	91%	89%	84%	75%	93%	82%



Note: The colour code compares VTH to DE. It is based on the difference of correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to show how they would be impacted by the VTH.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

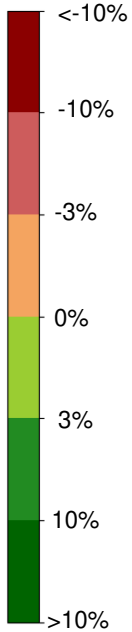
Static correlation shows that VTH calculated on CORE + South is still noisier and less correlated than DE for most countries, but improves compared to CORE-only

Results

- The results indicate **that, also for quarterly products, VTH based on demand-weighted CORE + South region tends to be noisier than DE** for most of the delivery years and country pairs.
- This indicates that **proxy-hedging with Germany could provide higher quality of hedging than with the simulated VTH for quarterly products, as for yearly**.
- Compared to the CORE-only, the VTH based on CORE + South **tends to improve correlation slightly,** but DE is still more correlated to almost all countries.
- **Beyond France, Spain** also has a slightly better correlation with the VTH than with Germany in the CORE + South region configuration, given its weight in the VTH calculation. Correlation between Italy and VTH improves but remains inferior to with Germany.

Price correlation (in log differences) between hub and country pairs, by delivery year for Q1+1, VTH based on demand-weighted **CORE + South region**

Year	2020		2021		2022		2023		2024	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country										
AT	98%	94%	99%	95%	100%	97%	100%	93%	98%	89%
BE	72%	79%	88%	89%	97%	95%	89%	87%	74%	71%
CZ	99%	95%	100%	95%	100%	97%	100%	93%	100%	90%
DE	100%	95%	100%	95%	100%	97%	100%	93%	100%	90%
ES	71%	78%	78%	79%	87%	89%	61%	65%	58%	56%
FR	88%	95%	81%	92%	92%	97%	80%	90%	71%	92%
HU	82%	79%	87%	84%	99%	97%	100%	93%	100%	90%
IT	91%	93%	93%	93%	91%	92%	84%	82%	93%	88%
NL	92%	91%	95%	92%	95%	94%	86%	83%	88%	83%
PL	39%	20%	64%	65%	45%	45%	32%	38%	47%	45%
RO	77%	75%	84%	84%	99%	97%	99%	80%	97%	96%
SI	69%	68%	88%	88%	100%	97%	100%	80%	99%	97%
SK	97%	93%	96%	92%	100%	97%	100%	93%	100%	90%



Note: The colour code compares VTH to DE. It is based on the difference of correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to show how they would be impacted by the VTH.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

For most of the countries, especially smaller ones, hedging in VTH appears riskier than proxy-hedging in Germany also for Q1+1 products

The graph shows the ratio of standard deviations of the spreads (country - hub) of front quarterly products (Q1+1) by delivery year.

For most of the countries, hedging in the virtual hub will be riskier than proxy-hedging in Germany.

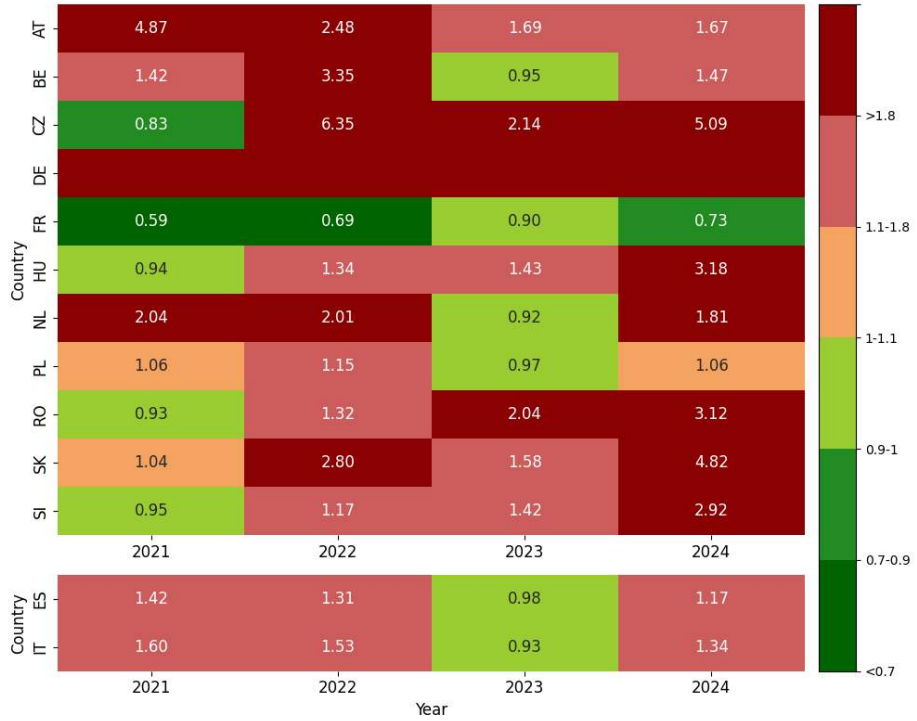
- For most of the countries, the ratio of the standard deviations (VTH/DE) is significantly higher than 1. This indicates that the volatility of the spreads compared to the reference markets is higher in the VTH configuration.
- For several countries, the ratio can be very high, such as AT, CZ, SI or SK, but also HU and BE at least in some years.

France presents lower volatility with VTH for every year.

Similar results can be observed for VTH calculated based on CORE + South region.

Ratio of the standard deviations of spreads (VTH/DE) by country and delivery year, for front quarterly (Q1+1) products

CORE region

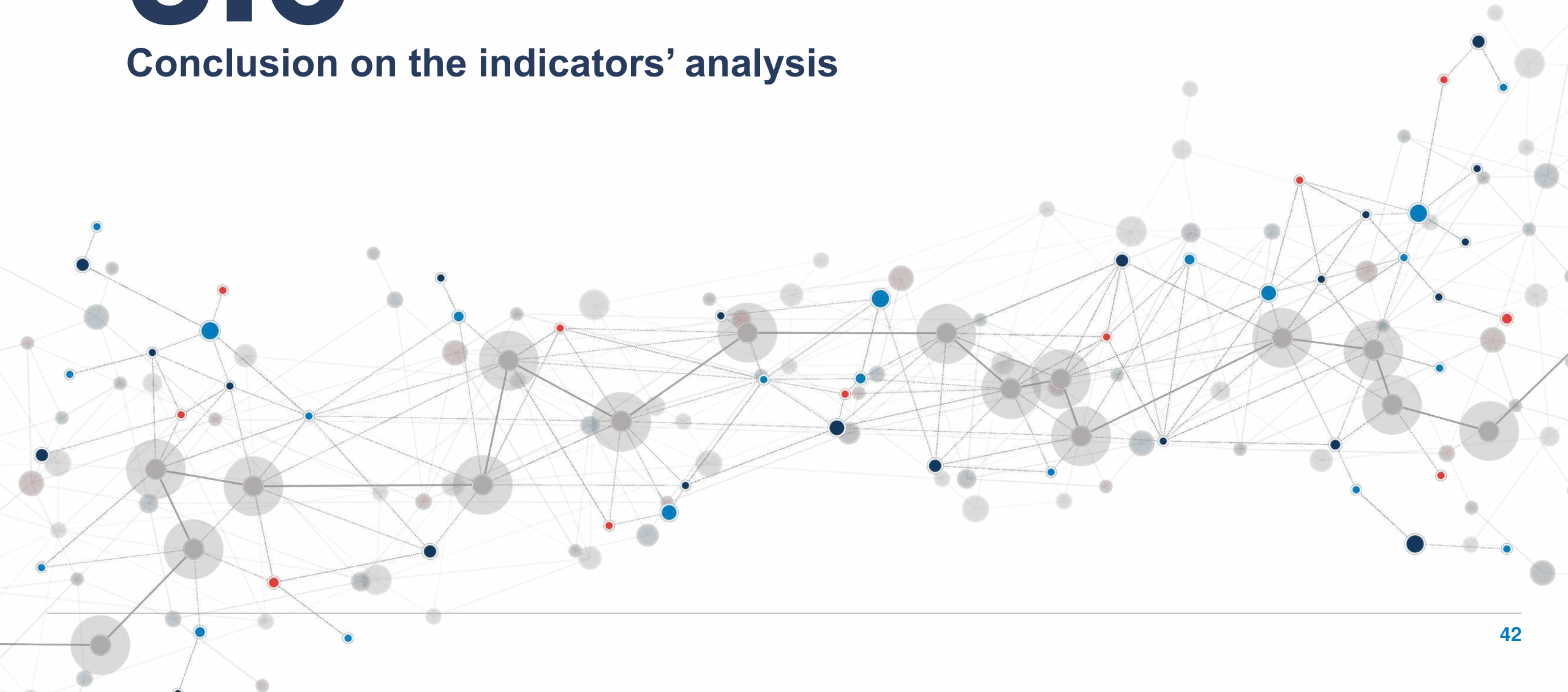


Note: liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

3.6

Conclusion on the indicators' analysis



This analysis indicates that Germany or Hungary will likely remain reference markets for proxy-hedging

Based on our estimation methodology and simulated VTH prices, the quality of proxy-hedging in Germany appears higher than in the VTH in most cases:

- **Price correlations are higher with Germany than with the VTH** for CAL products for the vast majority of countries whatever the geographical scope of VTH.
- **All countries, except for France in the CORE scenario** (and Poland to a less clear extent)**, show a higher spread volatility with VTH than with Germany.** Some countries show lower volatility of the spreads with the VTH in the CORE + South scenario, but volatility increases for other countries.
- In the CORE scenario, the VTH seems to have a smoothening effect on high spreads: even though correlation and volatility indicators tend to be better with Germany, the **distribution of spreads for many countries shows higher kurtosis with Germany than with the VTH**. However, this indicator is probably a tier-2 proxy of hedging quality, especially as, **when such large deviations occur, traders may decide not to trade / proxy-hedge and wait and see whether things normalise**.
- Similar results are observed (i) when considering Hungary as a proxy-hedging market (at least for countries where market participants would be more likely to proxy-hedge in Hungary than in Germany, i.e. Eastern countries) or (ii) for quarterly Q1 products.
- These results are unaffected by a change of the VTH price weighting approach to a production weight (cf. Annex 7.1).

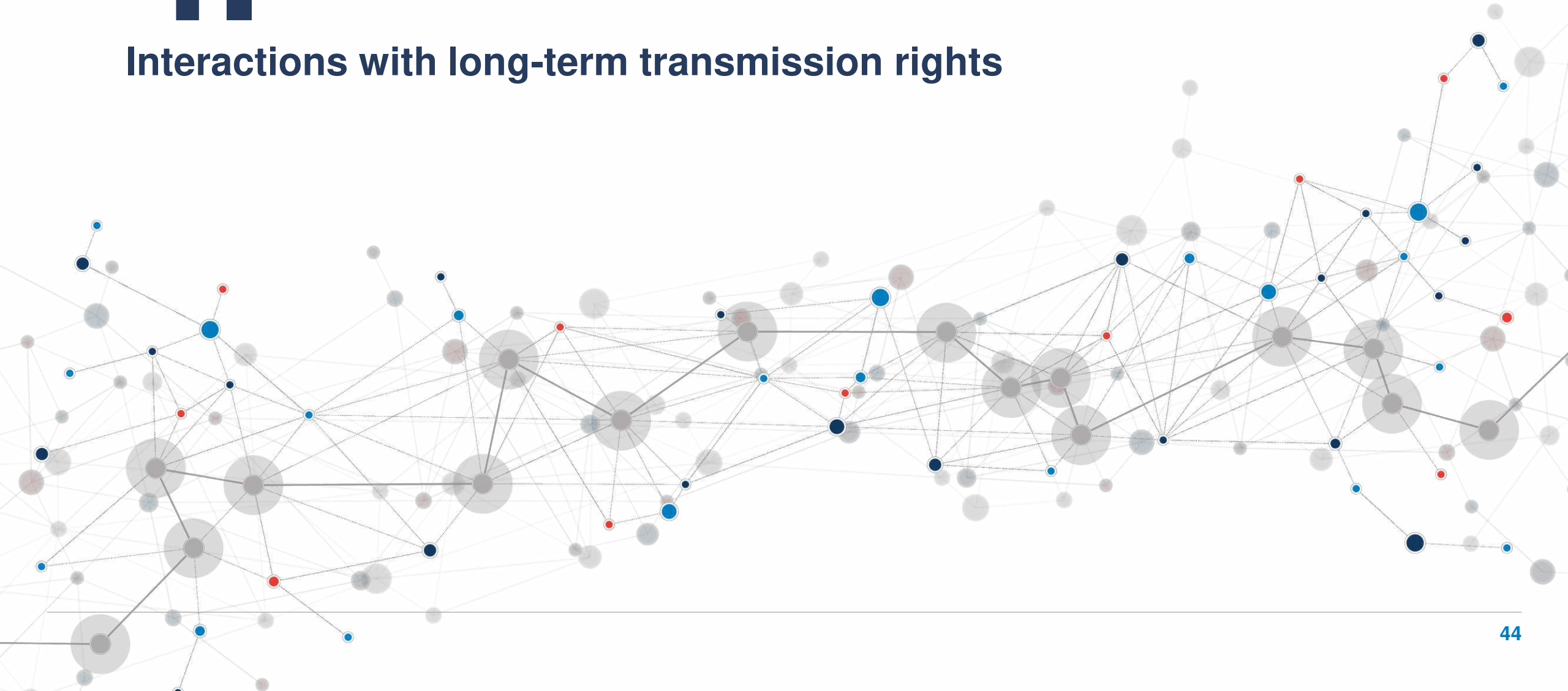
This analysis also underpins the risks in terms of liquidity impact of the creation of the VTH:

- The analysis indicates that proxy-hedging **will likely continue to be performed in Germany (or Hungary for MPs in some countries), with the risk of splitting liquidity, meaning that liquidity will not develop on the VTH enough to create a liquid hub.**
- **Conversely, it may negatively affect liquidity in Germany (/Hungary**), as MPs in other countries may move away from proxy-hedging in these markets to use the VTH.
- The **risk of liquidity split between hub and large bidding zones is seen as a major risk** by most stakeholders and also some academics.[1]

Notes: ENTSO-E (2024) Advocacy Note on Forward Markets. Neon energy, March 2024, Report on cross-border forward markets.

4.

Interactions with long-term transmission rights



The implications of a move towards zone-to-hub Long-Term Transmission Rights' allocation need to be carefully analysed

Capacity calculation in the virtual hub configuration is yet to be properly assessed[1]	▪ Conceptually, similar grid constraints may result in equivalent levels of capacities made available to the markets. ▪ However, it may be difficult to transpose capacity calculation in zone-to-hub and allocate the same underlying "physical" capacity while guaranteeing congestion income hedging for TSOs to cover LTTR firmness costs. ➢ The way capacity would be transposed in zone-to-hub LTTR volumes would **need to be further investigated** as well as the impact on TSOs' revenue risk exposure, but **it cannot be excluded at this stage that it may result in higher risks for TSOs or lower capacity allocated.**
Zone-to-hub LTTR will affect current hedging strategies and create transition costs	▪ LTTR options cannot be chained or decomposed, meaning that market participants will not be able to replicate zone-to-zone options based on zone-to-hub options. ➢ **Cross-border hedging by market participants will be affected and will need to adapt**, with unclear consequences at this stage on the ability to hedge equivalently. ➢ Amongst other implications for market participants of this reform, adapting hedging strategy will **increase transition costs**.
The risk of less adapted hedging through the hub may increase needs for LTTR	▪ As illustrated, VTH prices might be less correlated with forward prices in many markets, and volatility of the spreads higher. Risk of liquidity split between existing "proxy-hedging" markets and VTH may accentuate that risk. ▪ The **absence of zone-to-zone LTTRs may complicate cross-border hedging combined with proxy-hedging**. ➢ To "compensate" and maintain a comparable quality of hedging, **higher LTTR allocation could be desirable**. **Higher LTTR allocation would increase risks and costs borne by TSOs** (associated with firmness).

Notes: ENTSO-E (2024) Advocacy Note on Forward Markets. Neon (Report on cross-border forward markets).

When comparing LTTR design options, a similar counterfactual needs to be used, especially in terms of capacity calculation and risks taken by TSOs

Comparing options should be done with the same counterfactual

- If higher LTTR allocation could be desirable in the VTH setup, this may also be **true in the current setup for market participants**, e.g. as reflected in past positions from Energy Traders Europe or Eurelectric.
- Indeed, higher available cross-zonal capacity for zone-to-zone LTTRs would increase cross-border trading and hedging opportunities and improve basis risk coverage by market participants, esp. those proxy-hedging.

➢ Any **reforms improving capacity calculation/allocation** (e.g. flow-based, maximisation of capacity to the market) **or increasing risks taken by TSOs** (e.g. LTA inclusion removal or beyond) **for zone-to-hub LTTRs should also be considered in the counterfactual (zone-to-zone LTTRs)**, as it would also strongly improve correlation between markets and quality of proxy-hedging with existing liquid hubs.

