REPORT

Cross-border Forward Markets

An assessment of the status quo and proposed reforms of European long-term transmission rights

6 March 2024

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An assessment of the status quo and proposed reforms of European long-term transmission rights

Commissioned by 50Hertz Transmission GmbH, Amprion GmbH, Baltic Cable AB, TenneT TSO GmbH, and TransnetBW GmbH.

All analyses, arguments, views, and interpretations in this study are solely those of the authors and do not necessarily reflect those of the clients.

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Summary

LTTRs. EU law requires TSOs to issue long-term transmission rights (LTTRs). Unlike the term suggests, these contracts are not really about transmitting energy and not (only) rights. Instead, LTTRs are financial derivatives based on an underlying asset, which is the spread between two spot prices, e.g. bidding zones A and B. Two principle types of such derivatives exist, options and futures. While these are conventionally called FTR-options and FTR-obligations, we suggest calling them "spread options" and "spread futures", because that is what they are: options and futures on a (locational) price spread.

Inseparable from forward markets. LTTRs are inseparable from domestic forward markets. Issuing them is never just "allocating capacity" or "providing market access", but taking a position on domestic forward markets. This is most obvious for spread futures: selling a spread future between zones A and B is identical to selling a future in A and buying a future in B, i.e. taking a short and a long position in these zones. Doing so will always impact forward prices.

Scope. The EU is discussing a reform of cross-border forward markets. The list of proposed changes include a switch from spread options to spread futures, the introduction of a virtual trading hub, and earlier and more frequent LTTR auctions. This study aims at contributing to the discussion by addressing what we believe to be the principal economic question of TSO-issued LTTRs:

- Should they be issued at all, and why (objective)?
- What kind of contract (options or futures), and how much of them?
- To which marketplace should they be sold, and should the underlying be defined on a price index (virtual hub) rather than on a pair of zones?

This study is primarily economics in nature. Many additional technical, legal, and quantitative aspects would need to be clarified prior to an implementation of reforms. The ongoing implementation of flow-based long-term allocation is beyond the scope of this study. These are our principal insights and recommendations:

If and why. TSOs are in a good position to issue LTTRs, because the congestion income from spot markets provides the natural hedge for doing so. They should issue LTTRs, because otherwise import and export volumes would be missing in forward markets. While hedging congestion income is a sensible objective, it does not seem necessary for TSOs, because they are regulated entities. This is also not the objective that the law stipulates, which instead specifies that the reason for LTTR provision is to provide "hedging opportunities for market participants". It is not entirely clear to us what this concretely implies for the choice of derivative type and volume, so we have developed an interpretation based on a new analytical framework of forward markets, the "forward market equilibrium".

Forward market equilibrium. In the spot market, import and export volumes form part of demand and supply, which are in balance (Figure 1). Without LTTR provision, these volumes are missing on forward markets, leaving the forward market unbalanced and introducing a forward premium (Figure 2). This can be healed by bringing import and export volumes to the

forward market through LTTR provision (Figure 3). In the case of spread options, LTTRs should be issued equivalent to the volume of trade capacity, but not more. In the case of spread futures, selling the same number of MW would be generally too much, introducing a new distortion (Figure 4). Instead, spread futures should be issued equivalent to expected energy, i.e. net imports.

Demand-supply equilibria on spot and forward markets

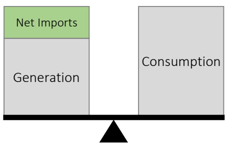


Figure 1. Spot market equilibrium of a net-importing country (balanced)

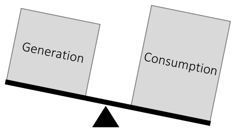


Figure 2. Forward market w/o import / export volumes (unbalanced)

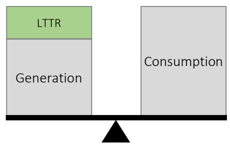


Figure 3. Forward market with LTTRs (re-balanced)

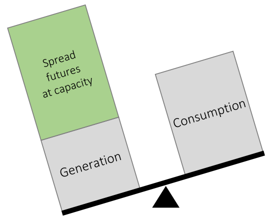


Figure 4. Forward market with spread futures at capacity (distorted)

Futures volumes. The proposed switch from spread options to spread futures is a bigger change than often believed, in particular regarding setting the right volume to issue, i.e. to decide how many MW of contracts should be auctioned off. Where it is plausible to sell options equivalent to transmission capacity, this is not the case for futures. Instead, TSOs would need to engage in delta hedging, the art of hedging an option by trading the underlying asset: they would need to continuously update expected trade and adjust volumes to harvest the time value of the (real) option that an interconnector is. This includes buying them back if expected imports turn into exports. Additional volumes must be issued if shorter products (quarters, months) emerge. The deeper reason that makes this necessary is that spread futures are bundles of futures, stretching over a longer period like a year where the underlying spot spread has an hourly granularity. All this is complex and effectively requires TSOs to acquire the competences of a commodity trading house.