Options exist to improve current forward markets in Continental Europe

- **Removal of LTA inclusion;**
- **Increasing auction frequency** of LTTR;
- **Longer product maturity**, e.g. 2-3 years, to align LTTRs with current market liquidity and hedging needs of market participants;
- **Secondary market for LTTRs** in place of the complex return system to the TSOs, to make LTTRs easier to re-trade and capacity rights better used by the market;
- **Improved capacity calculation**, through e.g. enhanced statistical NTC and supply function or flow-based LTTR calculation/allocation;
- Assess impact of **misguided policy interventions and stringer requirements stemming from financial regulation.**

Notes: ENTSO-E (2024) Advocacy Note on Forward Markets. Energy Traders Europe (2022) Response to ACER/CEER consultation on forward markets, Eurelectric (2022) Response to ACER/CER consultation on forward markets

LTTR obligations may be better adapted to a virtual hub configuration, but raise significant concerns from market participants

- Some link the move to virtual hubs with zone-to-hub LTTRs to the use of obligations.[1]
- However, if TSOs allocate pairs of LTTR obligations to replicate zone-to-zone, they will unlikely have positive impact on the virtual hub (same demand and offer created within the hub). **Zone-to-hub LTTR obligations allocated by TSOs only in pairs would not foster any liquidity development on the virtual hub for forward markets**, so it may **not provide sufficient incentives for the creation of a liquid virtual hub**.
- Moreover, it raises key questions: how to determine the volumes to be allocated by TSOs? What is the risk they would therefore be taking? **Would that be adapted to risk hedging for market participants?**

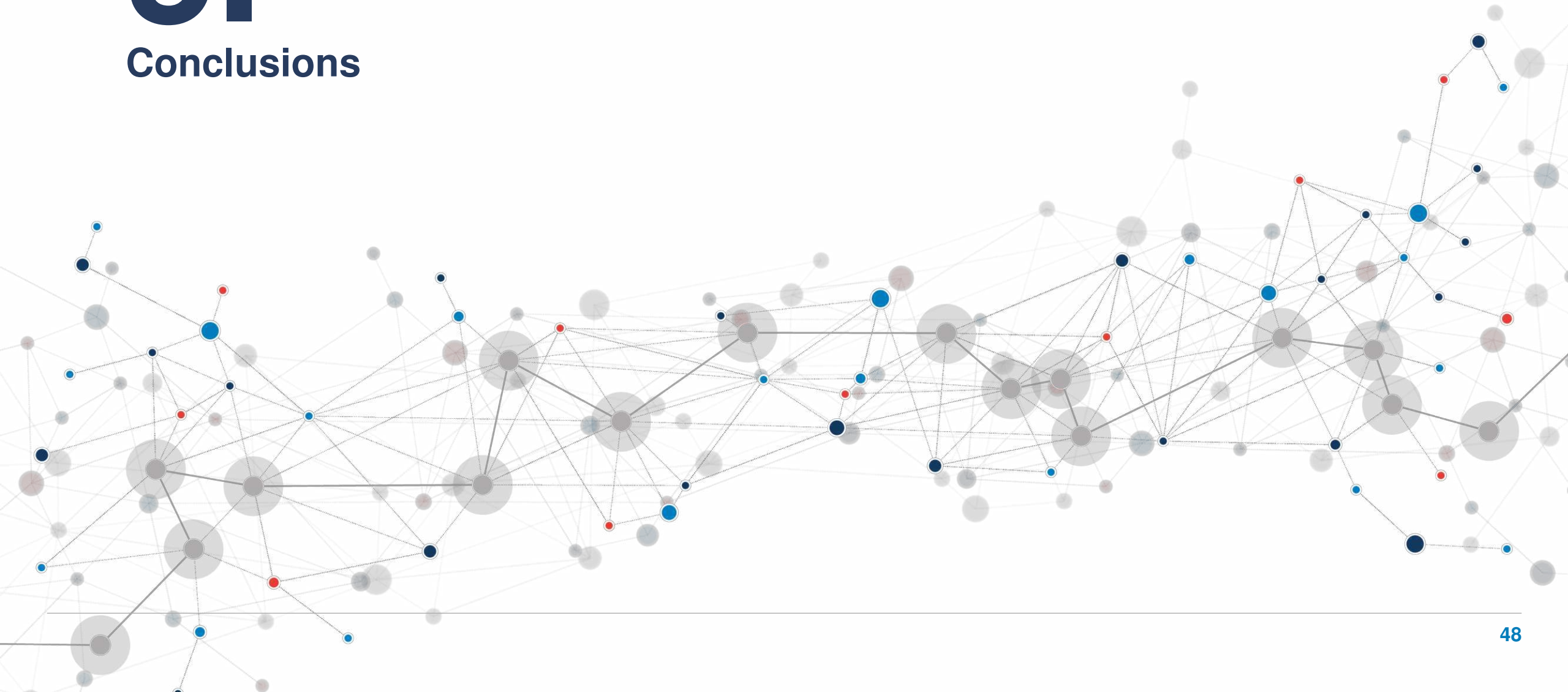
For some market participants, **LTTRs obligations would create additional risks and hence not be adapted to risk hedging**. Their position can be summarised as follows:

Disadvantages:
- In accordance with FCA objectives, the **choice of products for LTTRs should depend on the appetite of MPs**: there is however no interest from MPs as they do not want to be exposed to the full obligation.
- FTR obligations do not allow MPs to grasp opportunities in the same way as options because FTR obligations "lock" the situation forever/whatever the market context.

Advantages:
- FTR obligations could potentially allow TSOs to **increase the quantities of LTTR offered**. However, the **value of an obligation is lower than the value of an option**.
- FTR obligations would **only make sense if market participants would trade between themselves such or similar contracts**. In such cases, payment for the negative spread would be the consequence of risk premiums. This is however **not the case when TSOs allocate capacity**.

Notes: ENTSO-E (2024) Advocacy Note on Forward Markets, Neon (Report on cross-border forward markets), Energy Traders Europe (2022) Response to ACER/CEER consultation on forward markets, Eurelectric (2022) Response to ACER/CER consultation on forward markets

5.
Conclusions



Conclusions

The analysis of the virtual hub in the CORE region (and its potential extension to South) – based on our assumptions and estimation approach – does not highlight benefits of such an approach in terms of hedging quality for market participants.

- On the contrary, the quality of proxy-hedging with Germany or Hungary appears higher than with the VTH in most cases.
- The correlation between VTH and zone prices as well as the volatility of spreads are worse in the VTH case for most of the countries (e.g. Eastern).

The risk of liquidity split between VTH and physical hubs is major.

- The analysis underpins the **liquidity impact risks of the creation of the VTH** already identified by many stakeholders.
- **Traders (from many countries) are likely to continue to proxy-hedge in physical hubs such as Germany or Hungary, with the risk of splitting liquidity. This will also result in liquidity not developing as expected on the VTH to be able to create a liquid hub.**
- **Conversely, the move to VTH for some may negatively affect liquidity in physical hubs such as Germany and Hungary,** as some may move away from proxy-hedging in these markets to use the VTH.

The implications of a move towards zone-to-hub LTTR allocation need to be carefully analysed.

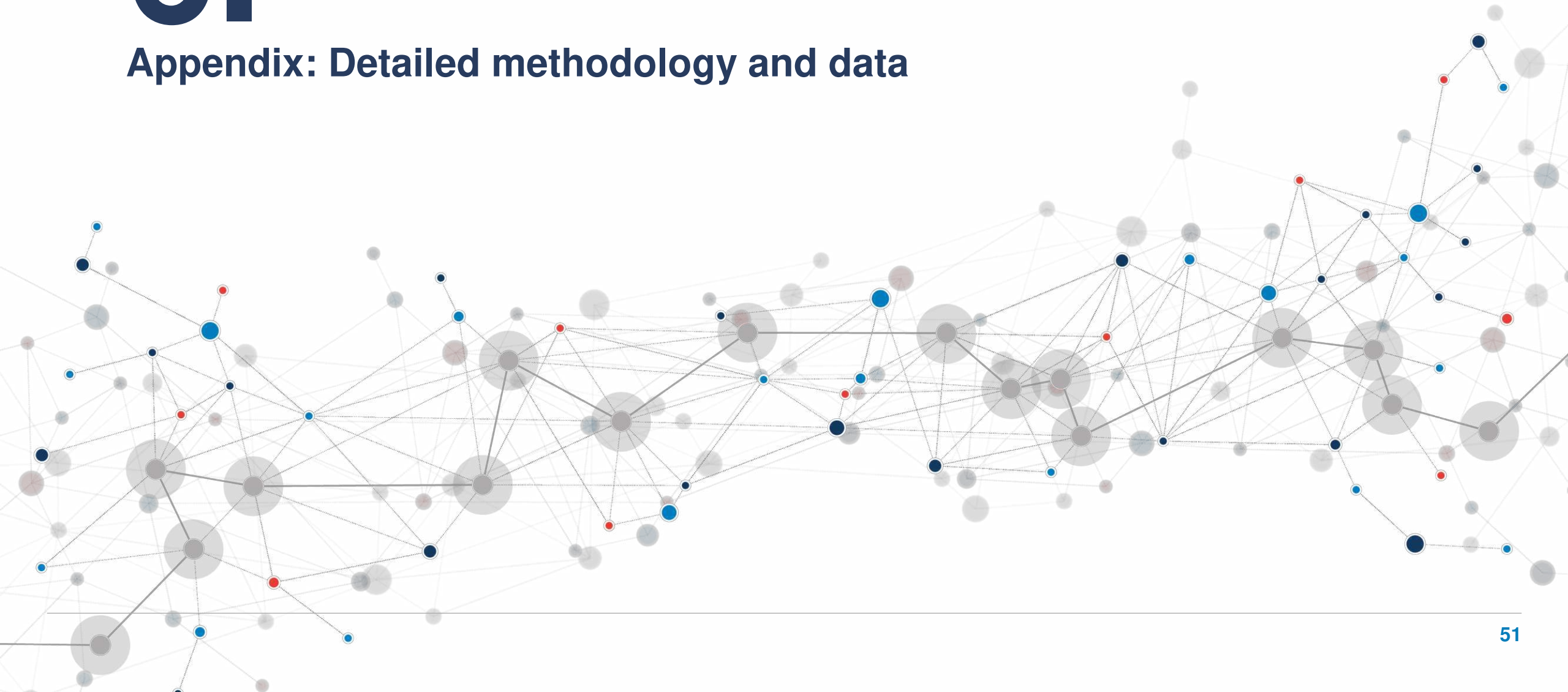
- **Capacity calculation in the virtual hub configuration is yet to be properly assessed**, but it cannot be excluded at this stage that it may result in **higher risks for TSOs or lower capacity allocated**.
- Cross-border hedging by market participants will be affected and will need to adapt, increasing **transition costs**.
- The risk of less optimal hedging through the hub may increase the need for LTTRs.

Ultimately, the proposed introduction of VTH risks negatively affecting forward markets, potentially resulting in higher hedging costs, reduced hedging opportunities and, consequently, higher costs for consumers.

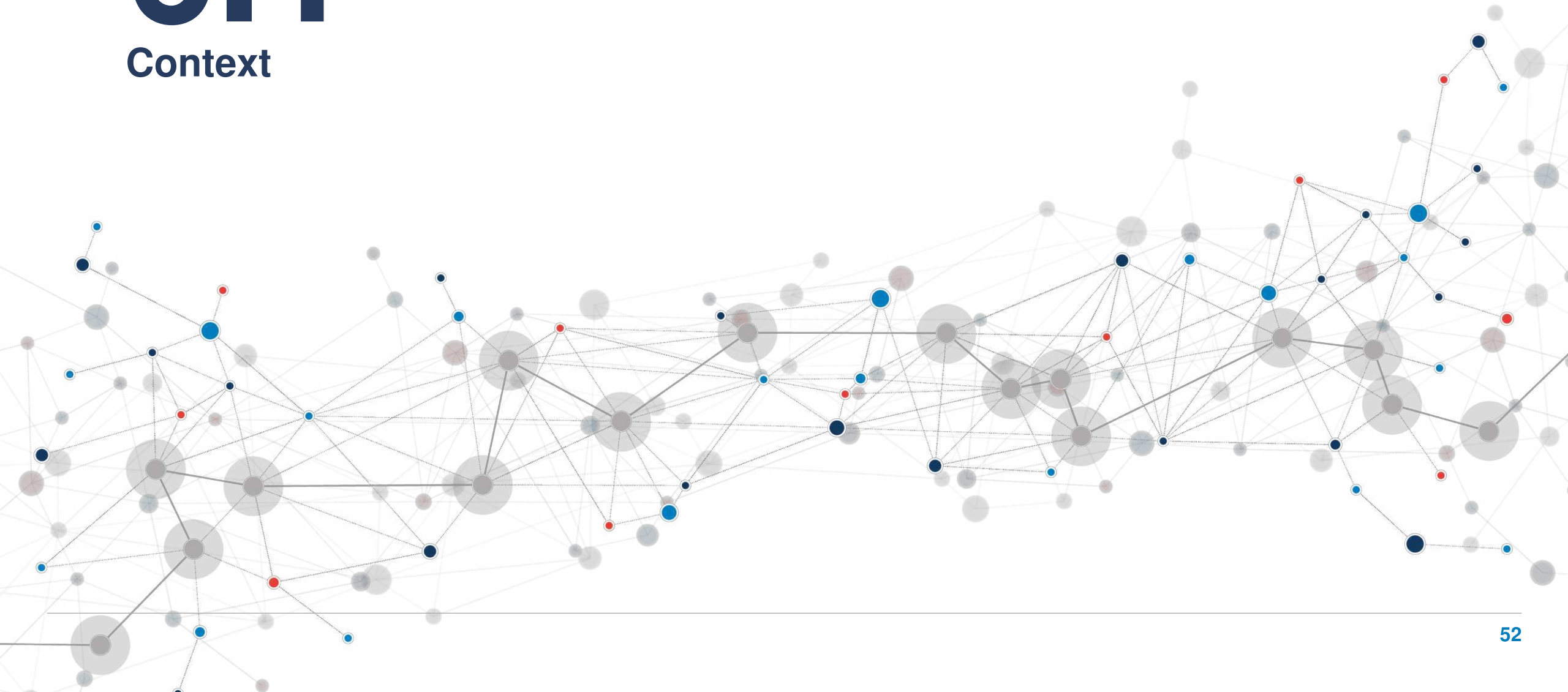
Appendix – Summary table

6.

Appendix: Detailed methodology and data



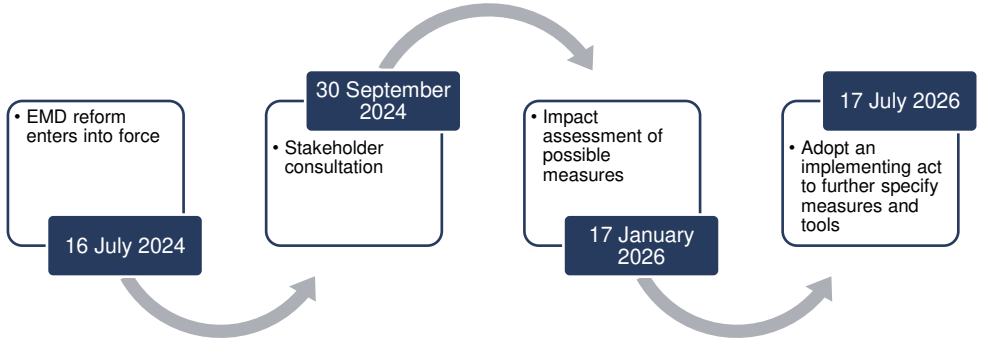
6.1
Context



The Electricity Market Design Reform requires the impact assessment to cover the possible introduction of regional virtual hubs for forward markets

- EMD reform consisted in several pieces of EU legislation[1], the main ones being:
  - **Electricity market regulation** (Regulation (EU) 2024/1747)[2] – amending Regulations (EU) 2019/942 and (EU) 2019/943, and
  - **Electricity market directive** (Directive (EU) 2024/1711)[3] – amending Directives (EU) 2018/2001 and (EU) 2019/944.

- **Article 9** of the amended electricity market regulation[2] introduces, among others, the concept of **regional virtual trading hubs** for forward markets into the European legislation.
  - *"§3: The design of the Union's forward markets shall comprise the necessary **tools to improve the ability** of market participants **to hedge price risks** in the internal electricity market.*
  - *§4: By 18 months from the date of entry into force, the Commission shall, after **consulting** relevant stakeholders, carry out an **assessment of the impact** of possible measures to achieve the objectives in §3. That impact assessment shall, inter alia, cover:*
    - *(a) possible changes to the frequency of allocation for long-term transmission rights;*
    - *(b) possible changes to the maturities of long-term transmission rights, in particular maturities extended up to at least three years;*
    - *(c) possible changes to the nature of long-term transmission rights;*
    - *(d) ways to strengthen the secondary market; and*
    - *(e) **the possible introduction of regional virtual hubs for the forward markets**."*



Source: 1 EC, 2024; 2 EU 2024 ; 3 EU, 2024

The Electricity Market Design Reform requires an impact assessment of regional virtual hubs for the forward market

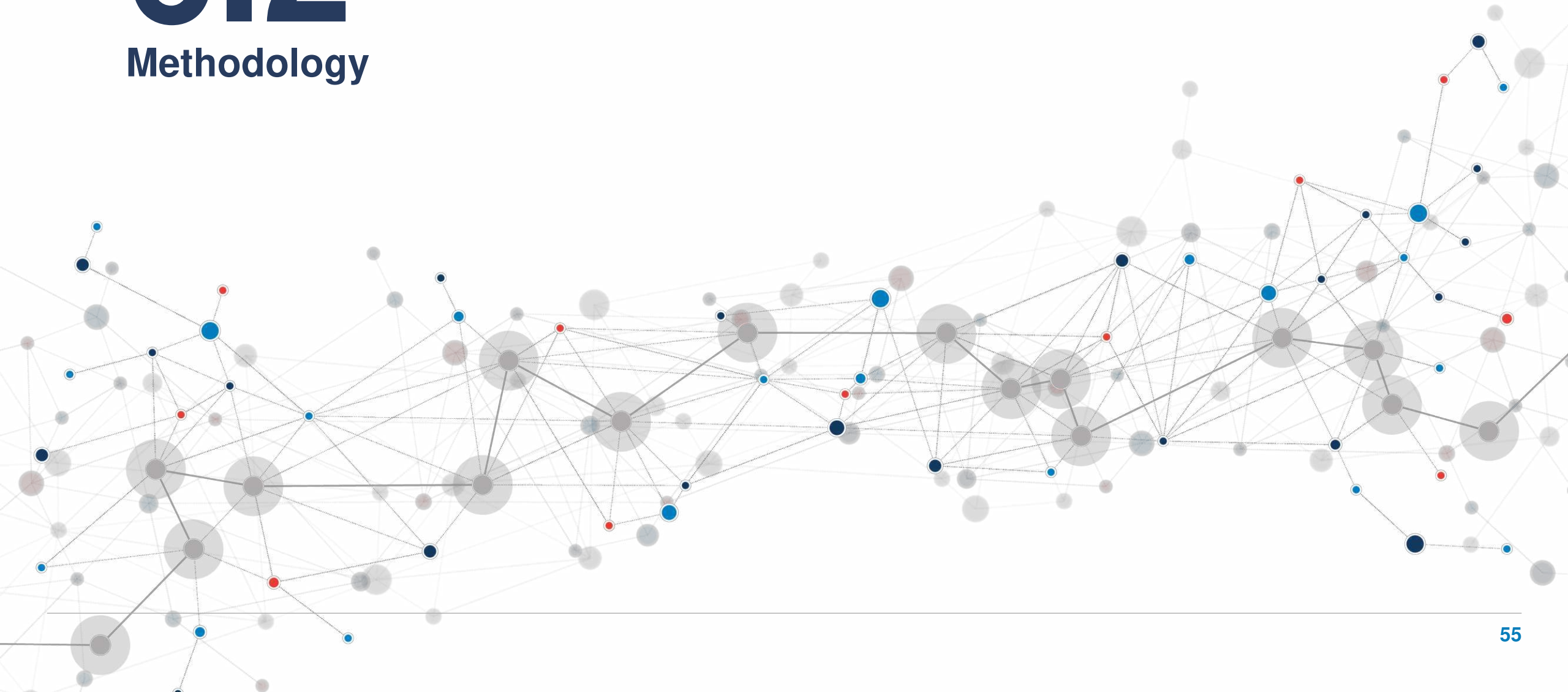
- The impact assessment of regional virtual hubs for the forward market shall cover the following (§5, Article 9):

Impact assessment of regional virtual hubs

Sub-clause	Item	Details
(a)	Geographical Scope of Regional Virtual Hubs	Define the geographical scope, determine bidding zones, address multi-hub zones, maximize price correlation
(b)	Electricity Interconnectivity of Member States	Assess interconnectivity levels, focus on Member States below 2020 and 2030 targets
(c)	Methodology for Calculating Reference Prices	Develop methodology for reference prices, maximize price correlation in forward markets
(d)	Participation in Multiple Regional Virtual Hubs	Examine the possibility for bidding zones to belong to multiple regional virtual hubs
(e)	Maximizing Trading Opportunities	Explore ways to maximize trading opportunities for hedging products and long-term transmission rights
(f)	Single Allocation Platform	Ensure the single allocation platform offers allocation and facilitates trading of long-term transmission rights
(g)	Implications of Pre-existing Intergovernmental Agreements	Assess implications of existing intergovernmental agreements and related rights