Models. The why, what, and how much questions are linked and can be summarized as two consistent models, A and B (Table). This suggests that spread futures should be issued equivalent to the expected traded energy. However, if TSOs continue to issue spread options instead, some of the buyers will engage in delta hedging and at least some re-balancing of forward markets will occur.

	Model A Hedging congestion income	Model B Balanced forward markets
Objective (why?)	Hedging congestion income	Balanced forward markets
Derivative type (what?)	Spread options (FTR-options)	Spread futures (FTR-obligations)
Volume (how much?)	Expected spot trade capacity	Expected spot traded energy (net imports)

Auctions. Regardless of objective, derivative type, and volume, we recommend that selling LTTRs is organized in dedicated auctions, that the auctioneer is selected through a competitive procurement process, and that the supply of LTTRs in the auction is price-elastic. There are trade-offs regarding frequency and timing of auctions; a sensible setup seems to be monthly auctions with increasing volumes during the three years before delivery. In the case of spread futures, TSOs are exposed to counterparty credit risk, hence they should be cleared by a clearinghouse. In addition, we regard revenue adequacy as a secondary issue and recommend phasing out non-firmness of derivatives as well as LTA inclusion.

Virtual hub. Today, Germany serves as the main European (physical) electricity trading hub, i.e. it is used for proxy hedging by market parties across the continent. It has been proposed to introduce a regional virtual trading hub instead, which is a composite price index that serves as the underlying asset of financial derivatives, in particular forward contracts. One must distinguish between "a virtual hub being established and used" and "LTTRs being defined as zone-to-hub". If TSOs issue zone-to-hub spread futures, they do not take any net position on the hub, and hence might not trigger the use of hub-based futures by market parties, so the two questions might have less to do with each other than commonly thought. In our view, the net benefits of introducing a virtual hub are linked to the potential split of a German bidding zone: only if that physical hub disappears, a virtual hub seems necessary. If a virtual hub is introduced, we recommend defining it as the weighted average of spot prices, rather than as a hypothetical unconstrained price. Weights should be stable for at least multiple years and could reflect long-term average electricity consumption.

Terminology

There is no unique set of established terms for cross-border forward markets and products traded here. For example, there are many different terms to describe the same financial derivative: FTR-obligation, spread product, electricity price area differential, spread future. Table 1 lists the terms we use in this report, their definitions, and alternative terminology used elsewhere.

Table 1. Terminology

Our terminology	Definition	Alternative terms
Spread option	A bundle of hourly option contracts (e.g. for one year) on the spread between spot prices of two bidding zones	Financial transmission right option FTR-option Use-it-or-sell-it PTR-option
Spread future	A future contract on the spread between spot prices of two bidding zones or a bidding zone and a price index	FTR-obligation Congestion revenue right Spread product Electricity price area differential Contract for differences Spread forward
LTTR	Long-term transmission right; any cross-border forward derivative that is issued by TSOs	TSO-issued forward products
Day-ahead congestion income	Congestion income resulting from the day-ahead market coupling	
Long-term congestion income	Income generated from selling LTTRs	LTTR auction proceeds
LTTR settlement payouts	Payments resulting from settling LTTRs	LTTR remuneration
Expected spot trade capacity	Expected spot market average trade capacity between two bidding zones during the settlement period of an LTTR in MW (e.g., one year)	"At capacity"
Expected net traded energy	Expected spot market net trade flows between two bidding zones during the settlement period of an LTTR in MW (e.g., one year)	"At expected energy" Expected net imports

1 Introduction

Forward markets. Liquid forward markets are foundational for any electricity market. Market parties such as generation companies and utilities use forward markets to hedge price risk, and these markets provide the price signal that underpins many long-term contracts and public policies. Like other commodity markets, they are subject to economies of scale, and financial traders tend to flock to liquid marketplaces. As a consequence, liquidity in European electricity forward trade tends to be concentrated on few markets, in particular Germany, much like the Netherlands for natural gas.