Source: Compass Lexecon analysis, based EU, 2024

6.2
Methodology



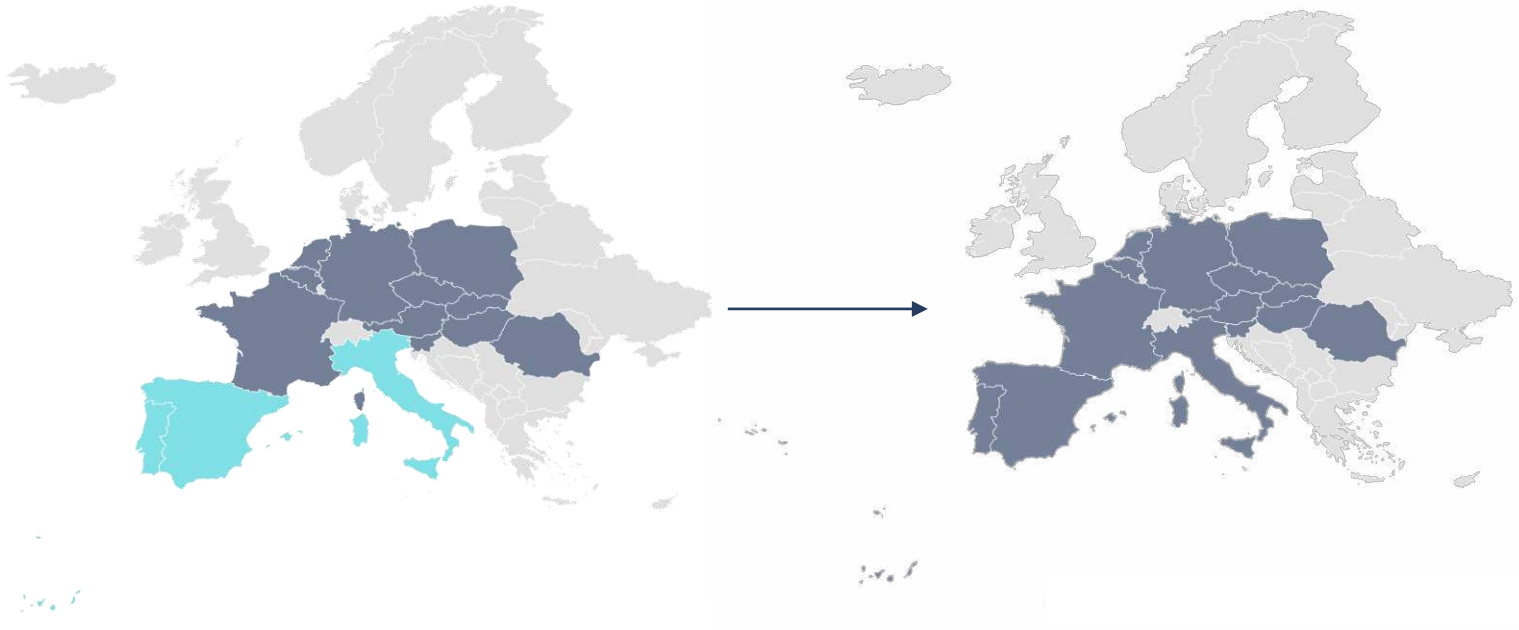
Scope definition

CORE vs. CORE + South

- The original hub of the analysis is composed of the CORE countries. We computed an extension of this hub by incorporating Southern Europe (ES, PT and IT), called CORE + South.
- We are also interested in measuring the impact on CORE countries of incorporating Southern Europe into the VTH as well as the relationship between Southern Europe and the CORE VTH. Hence results will be presented for all countries, but when “CORE” is mentioned, the VTH is calculated using only CORE countries.

CORE	CORE + South
Austria	Austria
Belgium	Belgium
Czech Republic	Czech Republic
France	France
Germany	Germany
Hungary	Hungary
	Italy
Netherlands	Netherlands
Poland	Poland
	Portugal
Romania	Romania
Slovakia	Slovakia
Slovenia	Slovenia
	Spain

Geographical scope considered in the calculation of the VTH
(in dark blue – CORE on the left ; CORE + South on the right)



Our methodology to estimate the virtual hub price on the forward market is a load or production weighted approach

1 Market design assumption: Virtual price is computed day-ahead based on weighted average defined ex-ante (load or production)

- **Virtual price is computed day-ahead based on weighted average**.
- This is **a common approach**, used in other markets, **simple and easy to replicate**, testing weights based on consumption and production levels.
- **We excluded approaches based on weights known ex-post.** These would create incompletely-defined contracts as the underlying would only be known ex-post.
- **We also excluded unconstrained price**, such as in the Nordics, because we **lack access to adequate data** to replicate this.

2 Modelling assumption: Forward prices on the virtual hub equal the (same) weighted average of the forward prices

- We assume forward market prices on the virtual hub equal the **weighted averages of the zonal forward prices**, using EEX, TGE and OMIP data.
  - This implicitly assumes that MPs will trade in the virtual hub forward market with regard to the day-ahead virtual hub in the same way as they do on other forward markets.
  - MPs thus take into account their **perspectives of each individual market when they trade**, rather than ex-post.
- **We compare hedging using the simulated virtual hub forward price with proxy-hedging on the German** (and Hungarian) **forward markets.**
- Beyond **different weights**, we also look at **different geographical scopes** for the calculation of the virtual hub price (Core or Core + South, i.e. IT, ES, PT).

Weights definition

Calculation of a virtual trading hub price

- **In this study,** we determine the virtual trading hub (VTH) price for the regions of interest by calculating a **volume-weighted average price**. The process involves **two main steps**:

Step 1: Calculate weights

– The ex-ante weight (*W*, %) for each country is based on a long-term average (2019-2023) of electricity consumption [1] or production [2] calculated as a percentage of the total demand across all zones over the specified period.

Step 2: Calculate VTH price

– The VTH price is calculated [3] based on the weighted average of the settlement prices ***P*** for each trading day ***i***.

– The VTH is calculated only if a certain number of countries have data on a given day, to avoid sudden movements due to the VTH being based only on one country's price. The minimum number of countries is 10 for CORE + South and 8 for CORE.

$$[1]\ W_{country} = \left(\frac{Consumption_{\ country}}{Consumption_{total}}\right) * 100$$

$$or$$

$$[2]\ W_{country} = \left(\frac{Production_{\ country}}{Production_{total}}\right) * 100$$

$$[3]\ VTH_{price} = \frac{\sum_{i=1}^{n} P_i * W_i}{\sum_{i=1}^{n} W_i}$$

Weights based on electricity consumption and production don't differ significantly, but nuances exist

Weights based on electricity consumption and production

- The country weights used in computing VTH price are based on historical (2019-2023) consumption and production data from ENTSO-E.

Small differences between the two weighting approaches

- The table on the right shows the weights *not dynamically adjusted*, i.e. calculated as $\frac{country's\ consumption}{overall\ consumption}$ (or production).
- The weights are overall quite similar across the two weighting approaches.
- The **CORE region typically has higher values compared to the combined CORE + South region**, indicating that the inclusion of Southern regions tends to lower the overall metrics.
- **The largest differences are for France and Italy,** which respectively see an **increase** of 1.79 pp. and a **decrease** of 2.20 pp. when passing from consumption to generation weights. This supports the fact that France is generally a **net exporter of electricity** and Italy a net importer.

Weights based on consumption and production for the two regions studied

Country	Consumption weighted		Production weighted	
	CORE	CORE + South	CORE	CORE + South
AT	3.93	2.88	3.64	2.73
BE	5.26	3.86	5.40	4.05
CZ	4.13	3.02	4.84	3.63
DE	31.08	22.78	30.93	23.20
ES	/	11.23	/	11.87
FR	28.78	21.09	30.57	22.93
HU	2.77	2.03	1.94	1.46
IT	/	13.14	/	10.94
NL	6.89	5.05	6.87	5.15
PL	10.84	7.95	9.57	7.18
PT	/	2.34	/	2.19
RO	3.69	2.70	3.56	2.67
SI	0.86	0.63	0.90	0.67
SK	1.78	1.31	1.76	1.32

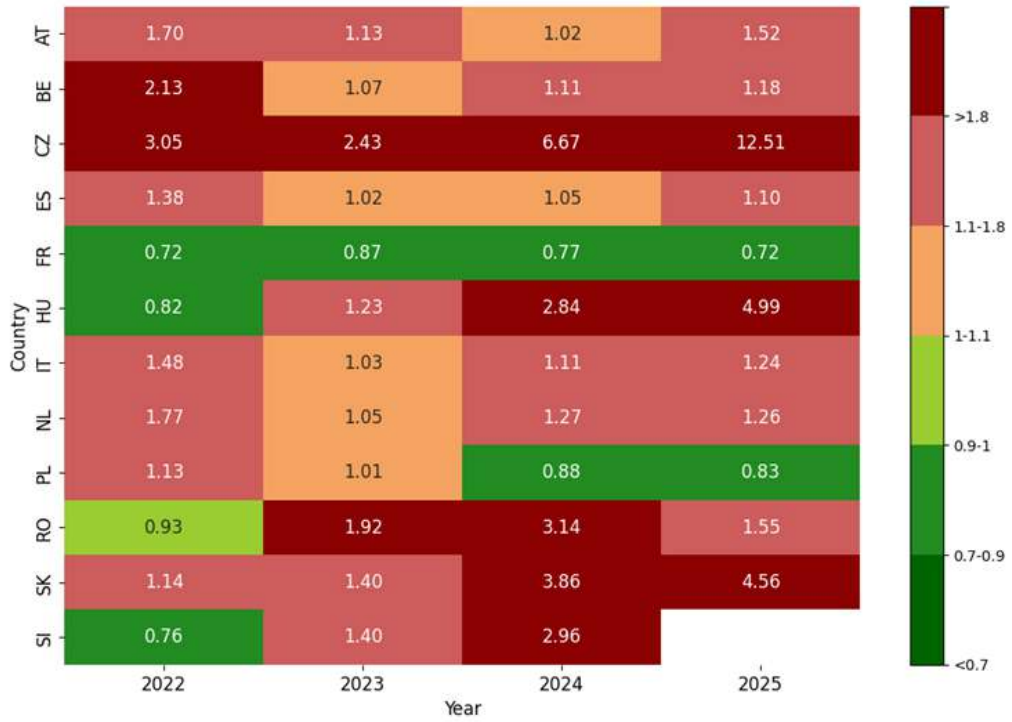
Source: Compass Lexecon analysis based on data from ENTSO-E

Indicators overview

Volatility ratios

Volatility ratios	
Definition	$\frac{std(average\_spreads(country,\ DE))}{std(average\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL+1/2/3. We are also comparing with HU prices instead of DE.
Interpretation	▪ A **ratio greater than 1** indicates that the price spreads with VTH are more volatile than with DE, suggesting that VTH has a **higher risk of price swings** relative to DE. ▪ Conversely, a **ratio less than 1** indicates that the price spreads with DE have higher volatility. ▪ Ratios indicate under which configuration the risks (volatility), proxied by standard deviations, are lower or higher.
Motivation	▪ This indicator is motivated by the need to **compare the relative risk** or volatility between different areas and hub configurations.

Example: Volatility ratios of yearly products by delivery year



 Source: Compass Lexecon analysis

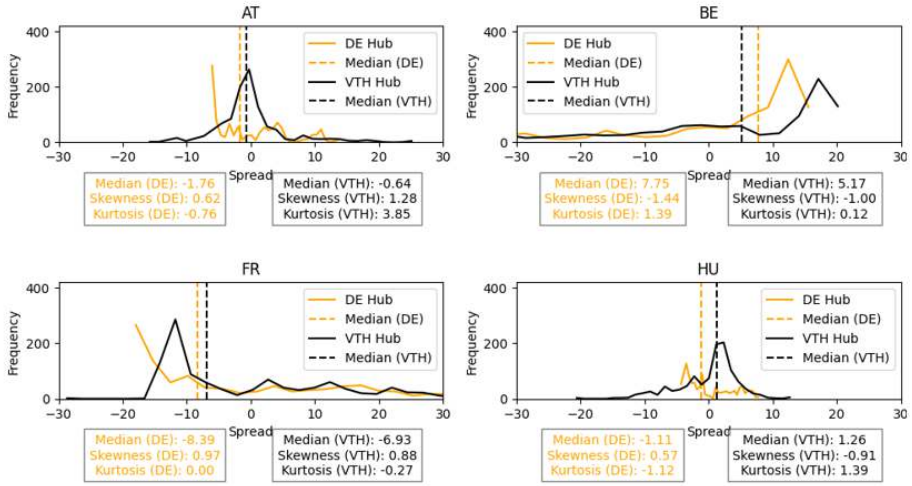
Indicators overview

Distribution of spreads

	Distribution of spreads
Definition	Normalized (de-meaned by yearly average) price differentials between area and hub prices (DE/HU/VTH) for single product (e.g. CAL2024) traded over its lifetime. Detailed sub-indicators are used: ▪ **Skewness** – looks at the asymmetry of distribution around the mean, **value close to 0** indicates distribution is approx. symmetric; identifies the direction of potential outliers. ▪ **Kurtosis -** measures the "tailed-ness" of the distribution**,** high kurtosis (>3) indicates higher probability of extreme price differences (outliers), whereas <3 indicates the opposite. **Value close to 3** corresponds to a normal distribution. ▪ **Median -** represents the midpoint of the distribution, **ideally close to 0**, i.e., half of price spreads above and half below 0, suggesting stability around the mean; less affected by outliers; provides a sense of the "typical" spread value.
Interpretation	▪ **Visual presentation of price spread distributions** centred around zero focuses on the deviations from the average spread rather than the absolute spread levels. De-meaning helps to identify and analyse the relative movements of the spread, making it easier to interpret volatility, trends, and patterns in the data. ▪ A **wide (narrow) distribution** suggests high (low) variability in price differences, which implies greater (lower) risk for entities exposed to both area and hub prices. ▪ **Additional statistical measures** (median, skewness, kurtosis) provide further depth to assessing spread distributions between different hub configurations.
Motivation	▪ By normalizing the spreads, one can focus on **deviations from typical behaviour**, which is crucial for risk assessment and hedging strategies. ▪ Zero-centered distributions can be more easily **compared across countries**. ▪ Understanding this distribution helps in pricing the **risk premium** required for hedging contracts. ▪ We mainly used kurtosis to measure the probability of outliers. Median is a systematic bias that can easily be hedged against.

Example: Price spread distribution (area - VTH) for VTH hub

CAL2024 product over its lifetime, CORE region, consumption weighted



Note: While not expecting that electricity prices and price spreads follow normal distribution, normal distribution provides a reference for comparison for the different hub configurations.

Source: Compass Lexecon analysis

Correlation is a crucial quantity in the valuation of many energy derivatives and assets

Why correlation matters

- Correlation is a **proper measure of dependence between two random variables.**
- The major use of correlation analysis is in the valuation of **multi-commodity derivatives** (in our case price spreads between two power commodities).
- **Correlation changes over time,** which can be due to conditional correlation (the correlation coefficient is time-dependent), covariance non-stationarity of the underlying processes, nonlinear dependence structure, and estimation noise.

Main decisions

1. Product view

- **Single product** (e.g. front year CAL+1) or **multi-product** by delivery year (e.g. all yearly products delivered in 2024, i.e. CAL2024).
- => Decision: Both product views are relevant and can be used for correlation analysis.

2. Natural log and differencing

- Correlation on price **levels or returns -** the standard practice in financial markets is to look at correlations between returns or logarithmic returns (return correlations).
- => Decision: Prefer logarithmic returns, because price-time series in financial markets are not stationary (volatilities and/or covariances grow without limit in time).

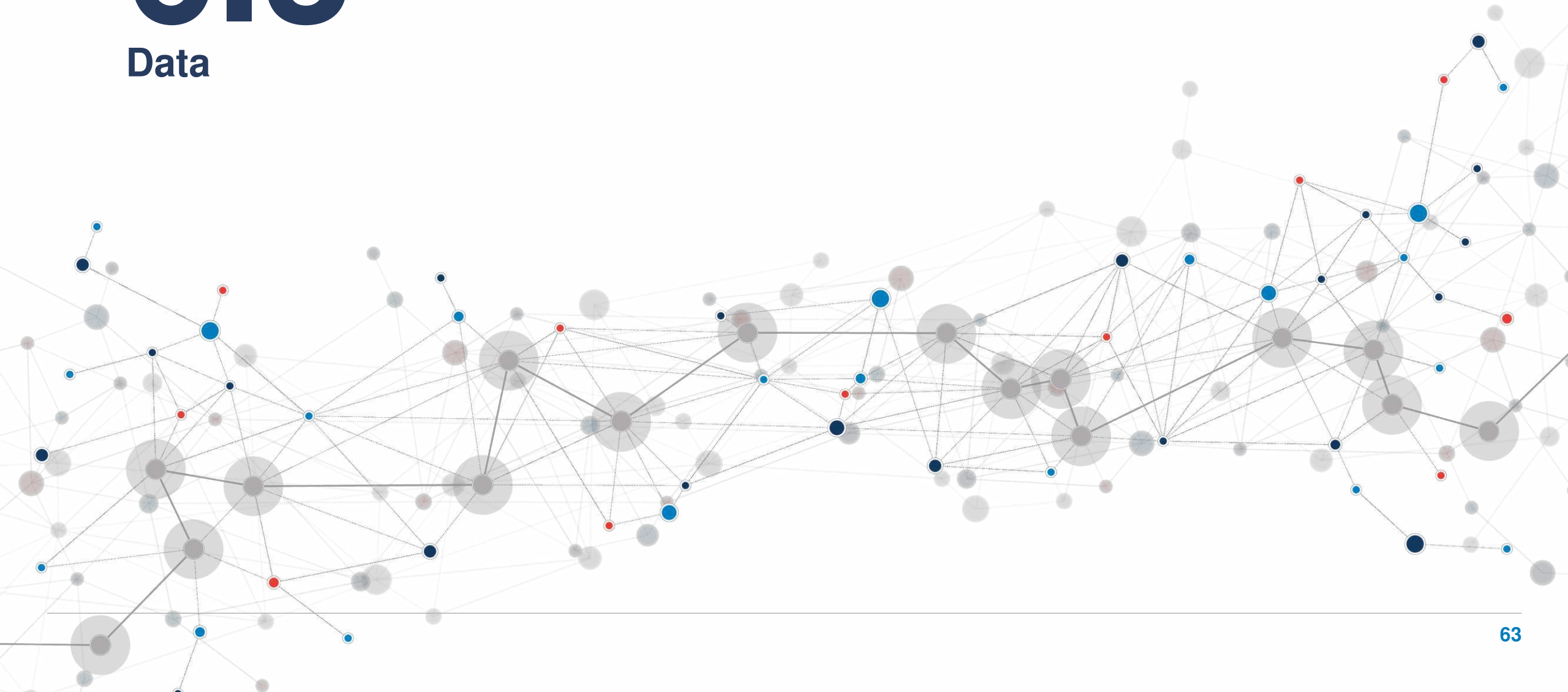
3. Rolling and static correlation

- **Rolling window correlation** shows a dynamic view of the conditional correlation (observing seasonal and market changes in correlations).
- **Static correlation** represents one single value that describes the average relationship.
- => Decision: Use both correlations, dynamic for understanding evolution, static for overall view.

Log and log difference correlation, benefits and drawbacks

Correlation Type	Benefits	Drawbacks
Log Correlation	▪ Captures long-term relationships between prices. ▪ Easier to compare assets with different price levels.	▪ May ignore short-term dynamics. ▪ Less useful for trading or return-focused analysis.
Log Difference Correlation	▪ Focuses on the correlation of returns, more relevant for traders and risk managers. ▪ Highlights short-term co-movement in performance. ▪ Addresses non-stationarity.	▪ Ignores long-term price trends. ▪ Can be more volatile and noisier.

6.3
Data



Data obtained – forward markets

Data overview

Data type	Provider	Geography	Time period	Variables
Trade data	EEX	AT, BE, BG, CZ, NL, FR, DE, GR, HU, IT, PL, RO, SK, SI, ES	Jan 2019 – Dec 2023	Date, Time, Contract, Commodity Subtype, Delivery Period Type, Contract Expiry, Load Type, On Exchanger Trade (Yes, No), Trade Quantity (MW, lots), Trade Volume (MWh), Trade Price (EUR/MWh)
Settlement and open interest (daily)	EEX	AT, BE, BG, CZ, NL, FR, DE, GR, HU, IT, PL, RO, SK, SI, ES	Jan 2019 - Apr 2024	Date, Contract, Commodity Subtype (BIZ), Delivery Period Type, Contract Expiry, Load Type, Open Interest (MW), Settlement Price (SPT, EUR/MWh)
Trade data	OMIP	ES, PT	Jul 2019 – Jun 2024	Date, Time, Contract, Commodity, Delivery Period, Type, Expiry, Load Type, Source, Quantity, Volume, Price
Trade and settlement data	GME	IT	Jan 2019 – Dec 2023	Date, Time, Contract (Trade), Commodity Subtype (BIZ), Delivery Period Type, Contract Expiry, Load Type, Venue, Trade Quantity (MW), Trade Volume (MWh), Trade Price (EUR/MWh), Settlement Price
LTTR	JAO (Engie)	AT, CZ, DE, HU, IT, SI, BE, FR, NL, BG, GR, RO, RS, BDL, GB, CH, SK, D1, D2, DK, EE, LV, EL1, ES, PT, IE, HR, IF1, IF2, NLL	Jan 2018 - Jan 2024	Border, Auction ID, Start Date, End Date, Bid Gate Opening, Bid Gate Closure, Provisional Auction Result Date, Offered Capacity, Total Requested Capacity, Total Allocated Capacity, Price, Resale, ATC, Participants Number, Winning Parties Number
OTC	ICE	BE, NL, FR, DE, IT, Nordics, ES	Jan 2019 – Dec 2023	Region, Hub, Product, Strip, Strip begin, Strip end, Order price, Deal time, Strike, P/C, Lots, Total volume, Bid/Offer, Deal ID, Parent ID, Market ID, IS block, Market type ID
Open interest (intraday)	TGE	PL	Jan 2019 – Dec 2023	Date, Contract, Open Interest (MWh), Open Interest (MW)
Trade data (intraday)	TGE	PL	Jan 2019 – Dec 2023	Date, Time, Contract (Trade), Delivery Period Type, Load Type, Trade Quantity, Trade Volume (MWH), Trade Price (PLN/MWh)

Source: Compass Lexecon analysis based on multiple sources (EEX, OMPI, JAO, GME, ICE, TGE)

Data obtained – spot markets

Data overview

Data type	Provider	Geography	Time period	Variables
Load data	ENTSO-E	AT, BA, BE, BG, CH, CY, CZ, DK, FR, DE, EE, ES, FI, GB, GR, HR, HU, IE, IT, LT, LU, LV, ME, MK, NL, NO, PL, PT, RO, RS, SE, SK, SI, UA	Jan 2019 – Jun 2024	Date and Time, Resolution Code, Area Code, Area Type Code, Area Name, Map Code, Total Load Value, Update Time
Generation data	ENTSO-E	AT, BA, BE, BG, CH, CY, CZ, DK, FR, DE, EE, ES, FI, GB, GR, HR, HU, IE, IT, LT, LU, LV, ME, MK, NL, NO, PL, PT, RO, RS, SE, SK, SI, UA	Jan 2019 – Jun 2024	Date and Time, Resolution Code, Area Code, Area Type Code, Area Name, Map Code, Production Type, Actual Generation Output,
Day ahead prices	ENTSO-E	AT, BE, BG, CH, CZ, DE_LU, DK1, DK2, EE, ES, FI, FR, GR, HR, HU, IE_SEM, IT-Calabria, IT-CNORTH, IT-CSOUTH, IT-NORTH, IT-SACOAC, IT-SACODC, IT-Sardinia, IT-Sicily, IT-SOUTH, LT, LV, ME, MK, NL, NO1, NO2, NO2NSL, NO3, NO4, NO5, PL, PT, RO, RS, SE1, SE2, SE3, SE4, SI, SK, UA_IPS	Jan 2019 – Jun 2024	Date and Time, Resolution Code, Area Code, Area Type Code, Area Name, Map Code, Price, Currency, Update Time

Source: Compass Lexecon analysis based on ENTSO-E transparency platform

Summary of the settlement price data

- Our current analysis focuses on **yearly baseload products** (CAL) using settlement prices.
- It focuses only on **the trading period 2019 – 2023.**
- CL settlement price data is based on:
  - **EEX settlement prices;**
  - **OMIP trade prices;**
  - **TGE trade prices.**
- When we rely on different sources of data for a given country (e.g. Poland), we create a volume-weighted reference price per day, to obtain as large a dataset as possible and to utilize all available trade information.

Missing observations

- **Some price data in our dataset is missing** (no quotation).
- Our treatment of NAs is a pairwise deletion, i.e. we use all available data for each calculation, in contrast to listwise deletion (remove entire row with one missing value).

Summary of the settlement price data, CAL+1/2/3 over 2019-2023

	Mean	Std	Min	Median	Max	NAs	Count
AT	107.6	88.6	36.5	66.3	1,015.0	38	3783
BE	94.3	69.1	33.6	60.9	676.0	114	3707
CZ	102.8	82.5	38.1	65.1	984.0	9	3812
DE	100.8	83.3	33.7	63.4	985.0	3	3818
ES	73.8	40.3	38.3	56.1	351.0	0	3821
FR	111.8	103.4	37.4	61.9	1,130.0	3	3818
HU	108.6	86.2	45.1	67.0	1,007.0	6	3815
IT	102.9	69.8	43.0	67.4	624.6	3	3818
NL	94.5	71.6	33.8	60.9	704.0	0	3821
PL	101.9	64.6	45.2	71.7	522.5	1,176	2645
PT	Confidential						
RO	98.2	93.1	45.4	56.7	982.0	1,443	2378
SI	116.5	113.3	44.7	58.5	1,007.5	2,210	1611
SK	106.2	86.7	41.2	66.5	1,001.5	108	3713
Total	**100.9**	**81.8**	**33.7**	**62.9**	**1,130.0**	**8,912**	**44,582**

Source: Compass Lexecon analysis based on data from EEX, TGE and OMIP

Price correlation of future prices among countries

Correlation matrix of settlement prices for calendar products (CAL+1/2/3) over the trading period 2019-2023

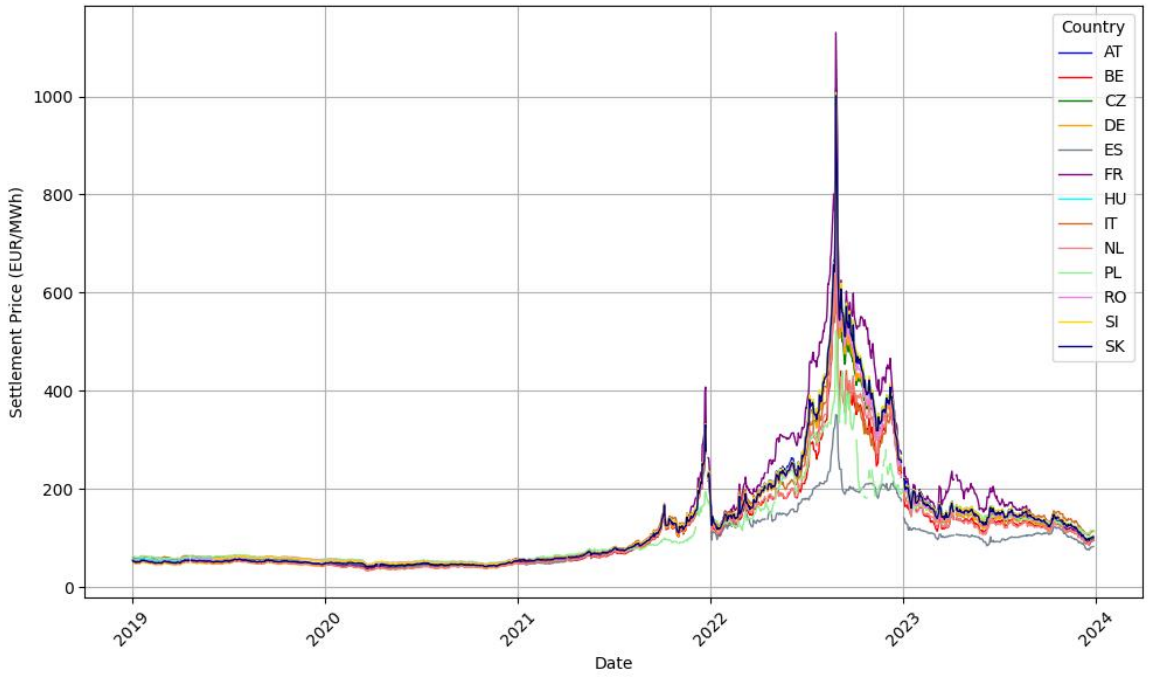
	AT	BE	CZ	DE	ES	FR	HU	IT	NL	PL	RO	SI	SK	VTH (C)	VTH (C+S)
AT	1	0.995	0.999	1	0.953	0.995	0.999	0.992	0.996	0.968	0.987	0.987	1	0.999	0.998
BE	0.995	1	0.994	0.994	0.961	0.988	0.994	0.995	0.997	0.964	0.975	0.976	0.994	0.994	0.995
CZ	0.999	0.994	1	1	0.957	0.996	0.999	0.992	0.996	0.967	0.988	0.988	1	0.999	0.999
DE	1	0.994	1	1	0.956	0.996	1	0.992	0.996	0.967	0.988	0.988	1	0.999	0.999
ES	0.953	0.961	0.957	0.956	1	0.95	0.953	0.973	0.964	0.925	0.921	0.929	0.953	0.957	0.964
FR	0.995	0.988	0.996	0.996	0.95	1	0.996	0.988	0.991	0.964	0.987	0.985	0.996	0.998	0.997
HU	0.999	0.994	0.999	1	0.953	0.996	1	0.991	0.996	0.967	0.99	0.99	1	0.999	0.998
IT	0.992	0.995	0.992	0.992	0.973	0.988	0.991	1	0.996	0.963	0.969	0.969	0.992	0.993	0.996
NL	0.996	0.997	0.996	0.996	0.964	0.991	0.996	0.996	1	0.958	0.98	0.981	0.996	0.996	0.997
PL	0.968	0.964	0.967	0.967	0.925	0.964	0.967	0.963	0.958	1	0.956	0.951	0.968	0.97	0.969
RO	0.987	0.975	0.988	0.988	0.921	0.987	0.99	0.969	0.98	0.956	1	0.998	0.989	0.987	0.984
SI	0.987	0.976	0.988	0.988	0.929	0.985	0.99	0.969	0.981	0.951	0.998	1	0.989	0.987	0.984
SK	1	0.994	1	1	0.953	0.996	1	0.992	0.996	0.968	0.989	0.989	1	0.999	0.999
VTH (C)	0.999	0.994	0.999	0.999	0.957	0.998	0.999	0.993	0.996	0.97	0.987	0.987	0.999	1	
VTH (C+S)	0.998	0.995	0.999	0.999	0.964	0.997	0.998	0.996	0.997	0.969	0.984	0.984	0.999		1

Note: The VTH price here is calculated using the CORE + South region for VTH (C+S) and only the CORE region for VTH (CORE). Consumption weighting is used.

Source: Compass Lexecon analysis based on data from EEX, TGE, OMIP and ENTSO-E

Detailed summary
CAL+1

Evolution of settlement prices for CAL+1 products, by delivery date



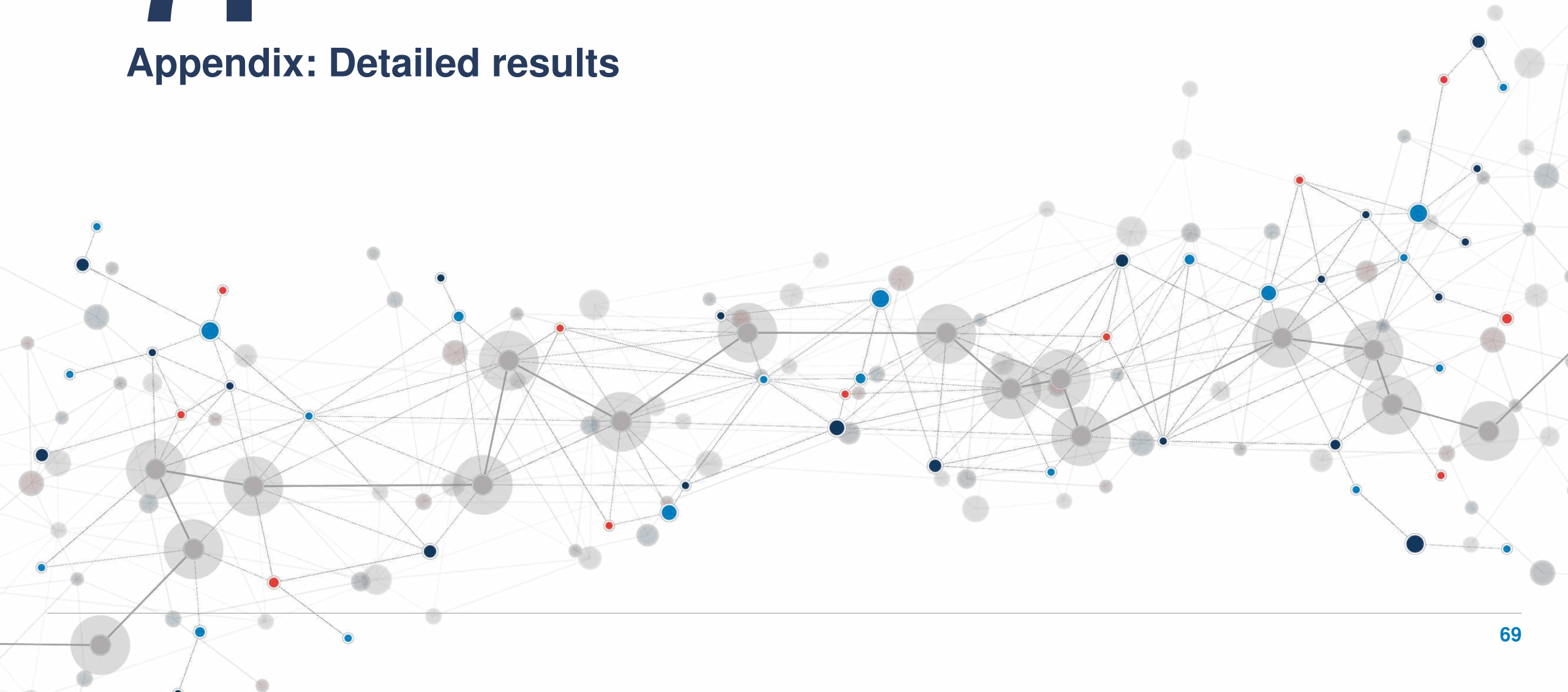
Summary statistics of CAL +1 CL data

	Mean	Std	Min	Median	Max	NAs	Count
AT	130.1	122.9	36.5	73.0	1,015.0	1	1,268
BE	112.4	94.7	33.6	68.2	676.0	0	1,269
CZ	124.8	114.7	38.1	73.1	984.0	3	1,266
DE	122.8	116.3	33.7	70.7	985.0	1	1,268
ES	93.6	55.5	38.3	72.5	351.0	0	1,269
FR	144.6	146.5	37.4	72.4	1,130.0	1	1,268
HU	134.1	121.7	45.1	76.1	1,007.0	2	1,267
IT	125.2	95.8	43.0	78.0	624.6	1	1,268
NL	114.2	98.2	33.8	70.5	704.0	0	1,269
PL	111.8	75.9	45.2	76	522.5	31	1,238
PT	Confidential						
RO	130.7	117.0	45.4	75.8	982.0	2	1,267
SI	140.9	125.1	44.7	99.2	1,007.5	108	1,161
SK	129.8	120.9	41.2	75.2	1,001.5	2	1,267
Total	**124.1**	**111.1**	**33.6**	**74.5**	**1,130.0**	**1,401**	**16,365**

Source: Compass Lexecon analysis based on data from EEX and TGE

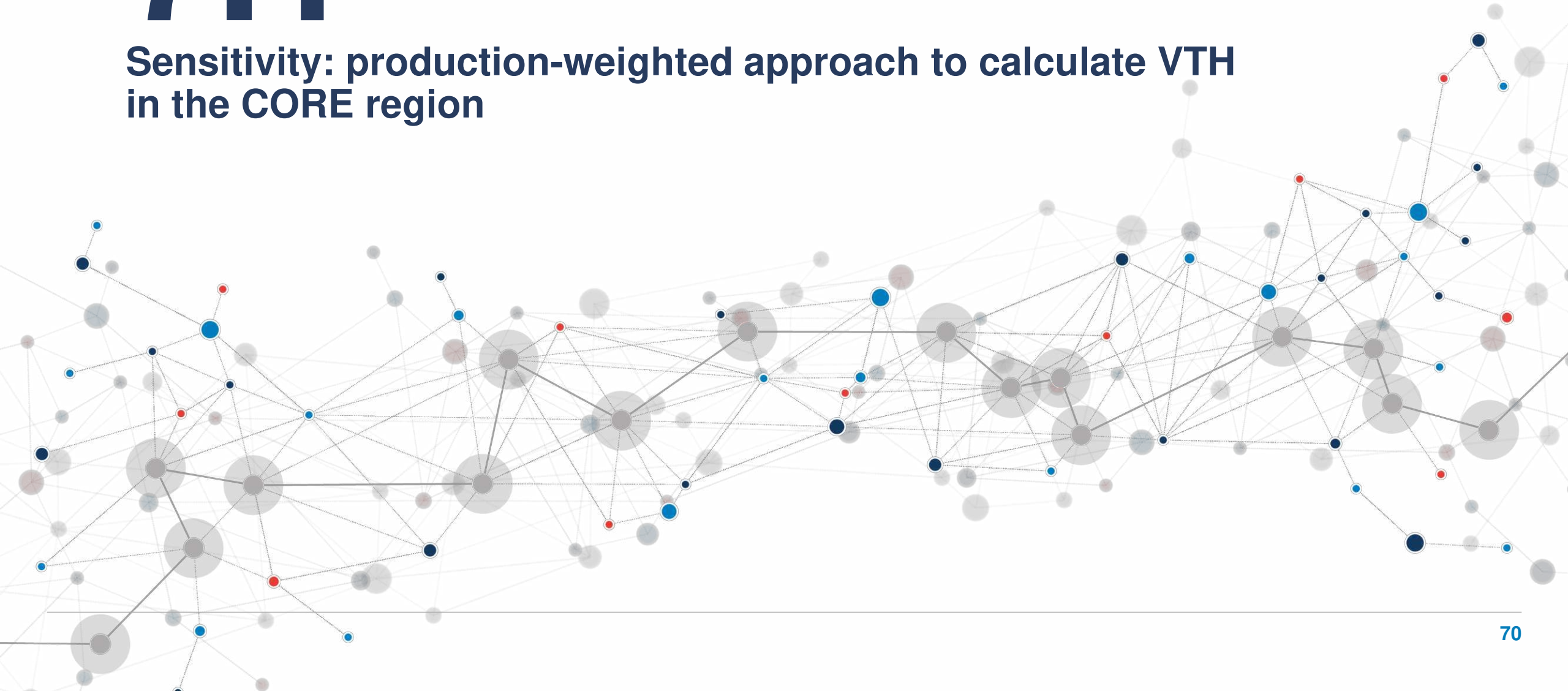
7.