Current setup. As of today, the main products traded on continental European electricity forward markets are financial forward and futures contracts. Options and other derivatives play a secondary role. The underlying asset of forwards and futures are hourly zonal spot prices. The most liquid product is the front year base contract. For Europe as a whole, trading volumes are roughly split into equal shares across energy exchanges, cleared OTC, and non-cleared OTC, but these shares vary considerably between countries. Trading volumes differ greatly between countries: Germany has a churn rate of 6 to 8 while most other markets have churn rates around 2 or less; many zones feature no significant trading volume at all.

Cross-border hedging. Electricity market parties across Europe often rely on the German market for hedging, and to a lesser degree on a few other markets (France, Hungary, and more recently Italy, Czech Republic, and the Netherlands). They can do so because electricity prices tend to be well correlated across borders, especially over longer time periods such as a year. When engaging in such proxy hedging, market parties often keep the remaining basis risk, the risk of domestic spot prices diverging from German spot prices, on their books. An alternative is to hedge the risk of zone-to-zone price spreads between bidding zones with cross-border derivatives, such as TSO-issued long-term transmission rights. LTTRs are regulated in the Forward Capacity Allocation Guideline.

ACER proposal. In June 2022, ACER published a policy paper on forward markets, preparing the ground for a possible recast of the FCA Guideline; it updated the paper in February 2023. The Agency proposed several fundamental reforms, including issuing spread futures (FTR-obligations) instead of spread options (FTR-options) and introducing a virtual trading hub. The European Commission picked up these ideas in their electricity market reform proposal and included them in revised Article 9 of the Electricity Market Regulation. The outcome of the reform discussion is that the Commission will conduct an impact assessment covering possible changes to frequency, maturity and nature of LTTRs, ways to strengthen secondary markets and the possible introduction of a virtual hub.

This study. Against this backdrop, this study provides analyses and arguments regarding reforms of the European cross-border forward markets. It is meant to provide input for a future EU impact assessment. In particular, we address the following four fundamental questions:

- Should TSOs provide LTTRs at all? (if)
- What is the objective such a provision aims to achieve? (why)
- What kind of derivative should be issued, options or futures? (what)
- Which volume should, and can, be offered? (how much)

Subsequently, we discuss three related questions:

- Should congestion income always exceed LTTR payouts? (revenue adequacy)
- Who should organize auctions and clearing? (marketplace)
- Should forward products refer to spot prices of bidding zones or a composite price index? (virtual hub)

2 Background

This section discusses proxy hedging and cross-border hedging needs, summarizes European cross-border forward markets as of today, defines our terminology, and outlines the ACER reform proposals.

2.1 Proxy Hedging and Cross-Border Derivatives

Guiding questions. Facing limited liquidity on domestic electricity forward markets, generators, industrial consumers, and retail suppliers can use a range of forward markets to stabilize future revenue streams. Those may rely on cross-border derivatives or, alternatively, proxy hedging. In the following, we discuss the market needs for cross-border products.

Hedging needs. As a first step, we take a step back from the question of cross-border products and discuss the underlying need for hedging among market parties. The hedging needs of industry and households on the demand side and renewable and conventional generators on the supply side differ. Understanding the need for hedging becomes, amongst other reasons, important in the later sections for determining the maturities and volume of cross-border products. If TSOs would offer volumes far in advance of market actors' hedging needs, they risk selling the cross-border products at a significant discount (i.e. “too cheap”) as natural demand is lacking and commodity traders would have to absorb the volumes at a discount.

Generation and demand. Low-carbon generators are high fixed cost, low variable cost assets. Therefore, they have a strong desire to hedge long-term to secure stable revenues. The demand side, however, has shorter hedging horizons. The energy intensive industry prefers to procure part of the electricity input at shorter term prices because prices for their output products are often correlated with power prices, so fixing input prices would increase profit risks, rather than helping reduce them. Electricity retailers serving household customers also prefer hedging shorter term, in line with their downstream obligations towards end consumers. Therefore, electricity forward markets have a structural supply surplus, usually resulting in a forward discount, so that it is on expectation cheaper to buy forward than spot.