Appendix: Detailed results



7.1

Sensitivity: production-weighted approach to calculate VTH in the CORE region

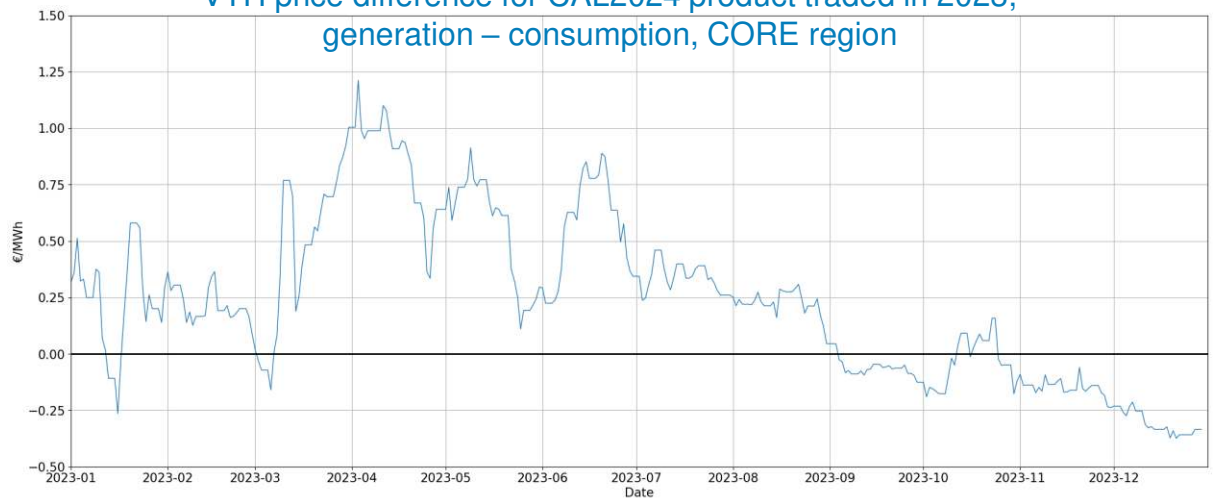


VTH for the CORE region based on consumption and production weights

Quotations in 2023 for the CAL2024

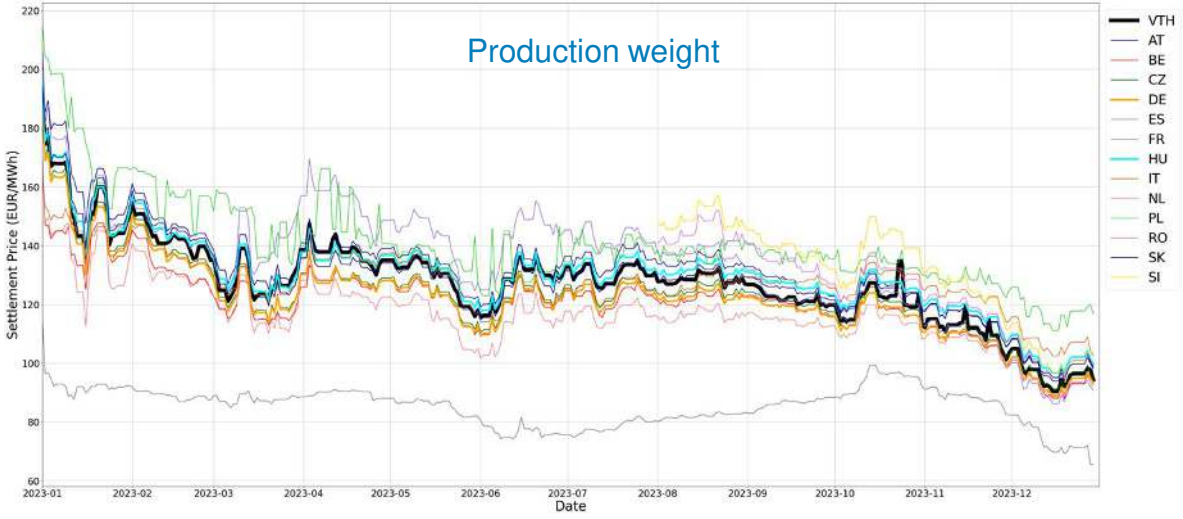
- Different weighting approaches by consumption and production volumes have a very limited impact on the shape and level of the VTH.
- The VTH price for the CORE region is on **average 0.24€/MWh higher with the production weighting,** as France is more weighted.
- Production weighted VTH price is overall higher than the consumption weighted price until September 2023, where the consumption weighted price becomes higher.
- The difference ranges between -0.37 €/MWh and 1.21 €/MWh.

VTH price difference for CAL2024 product traded in 2023, generation – consumption, CORE region

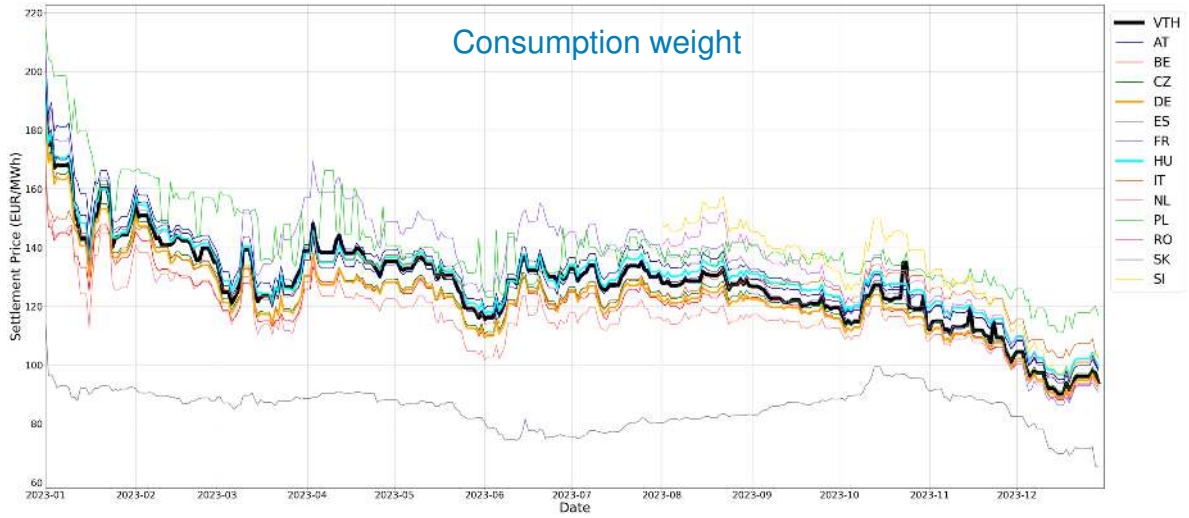


CAL+1 products traded in 2023 for delivery in 2024, CORE region

Production weight



Consumption weight

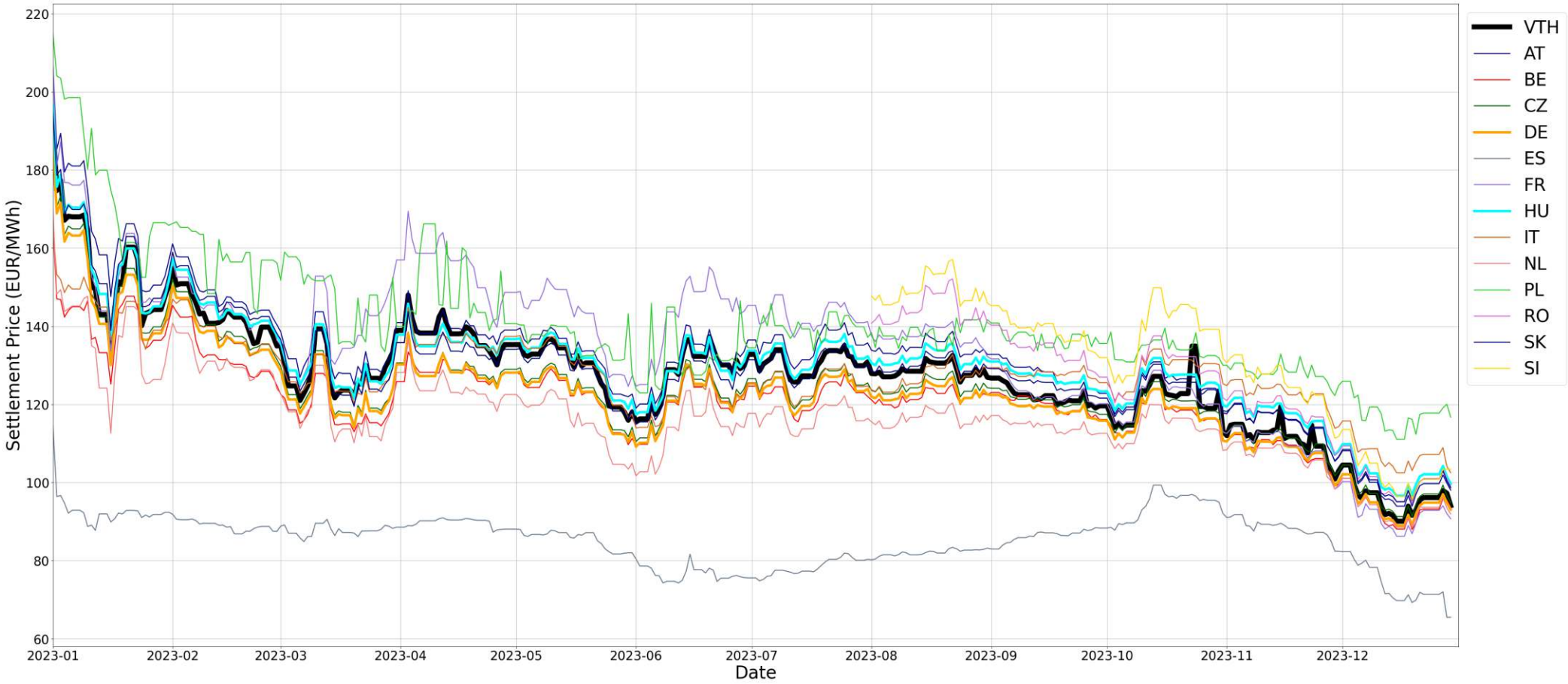


Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

VTH for the CORE region based on consumption and production weights

Quotations in 2023 for the CAL2024 – production weight

CAL+1 products traded in 2023 for delivery in 2024, CORE region, production weight

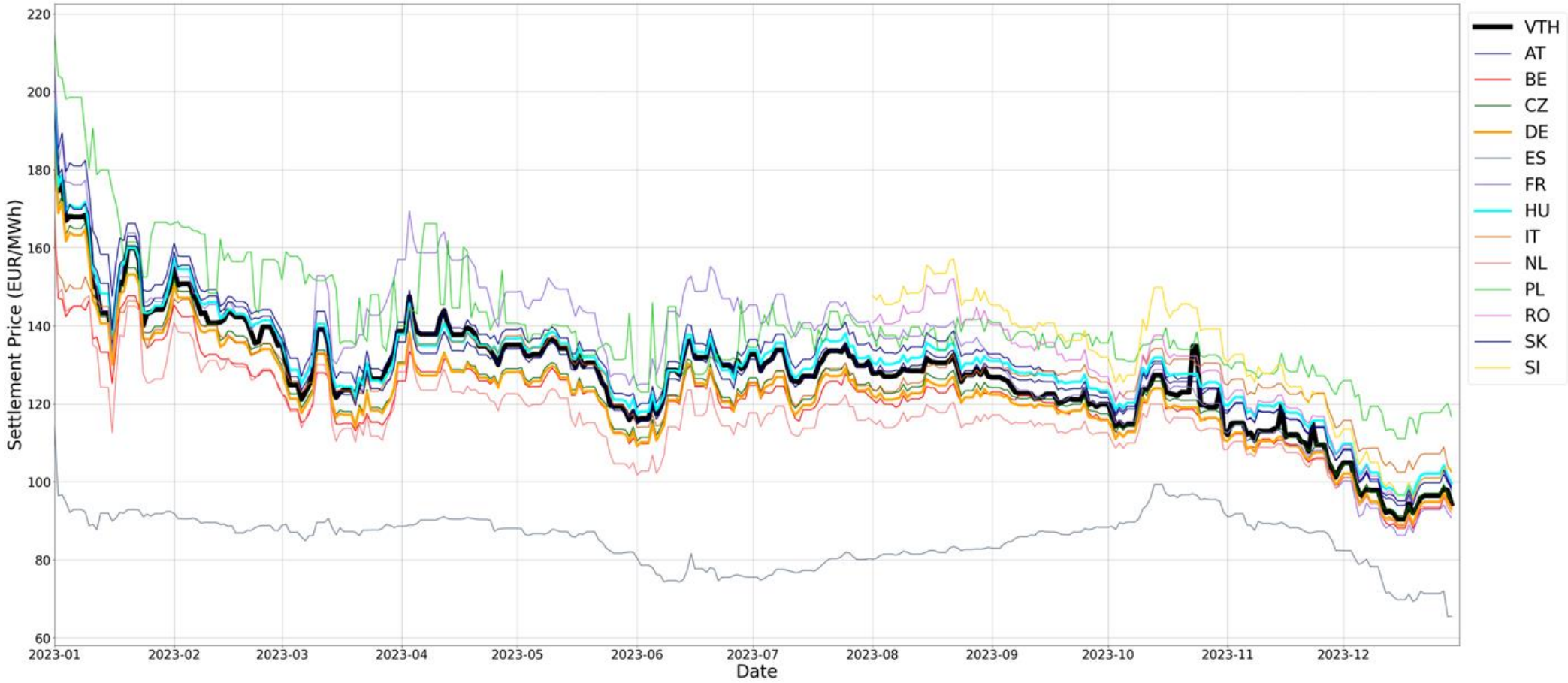


Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

VTH for the CORE region based on consumption and production weights

Quotations in 2023 for the CAL2024 – consumption weight

CAL+1 products traded in 2023 for delivery in 2024, CORE region, consumption weight



Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

Given the limited impact on the VTH, using a production weight has only minor impacts on indicators, and none on conclusions

Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1/2/3, VTH based on consumption-weighted **CORE region**

Year	2022		2023		2024		2025	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country								
AT	100%	94%	100%	94%	99%	90%	99%	89%
BE	96%	92%	90%	86%	82%	77%	77%	78%
CZ	100%	94%	100%	94%	100%	91%	100%	90%
DE	100%	94%	100%	94%	100%	91%	100%	90%
FR	97%	94%	94%	94%	88%	89%	85%	90%
HU	98%	93%	99%	94%	99%	90%	100%	90%
NL	97%	92%	93%	88%	94%	87%	79%	78%
PL	60%	63%	52%	58%	28%	35%	8%	26%
RO	98%	93%	99%	93%	100%	97%	99%	95%
SI	98%	95%	100%	95%	100%	97%		
SK	99%	93%	100%	94%	100%	91%	100%	90%
Countries outside the VTH calculation area								
ES	85%	82%	65%	65%	46%	46%	35%	42%
IT	94%	89%	88%	83%	87%	82%	62%	54%

Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1/2/3, VTH based on production-weighted **CORE region**

Year	2022		2023		2024		2025	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country								
AT	100%	95%	100%	95%	99%	92%	99%	90%
BE	96%	93%	90%	87%	82%	79%	77%	79%
CZ	100%	95%	100%	95%	100%	92%	100%	91%
DE	100%	95%	100%	95%	100%	92%	100%	91%
FR	97%	95%	94%	95%	88%	90%	85%	91%
HU	98%	94%	99%	95%	99%	92%	100%	91%
NL	97%	93%	93%	89%	94%	88%	79%	79%
PL	60%	63%	52%	58%	28%	33%	8%	24%
RO	98%	94%	99%	94%	100%	97%	99%	96%
SI	98%	96%	100%	96%	100%	97%		
SK	99%	95%	100%	95%	100%	92%	100%	91%
Countries outside the VTH calculation area								
ES	85%	83%	65%	66%	46%	47%	35%	41%
IT	94%	90%	88%	84%	87%	83%	62%	54%

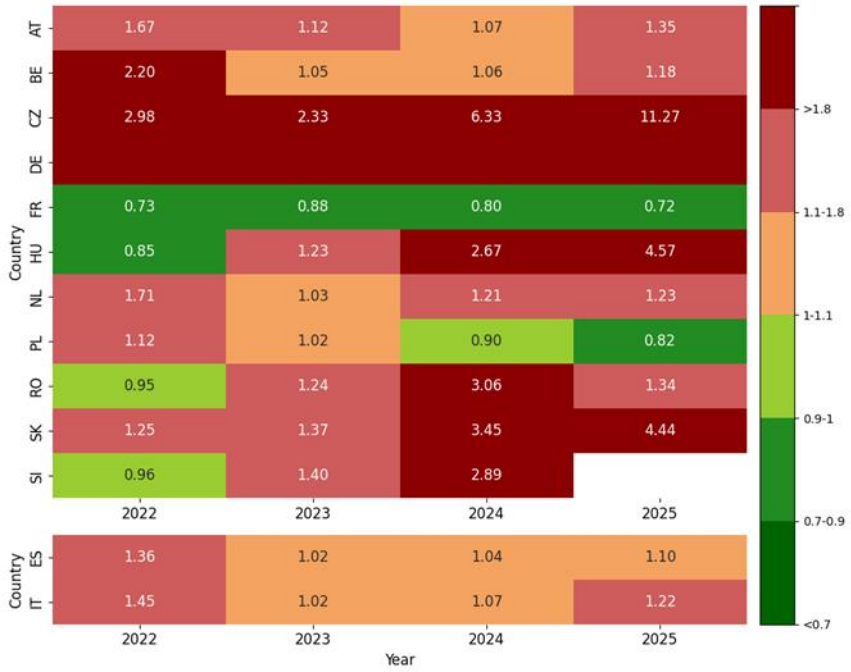
Note: The colour code compares VTH to DE. It is based on the difference in correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to show how they would be impacted by the VTH.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

Given the limited impact on the VTH, using a production weight has only minor impacts on indicators, and none on conclusions

Ratio of the standard deviations of spreads (VTH/DE) by country and delivery year, consumption-weighted

CORE region



Ratio of the standard deviations of spreads (VTH/DE) by country and delivery year, production-weighted

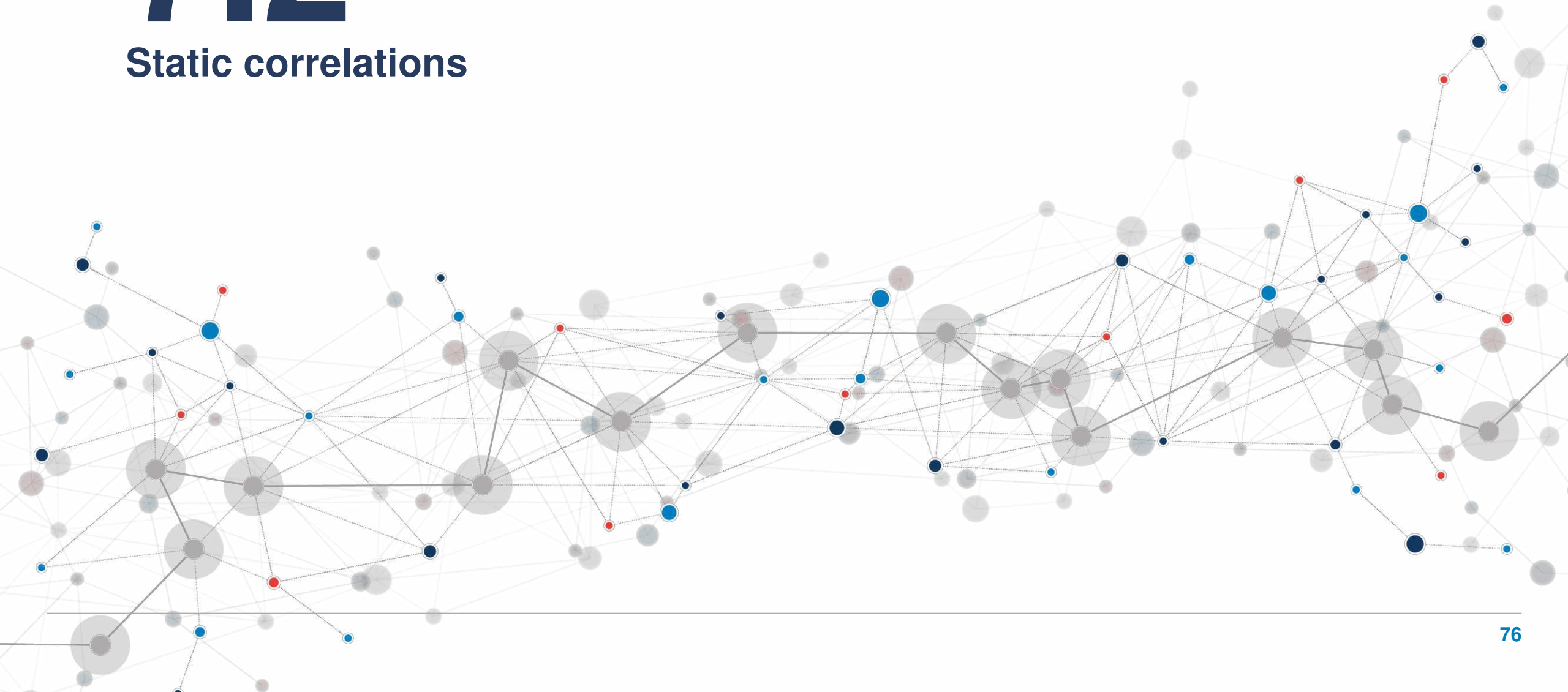
CORE region

Note: Liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

7.2

Static correlations



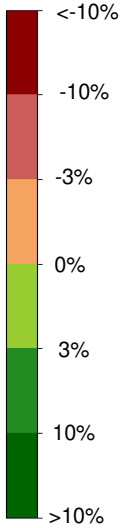
Static correlations – Consumption weighted results

Comparison between Germany and VTH

- In the **CORE** hub configuration, **price correlation between Germany and other zones is generally higher than with the VTH**. **Exceptions are with Spain, France and Poland**, where the correlations are mainly neutral or better with VTH compared to DE.
- Price correlation **improves for VTH CORE + South** for most countries in years 2022, 2023 and 2024, but impacts go in both ways in 2025 compared to VTH CORE. Price correlation remains however higher with Germany in most countries (same exceptions as for CORE).

Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1/2/3, VTH based on demand-weighted **CORE region**

Year	2022		2023		2024		2025	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country								
AT	100%	94%	100%	94%	99%	90%	99%	89%
BE	96%	92%	90%	86%	82%	77%	77%	78%
CZ	100%	94%	100%	94%	100%	91%	100%	90%
DE	100%	94%	100%	94%	100%	91%	100%	90%
ES	85%	82%	65%	65%	46%	46%	35%	42%
FR	97%	94%	94%	94%	88%	89%	85%	90%
HU	98%	93%	99%	94%	99%	90%	100%	90%
IT	94%	89%	88%	83%	87%	82%	62%	54%
NL	97%	92%	93%	88%	94%	87%	79%	78%
PL	60%	63%	52%	58%	28%	35%	8%	26%
RO	98%	93%	99%	93%	100%	97%	99%	95%
SI	98%	95%	100%	95%	100%	97%		
SK	99%	93%	100%	94%	100%	91%	100%	90%



Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1/2/3, VTH based on demand-weighted **CORE + South region**

Year	2022		2023		2024		2025	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country								
AT	100%	96%	100%	96%	99%	92%	99%	87%
BE	96%	93%	90%	89%	82%	79%	77%	77%
CZ	100%	96%	100%	96%	100%	93%	100%	87%
DE	100%	96%	100%	96%	100%	93%	100%	87%
ES	85%	87%	65%	71%	46%	53%	35%	48%
FR	97%	96%	94%	95%	88%	90%	85%	85%
HU	98%	95%	99%	95%	99%	92%	100%	87%
IT	94%	93%	88%	88%	87%	87%	62%	63%
NL	97%	94%	93%	91%	94%	88%	79%	76%
PL	60%	63%	52%	57%	28%	34%	8%	26%
RO	98%	95%	99%	95%	100%	97%	99%	93%
SI	98%	97%	100%	97%	100%	97%		
SK	99%	95%	100%	96%	100%	93%	100%	87%

Note: The colour code compares VTH to DE. It is based on the difference in correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to show how they would be impacted by the VTH.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

DE is a better proxy hub for hedging most power price risks due to its better hedge ratios, which are driven by higher correlation and more similar volatility profile compared to the underlying countries

Metrics[1]

- **Hedge ratio** determines the proportion of exposure that should be hedged using a derivative to minimize risk. It is the ratio of the size of the position taken in derivative contracts to the size of the exposure: $\beta = Correlation_{Proxy,Country} \times \frac{Standard\ deviation\ of\ Proxy}{Standard\ deviation\ of\ Country}$
- Two key aspects: **correlation** and **volatility**. Higher correlation and closer volatility match yield a better hedge.
- **Ideal hedge ratio** is close to 1, which fully offsets price risk.
- **Lower hedge ratio** (below 1) could lead to under-hedging, where only part of the risk is mitigated, leaving more unhedged exposure.
- **Higher hedge ratio** (above 1) could lead to over-hedging, where hedging asset might overreact to market movements, increasing exposure rather than mitigating it.

Results using CAL2023 example

- **Hedge ratio** using Germany (DE) for most countries is closer to 1, which is mainly due to the higher correlation and better match of price volatility with the underlying countries.

=> From a risk management perspective, Germany (DE) is the better proxy hub for hedging most countries due to its higher correlation leading to hedging ratio close to 1 compared to VTH.

Hedge ratios of hubs and their difference

Delivery year 2023 for CAL+1/2/3, VTH based on demand-weighted **CORE**

Year	2023		
Zone	Hedge ratio DE	Hedge ratio VTH	Hedge ratio difference VTH-DE
Country			
AT	1.04	0.93	-0.12
BE	0.91	0.82	-0.09
CZ	1.00	0.89	-0.11
DE	1.00	0.89	-0.11
FR	1.04	0.97	-0.07
HU	1.06	0.94	-0.12
NL	0.93	0.83	-0.09
PL	0.50	0.53	0.03
RO	1.03	0.91	-0.11
SI	0.69	0.62	-0.07
SK	1.00	0.89	-0.11
Countries outside the VTH calculation area			
ES	0.89	0.85	-0.04
IT	1.07	0.95	-0.11

Source: Compass Lexecon analysis
Note: Negative hedge ratio difference indicates lower hedge ratio of VTH compared to DE.

Sources: Derived from Hull, 2021. Options, Futures, and Other Derivatives, 11th edition.
Note: The optimal hedge ratio is the product of the coefficient of correlation between returns of proxy and country prices and the ratio of the standard deviation of proxy returns to the standard deviation of country returns.

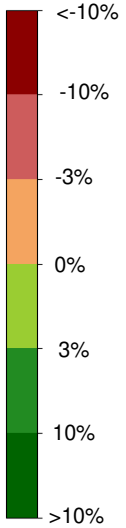
Static correlations – Consumption weighted results

Comparison between Hungary and VTH

- In the **CORE hub configuration**, **price correlation between Hungary and other zones is generally higher than with the VTH,** as was the case with Germany. **Exceptions remain with Spain, France and Poland**, where the correlations are mainly neutral or better with VTH compared to HU.
- However, **results improve for VTH CORE + South as the settlement prices in the VTH get better correlated than HU for most countries**, except RO and SI. This contrasts with DE, for which settlement prices showed higher correlation than VTH's in both specifications.

Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1/2/3, VTH based on demand-weighted **CORE region**

Year	2022		2023		2024		2025	
Zone	HU	VTH	HU	VTH	HU	VTH	HU	VTH
Country								
AT	98%	94%	99%	94%	99%	90%	98%	89%
BE	96%	92%	90%	86%	82%	77%	77%	78%
CZ	99%	94%	99%	94%	99%	91%	100%	90%
DE	98%	94%	99%	94%	99%	91%	100%	90%
ES	86%	82%	64%	65%	46%	46%	35%	42%
FR	96%	94%	94%	94%	88%	89%	85%	90%
HU	100%	93%	100%	94%	100%	90%	100%	90%
IT	94%	89%	87%	83%	86%	82%	62%	54%
NL	96%	92%	92%	88%	93%	87%	79%	78%
PL	59%	63%	52%	58%	28%	35%	8%	26%
RO	100%	93%	99%	93%	100%	97%	100%	95%
SI	100%	95%	100%	95%	100%	97%		
SK	98%	93%	99%	94%	99%	91%	100%	90%



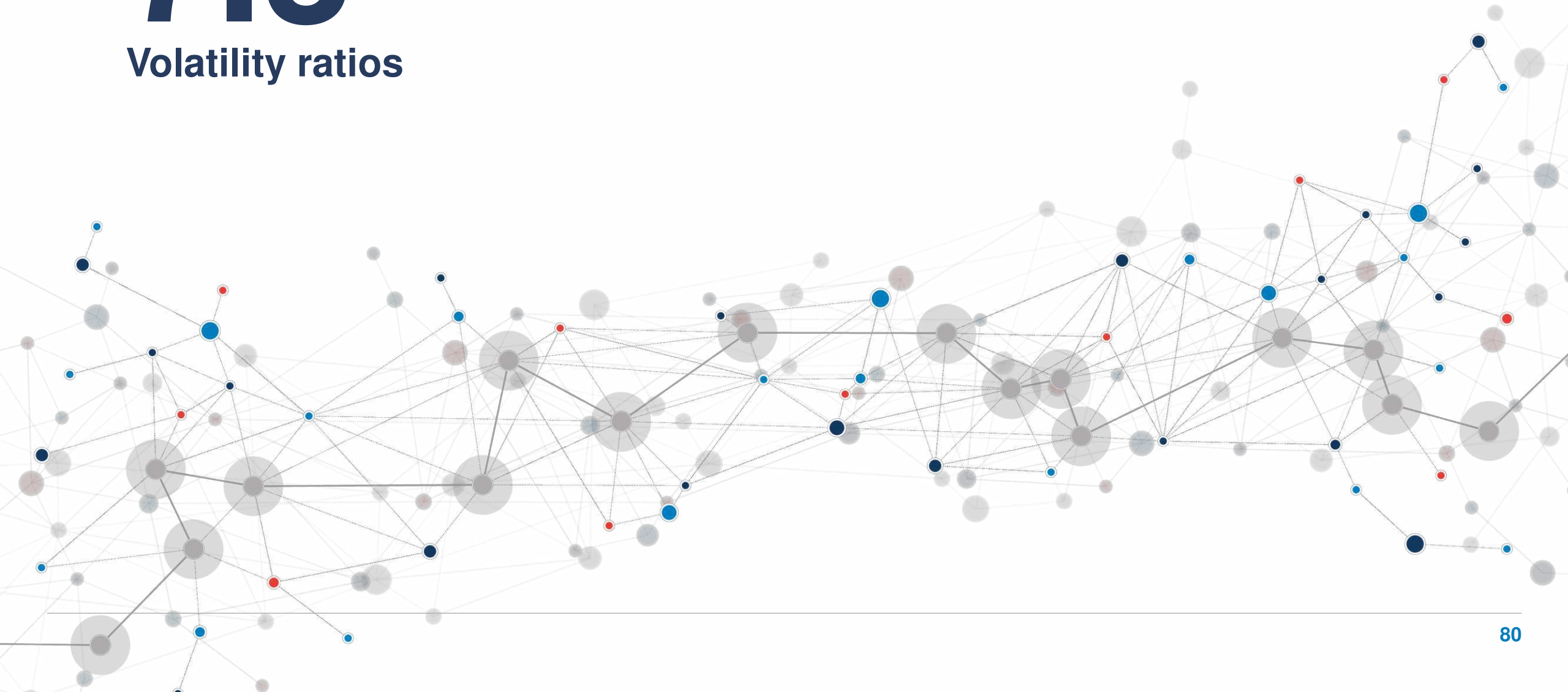
Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1/2/3, VTH based on demand-weighted **CORE + South region**

Year	2022		2023		2024		2025	
Zone	HU	VTH	HU	VTH	HU	VTH	HU	VTH
Country								
AT	98%	96%	99%	96%	99%	92%	98%	87%
BE	96%	93%	90%	89%	82%	79%	77%	77%
CZ	99%	96%	99%	96%	99%	93%	100%	87%
DE	98%	96%	99%	96%	99%	93%	100%	87%
ES	86%	87%	64%	71%	46%	53%	35%	48%
FR	96%	96%	94%	95%	88%	90%	85%	85%
HU	100%	95%	100%	95%	100%	92%	100%	87%
IT	94%	93%	87%	88%	86%	87%	62%	63%
NL	96%	94%	92%	91%	93%	88%	79%	76%
PL	59%	63%	52%	57%	28%	34%	8%	26%
RO	100%	95%	99%	95%	100%	97%	100%	93%
SI	100%	97%	100%	97%	100%	97%		
SK	98%	95%	99%	96%	99%	93%	100%	87%

Note: The colour code compares VTH to DE. It is based on the difference in correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to show how they would be impacted by the VTH.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

7.3
Volatility ratios

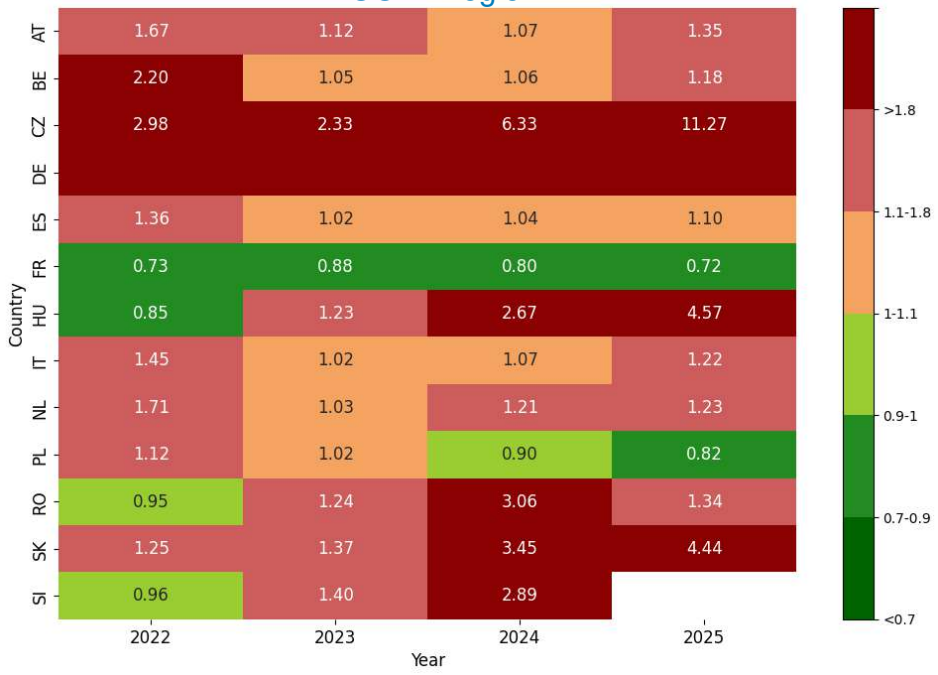


Volatility ratios – Consumption weighted results

Comparison between Germany and VTH

Ratio of standard deviations of spreads (VTH/DE) by country and delivery year, consumption-weighted

CORE region



CORE + South region

Comparison between regions*

Note: Liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3.

Note: * The colour ladder indicates if CORE + South specification is better (green), worse (red) or neutral (yellow) compared to the CORE-only specification.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

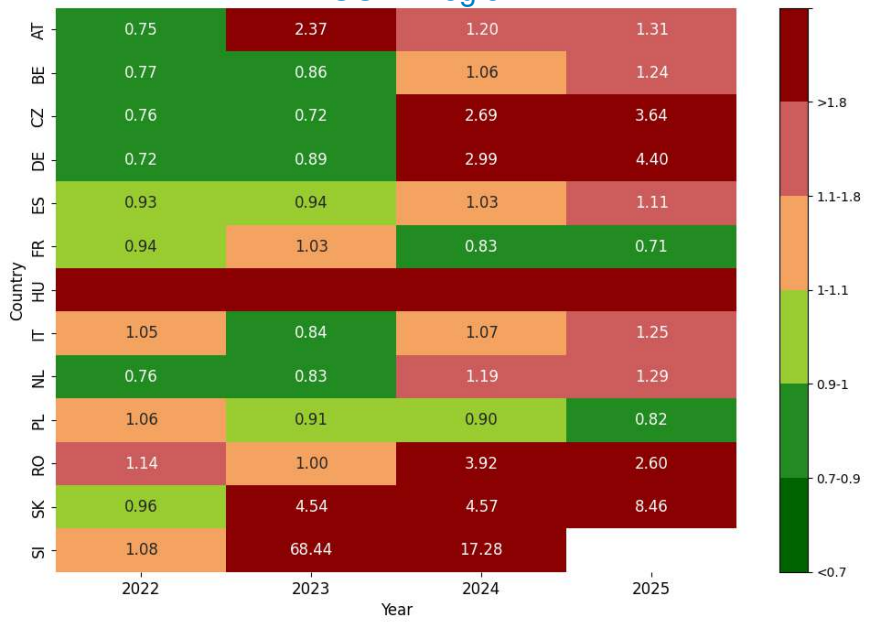
Volatility ratios – Consumption weighted results

Comparison between Hungary and VTH

- When comparing with the liquidity ratios for Germany, the VTH performs better compared to Hungary than to Germany (the matrix is much greener here). This is because the volatility of spreads with Hungary was higher initially, especially for countries where market participants would rather proxy-hedge in Germany.
- One insight that can be noticed here, but not with DE, is that in periods of low volatility (delivery year of 2022, i.e. trading year of 2019 to 2021), the VTH seems far better than HU, especially with the CORE + South region. There is a clear degradation of the liquidity ratios over time, which can be linked to increased market volatility.

Ratio of the standard deviations of spreads (VTH/HU) by country and delivery year

CORE region



CORE + South region

Note: Liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3.

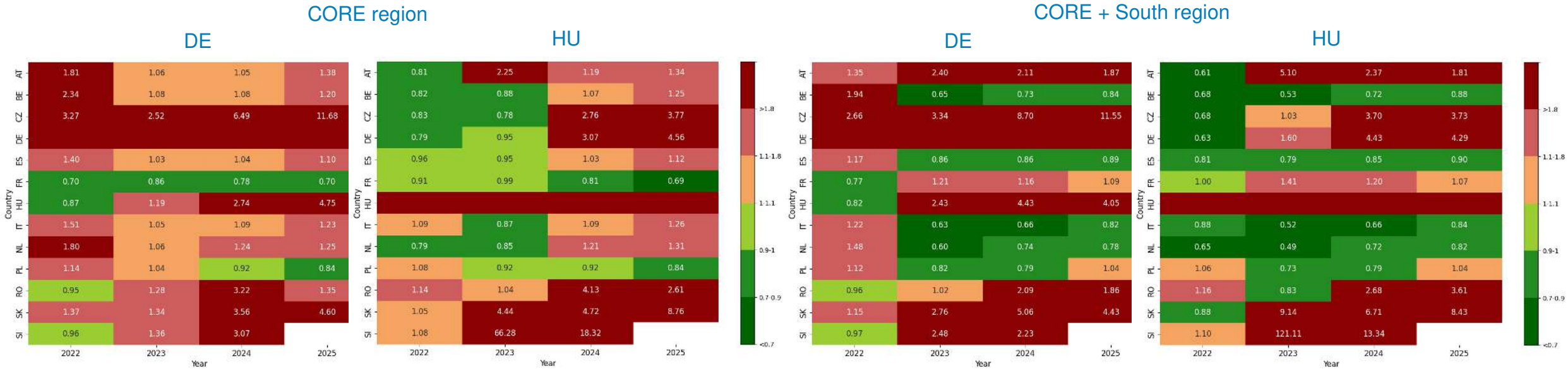
Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

Volatility ratios – Production weighted results

Comparison between Germany/Hungary and VTH

- The same conclusions can be drawn here for both the German and Hungarian hubs, the weighting having a limited impact on overall results.
- The CORE VTH is more suitable for FR and PL than Germany, but when extending to CORE + South, BE, ES, IT and NL are better off with the VTH than DE. We notice a similar pattern with HU.
- Here again, when looking at HU matrices, we notice that in 2022, the VTH shows better results, but they are declining over time. With DE, ratios are stable with CORE VTH, but there is an improvement in 2023 and 2024 with the CORE + South VTH.

Ratio of the standard deviations of spreads (VTH/hub) by country and delivery year

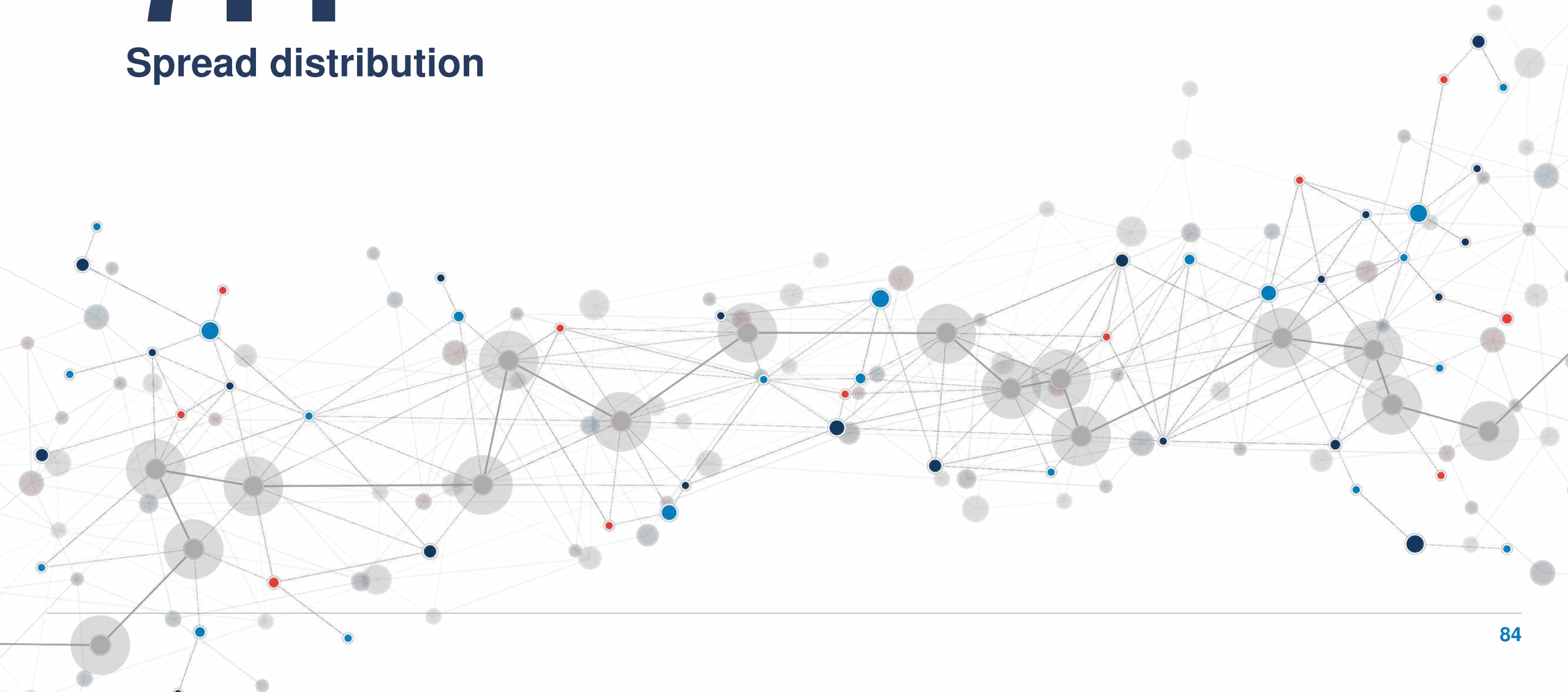


Note: Liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

7.4

Spread distribution



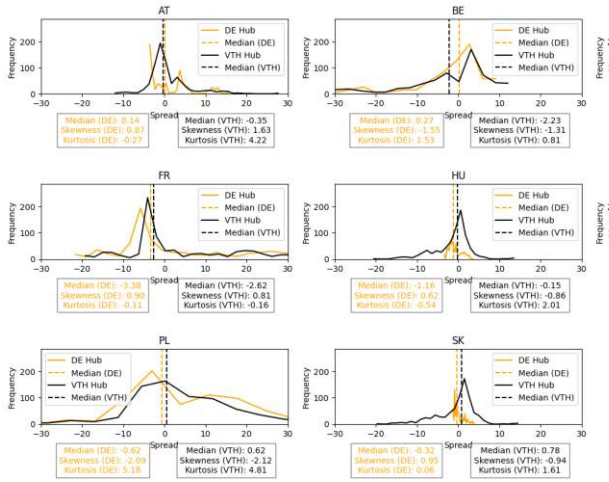
Spread distributions – Consumption weighted results

Comparison between Germany and VTH

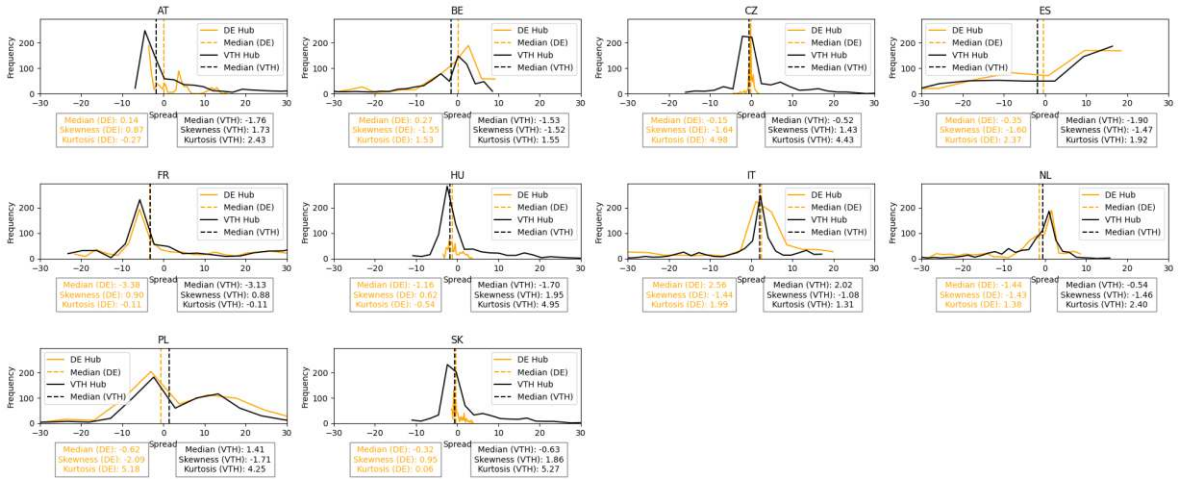
- The size of the sample greatly impacts the distribution of price spreads with VTH, especially for smaller countries like AT, BE, CZ, HU, NL and SK.
- However, no general conclusion can be drawn for all countries: while AT, FR and HU seem better off with the CORE VTH, other countries show a more normal distribution with the CORE + South VTH.
- It is also hard to draw a general conclusion on which hub is best: for example, AT presents more normal distributions with the VTH than with DE, while the contrary is true for IT and NL.
- Concerning distribution statistics, spreads with DE show lower medians than with VTH, especially for the CORE VTH. The symmetry of the distribution (measured by the skewness) is overall similar between specifications.

Price spreads distribution (area - hub) for DE and VTH hubs, CAL2024 products

CORE region



CORE + South region



Note: All distribution figures have a mean value of 0 (de-meaned).

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

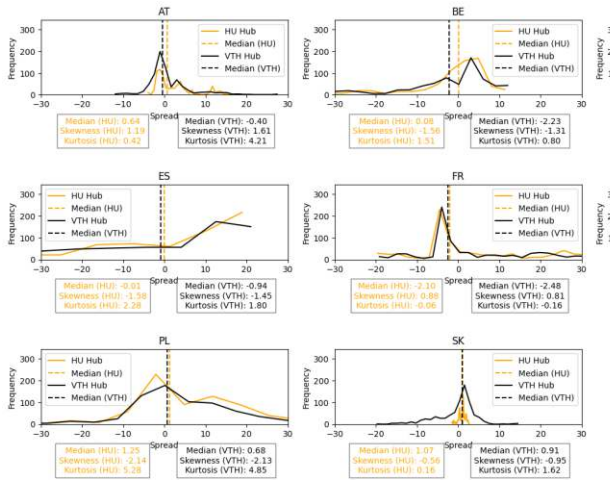
Spread distributions – Consumption weighted results

Comparison between Hungary and VTH

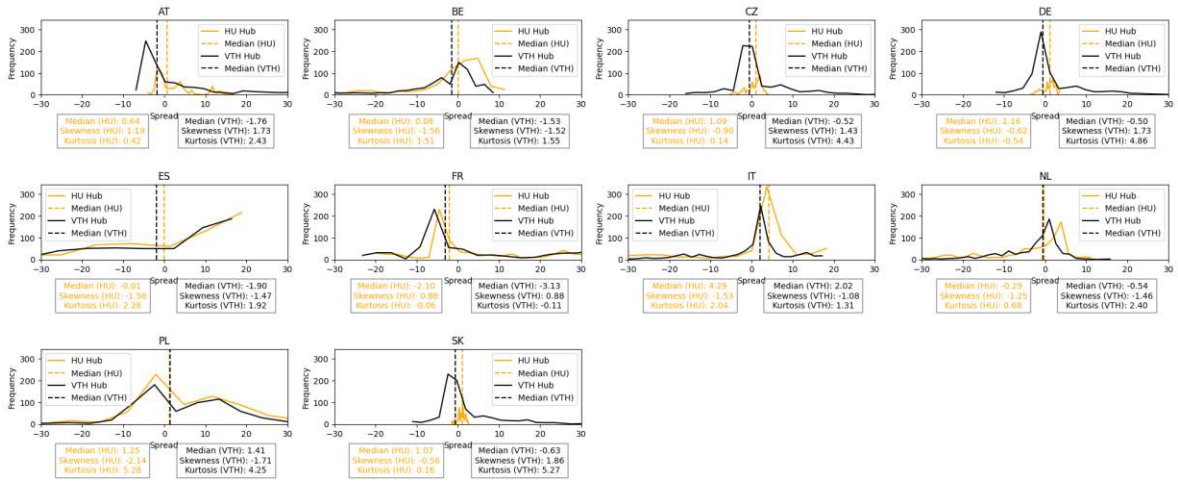
- The distribution of price spreads with Hungary appears less normal than with Germany, suggesting that hedging using DE would be more appropriate than with HU.
- As seen previously, it is not possible to draw a general conclusion between the CORE / CORE + South and the HU / VTH arbitrages.
- When comparing distribution statistics, HU also shows lower medians than VTH, but skewness is similar for both hubs, in all configurations.

Price spreads distribution (area - hub) for HU and VTH hubs, CAL2024 products

CORE region



CORE + South region



Note: All distribution figures have a mean value of 0 (de-meaned).

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

Spread distributions – Production weighted results

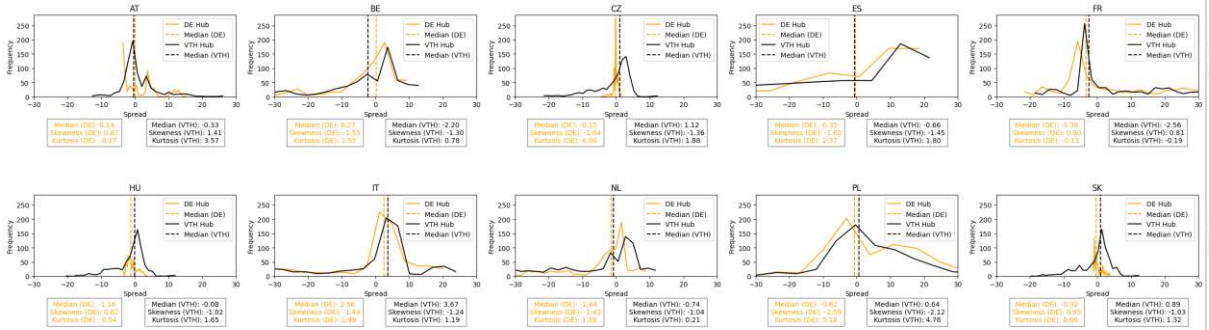
Comparison between Germany//Hungary and VTH

- The same conclusions can be drawn here for both German and Hungarian hubs, since as mentioned previously, the weighting has a small impact on overall results. One exception would be HU, which in this setup seems better off with the CORE + South VTH while it showed better distribution with CORE before.
- Distribution statistics also lead to the same conclusions: higher medians with VTH, and similar skewness.

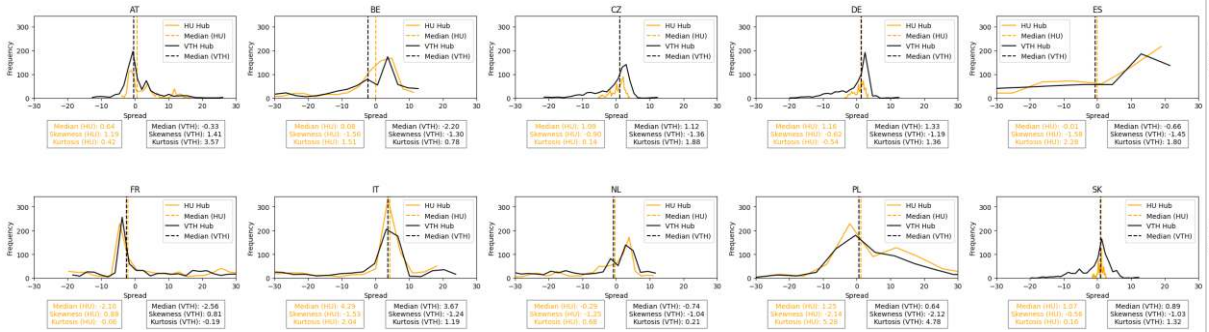
Price spreads distribution (area - hub) for DE / HU and VTH hubs, CAL2024 products

CORE region

DE

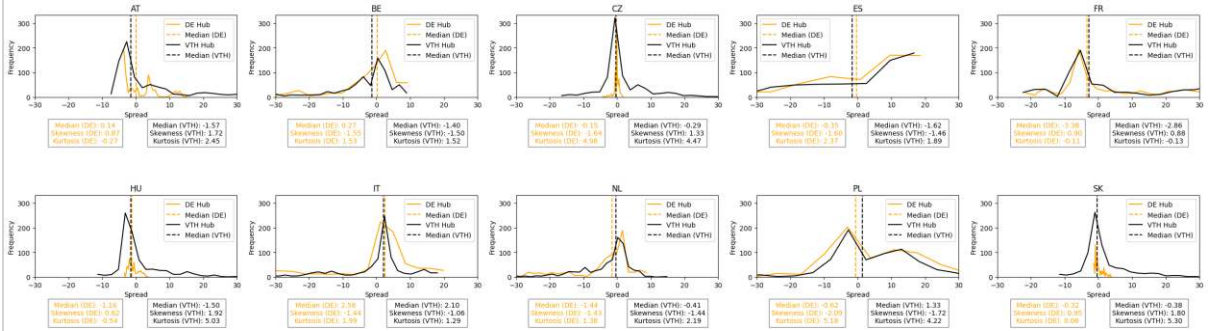


HU

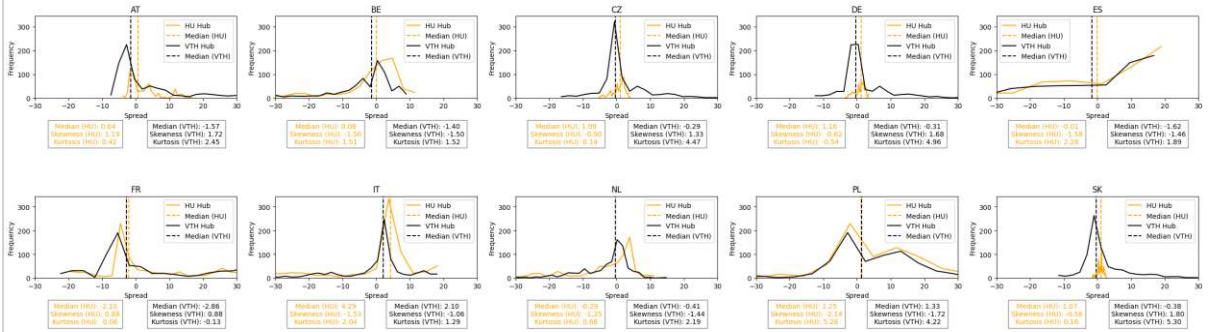


CORE + South region

DE

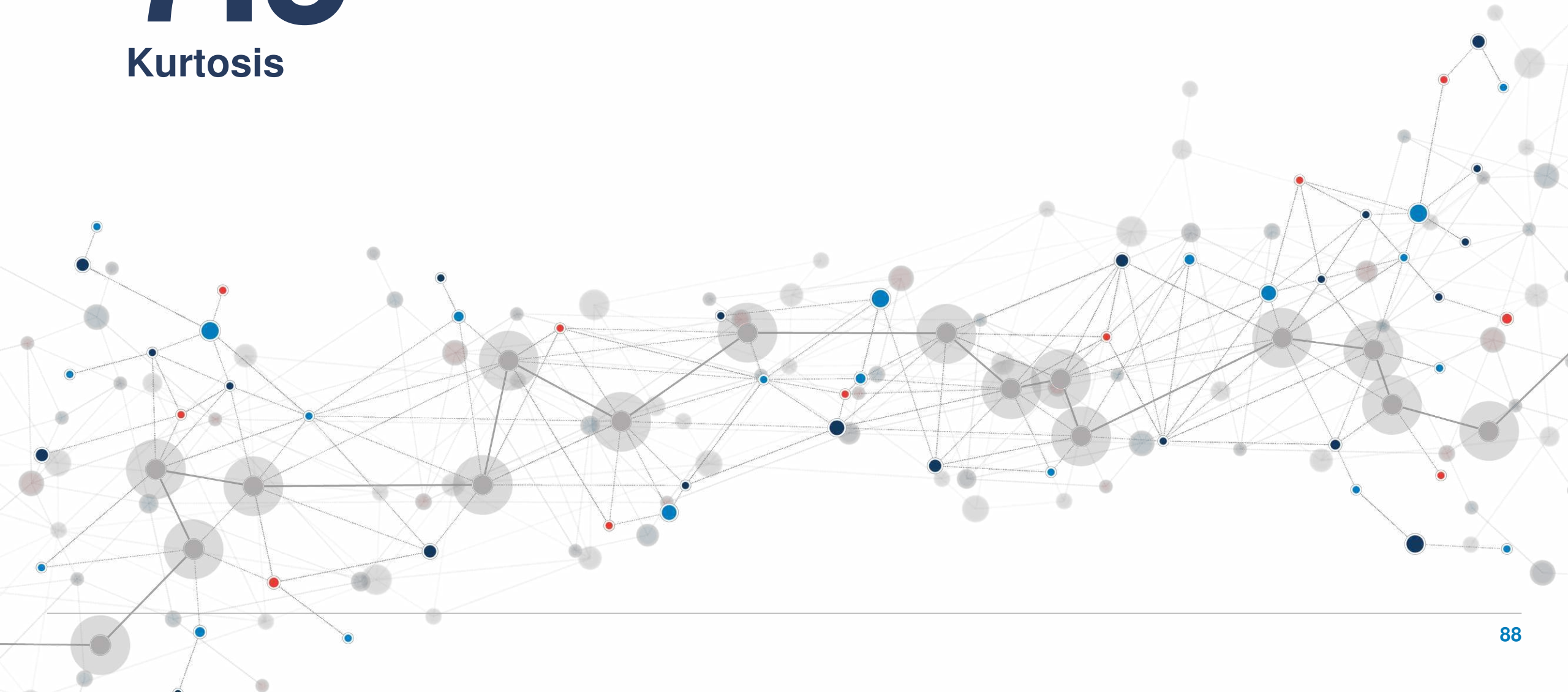


HU



Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data
Note: All distribution figures have a mean value of 0 (de-meaned).

7.5
Kurtosis



Kurtosis – Consumption weighted results

Comparison between Germany/Hungary and VTH

- The tables below show mixed results, as kurtosis may improve for a few countries with the VTH but also conversely. Only for the CORE region, when compared to DE, the kurtosis is lower for a majority of countries with the VTH.

Overview of summary statistics for spreads distribution (area - hub) for CAL2024 products

CORE region

Country	DE	VTH
AT	-0.27	4.22
BE	1.53	0.81
CZ	4.98	2.05
ES	2.37	1.82
FR	-0.11	-0.16
HU	-0.54	2.01
IT	1.99	1.23
NL	1.38	0.28
PL	5.18	4.81
SK	0.06	1.61
DE		1.59
VTH	1.59	

Country	HU	VTH
AT	0.42	4.22
BE	1.51	0.81
CZ	0.14	2.05
DE	-0.54	1.54
ES	2.28	1.80
FR	-0.06	-0.16
IT	2.04	1.22
NL	0.68	0.28
PL	5.28	4.81
SK	0.16	1.61
HU		2.00
VTH	2.00	

> 0.5
0.5
0
-0.5
< -0.5

CORE + South region

Country	DE	VTH
AT	-0.27	2.43
BE	1.53	1.55
CZ	4.98	4.43
ES	2.37	1.92
FR	-0.11	-0.11
HU	-0.54	4.95
IT	1.99	1.31
NL	1.38	2.40
PL	5.18	4.25
SK	0.06	5.27
DE		4.86
VTH	4.86	

Country	HU	VTH
AT	0.42	2.43
BE	1.51	1.55
CZ	0.14	4.43
DE	-0.54	4.86
ES	2.28	1.92
FR	-0.06	-0.11
IT	2.04	1.31
NL	0.68	2.40
PL	5.28	4.25
SK	0.16	4.27
HU		4.95
VTH	4.95	

Note: The colour indicators show whether using VTH is better (green) or worse (red) compared to DE. Values lower than 3 indicate a lower likelihood of outliers (compared to normal distribution) and above 3, a higher likelihood of extreme outliers. The colour coding is based on the difference of kurtosis between VTH and DE: $kurt_{VTH} - kurt_{DE}$.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

Kurtosis – Production weighted results

Comparison between Germany/Hungary and VTH

- The picture given by the kurtosis comparison is the same with the production weighting as with the consumption weighting. The tables below show mixed results, as the kurtosis may improve for a few countries with the VTH but also conversely. Only for the CORE region, when compared to DE, the kurtosis is lower for a majority of countries with the VTH.

Overview of summary statistics for spreads distribution (area - hub) for CAL2024 products

CORE region

Country	DE	VTH
AT	-0.27	3.57
BE	1.53	0.78
CZ	4.98	1.88
ES	2.37	1.80
FR	-0.11	-0.19
HU	-0.54	1.65
IT	1.99	1.19
NL	1.38	0.21
PL	5.18	4.78
SK	0.06	1.32
DE		1.36
VTH	1.36	

Country	HU	VTH
AT	0.42	3.57
BE	1.51	0.78
CZ	0.14	1.88
DE	-0.54	1.36
ES	2.28	1.80
FR	-0.06	-0.19
IT	2.04	1.19
NL	0.68	0.21
PL	5.28	4.78
SK	0.16	1.32
HU		1.65
VTH	1.65	

> 0.5
0.5
0
-0.5
< -0.5

CORE + South region

Country	DE	VTH
AT	-0.27	2.45
BE	1.53	1.52
CZ	4.98	4.47
ES	2.37	1.89
FR	-0.11	-0.13
HU	-0.54	5.03
IT	1.99	1.29
NL	1.38	2.19
PL	5.18	4.22
SK	0.06	5.30
DE		4.96
VTH	4.96	

Country	HU	VTH
AT	0.42	2.45
BE	1.51	1.52
CZ	0.14	4.47
DE	-0.54	4.98
ES	2.28	1.89
FR	-0.06	-0.13
IT	2.04	1.29
NL	0.68	2.19
PL	5.28	4.22
SK	0.16	5.30
HU		5.03
VTH	5.03	

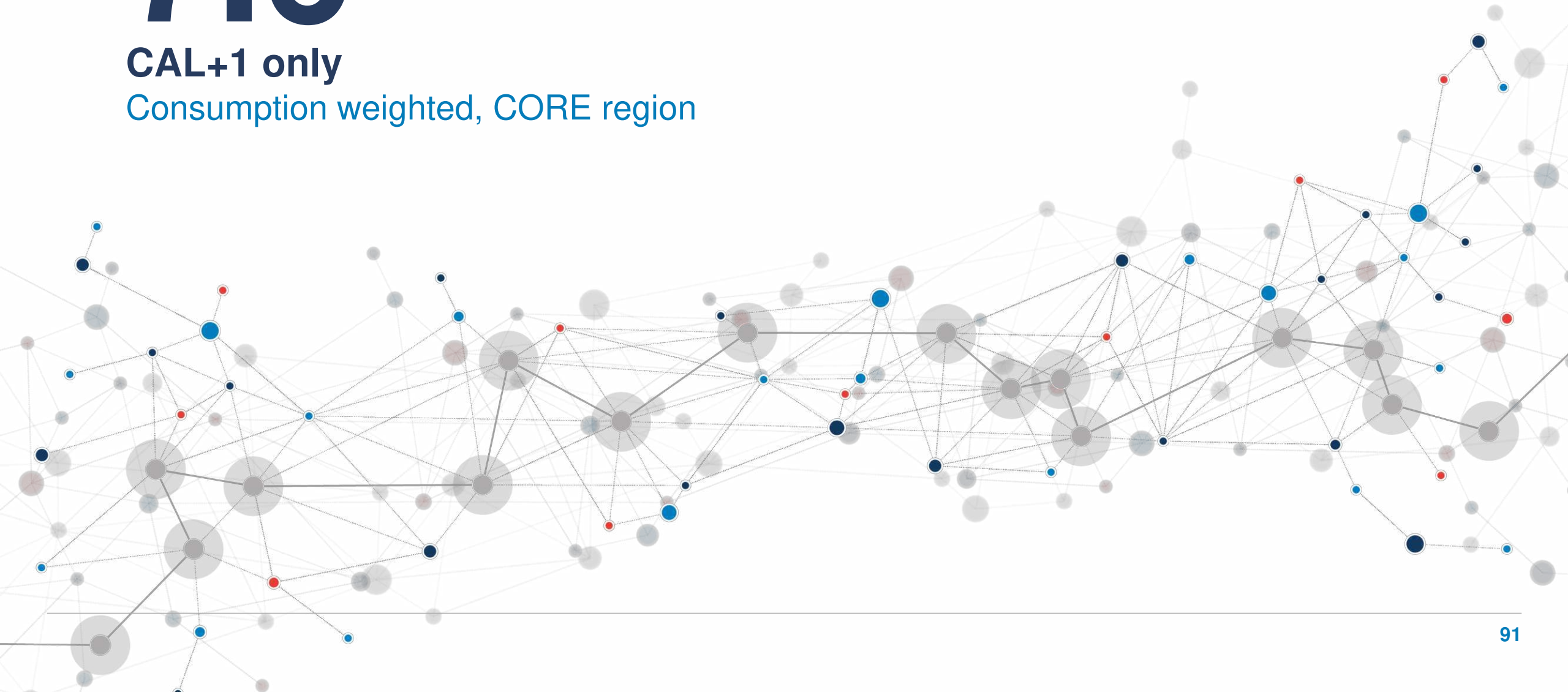
Note: The colour indicators show whether using VTH is better (green) or worse (red) compared to DE. Values lower than 3 indicate a lower likelihood of outliers (compared to normal distribution) and above 3, a higher likelihood of extreme outliers. The colour coding is based on the difference of kurtosis between VTH and DE: $kurt_{VTH} - kurt_{DE}$.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

7.6

CAL+1 only

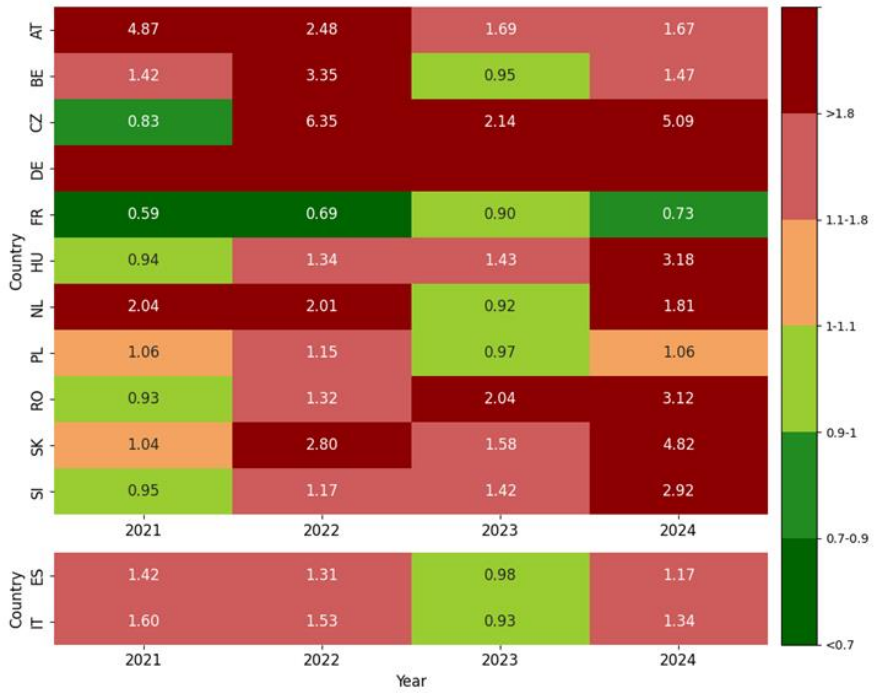
Consumption weighted, CORE region



Liquidity ratios and static correlations

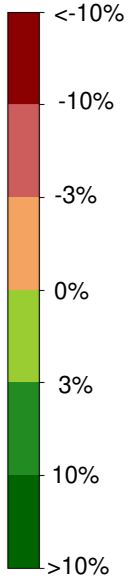
- The variation across years is much more significant with CAL+1 than with all CAL products. This can be due to the fact that for CAL+1, MPs only look at the next year, so a more foreseeable future. In particular, we notice a shift in 2023.
- Both comparisons are less advantageous for the VTH here, although the liquidity ratios improve in 2023.

Ratio of the standard deviations of spreads (VTH/DE) by country and delivery year for CAL+1 products **CORE region**



Price correlation (in log differences) between hub and country pairs, by delivery year for CAL+1, VTH based on demand-weighted **CORE region**

Year	2020		2021		2022		2023		2024	
Zone	DE	VTH	DE	VTH	DE	VTH	DE	VTH	DE	VTH
Country										
AT	100%	94%	100%	97%	100%	99%	100%	95%	99%	97%
BE	93%	90%	96%	94%	98%	97%	90%	87%	91%	91%
CZ	100%	94%	99%	96%	100%	99%	100%	95%	100%	97%
DE	100%	94%	100%	97%	100%	99%	100%	95%	100%	97%
FR	97%	94%	94%	96%	98%	99%	94%	95%	87%	95%
HU	94%	89%	94%	94%	100%	98%	100%	95%	100%	97%
NL	97%	93%	98%	95%	98%	98%	93%	89%	96%	95%
PL	58%	61%	69%	72%	59%	62%	51%	57%	25%	29%
RO	92%	88%	94%	93%	99%	98%	99%	94%	100%	97%
SI	91%	83%	92%	91%	100%	98%	100%	95%	100%	97%
SK	99%	94%	98%	95%	100%	99%	100%	95%	100%	97%
Countries outside the VTH calculation area										
ES	73%	70%	88%	87%	90%	89%	63%	64%	58%	58%
IT	92%	89%	96%	95%	96%	95%	86%	82%	95%	93%



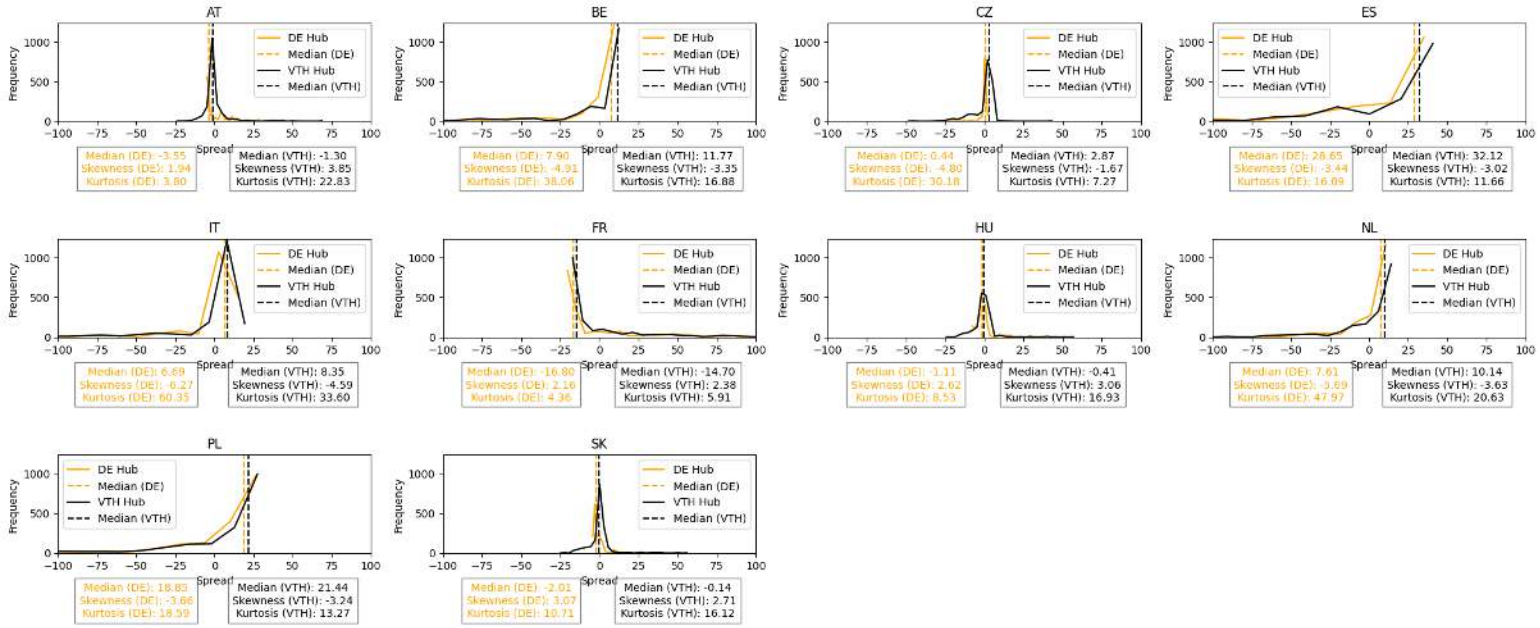
Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

Note: Liquidity ratios are defined as $\frac{std(average\_spreads(country,DE))}{std(caverage\_spreads(country,VTH))}$ for a product category (e.g. CAL) by delivery year. The average spreads are calculated as the daily average of spreads for CAL +1/2/3. For static correlations, the colour code compares VTH to DE. It is based on the difference of correlations between VTH and DE: $corr_{VTH} - corr_{DE}$. ES and IT are represented in this table even though they are not part of the VTH calculation to show how they would be impacted by the VTH.

Spread distributions and kurtosis

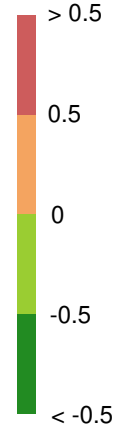
- The distributions are particularly peaked for all countries, which can explain the high kurtosis.
- Spreads with the VTH have smaller kurtosis, and this effect is more pronounced than with all CAL products.

Price spreads distribution (area - hub) for DE and VTH hubs, CAL+1 product



Overview of summary statistics for spreads distribution (area - hub) for CAL+1 product

Country	DE	VTH
AT	3.80	22.83
BE	38.06	16.88
CZ	30.18	7.27
ES	16.09	11.66
FR	4.36	5.91
HU	8.53	16.93
IT	60.35	33.60
NL	47.97	20.63
PL	18.59	13.27
SK	10.71	16.12
DE		8.97
VTH	8.97	



Note: The colour indicators show whether using VTH is better (green) or worse (red) compared to DE. Values lower than 3 indicate a lower likelihood of outliers (compared to normal distribution) and above 3, a higher likelihood of extreme outliers. The colour coding is based on the difference of kurtosis between VTH and DE: $kurt_{VTH} - kurt_{DE}$.

Sources: CL analysis based on EEX, TGE, OMIP and ENTSO-E data

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CONTACT DETAILS

Fabien Roques
Executive Vice President & Head of Energy Practice
froques@compasslexecon.com
Direct: + 33 1 53 05 36 29
Mobile : +33 7 88 37 15 01

Charles Verhaeghe
Vice President - Energy Practice
cverhaeghe@compasslexecon.com
Mobile : +33 6 10 88 73 84

Berlin
Kurfürstendamm 217
Berlin, 10719

Brussels
23 Square de Meeûs
Brussels, 1000

Copenhagen
Bredgade 6
Copenhagen, 1260

Düsseldorf
Kö-Bogen
Königsallee 2B
Düsseldorf, 40212

Helsinki
Unioninkatu 30
Helsinki, 00100

Lisbon
Praça Marquês de Pombal 14
Lisboa Lisboa 1250-162

London
5 Aldermanbury Square
London, EC2V 7HR

Madrid
Paseo de la Castellana 7
Madrid, 28046

Milan
Via San Raffaele 1
Milan, 20121

Paris
22 Place de la Madeleine
Paris, 75008