Proxy hedging. Hedging must not be confused with procuring or selling electricity. Price hedging is all about mitigating price risk, i.e. the impact that unexpected price fluctuations have on the cash flow of a firm. To hedge against price risk, it is not necessary to sell or buy the actual commodity that a firm produces or needs. Instead, firms may buy or sell a financial derivative that is well correlated with its actual output in terms of price movements. This is called “proxy hedging”. In electricity markets, proxy hedging comes in the form of geography (trading a forward in a different bidding zone than the one you are located in), time (trading a forward with near-term delivery to hedge production in the more distant future) and commodities (trading natural gas or carbon permits instead of electricity). In practice, for example, a Belgian utility might hedge using a combination of the more liquidly traded German and French power futures, which are highly correlated to the Belgian power price, possibly in combination with Dutch natural gas futures. In practice, such strategies are often combined and substituted over time, e.g. swapping a proxy hedge for a local hedge once domestic liquidity improves for shorter maturities.

Basis risk. Proxy hedges come, however, with basis risk. This means, they are no perfect hedges, and the risk that the price of the proxy deviates from the actual output remains with the hedging entity. For example, a Belgian utility that has hedged on the German and French markets faces the risk that the Belgian price could deviate significantly from the German and French prices at the time of delivery, e.g., due to domestic Belgian factors and constrained interconnectors. Basis risk tends to be larger if bidding zones are only weakly interconnected, but also depends on other factors such as the generation mix and joint exposure to price shocks. Put differently, a cross-border proxy hedge protects against price shocks that impact the price level across both markets, but not shocks that affect the price spread between these markets.

2.2 Terminology

Transmission rights. Both the terms "long-term transmission right" and "financial transmission right" are established in academic literature, regulatory documents and used by practitioners. They stem from a time when these were mostly physically settled contracts that resulted in actual electricity being traded. Today, given that today they refer mostly to financial derivatives, they can be a bit misleading. Financial transmission rights are not really about "transmission", because they are not about transmitting energy. Also, they are not necessarily "rights", because they can also be an obligation. Instead, one should better speak of "financial derivatives on a locational spread", i.e. derivatives on an underlying asset that is the difference between two spot prices, e.g. bidding zones A and B. There exist two fundamental types of such derivatives, options or futures on that spread. We hence refer to them as spread options and spread futures instead of the conventional terminology FTR-options and FTR-obligations. Despite these concerns, we use the established term long-term transmission rights to refer to cross-border derivatives that are issued by TSOs. We do so regardless of the type of derivative (physical or financial, future or option) and regardless of how and where they are sold and traded.

Cross-border. Also, the term "cross-border" is widely used in this context, such as in "cross-border products" or, like the title of this study, "cross-border forward markets", which we use to connect to preexisting discussions. This can be misleading, too, since these contracts are not limited to neighboring countries. They can refer to the spread between any spot prices, say Germany and Spain, or Germany and Texas. It does not even have to be an actual location, but can be a composite price index, i.e. a virtual hub.

Spread futures. A particular source of confusion is the many names given to the same derivative which we call a spread future. It is referred to as FTR-obligation, congestion revenue right, spread product, price area differential, or contract for differences. All these terms refer to the same financial contract: a cash-settled derivative that results in payments that depend on the spread between spot prices in bidding zone A and B during the settlement period of length T:

$$Payment = contract\_price - \sum_{t}^{T}(spot\_price_t^A - spot\_price_t^B)$$

- The term "FTR-obligation", which is used both by the academic literature, EU legislation, as well as some US systems such as PJM, emphasizes that it is not an option, the other type of FTR commonly used. But the term is a bit counterintuitive because it is not just a "right" to receive a future payment, but also the obligation to pay a charge, depending on spot price spreads. Also, it is a financial contract, hence the term "transmission" can be misleading.
- In the US power markets CAISO and ERCOT the same derivative is called a "congestion revenue right". Also, this term is slightly counterintuitive, because it may result in a charge rather than a payment to the owner.
- EEX uses the term "spread product" and Nasdaq Commodities "electricity price area differential" (EPAD).
- The derivative is a "contract for differences", where the strike price is the buy price.

We prefer the term "(locational) spread future", because the contract is identical to a conventional (domestic) electricity futures contract, only that the underlying is not spot prices, but the spread between two zones' spot prices. Whether to use the term "futures" or "forwards" depends on whether it is a cleared product: futures are cleared products (and must therefore be standardized), forwards are not. As clearing is likely necessary, we use the term "spread futures".

2.3 Cross-border Derivatives Today

LTTRs. Long-term transmission rights are cross-border derivatives issued by TSOs. They are required to provide them according to Article 9 of the Electricity Market Regulation in combination with the Forward Capacity Allocation Guideline. TSOs may choose between three types of contracts: physical transmission rights with use-it-or-sell-it condition, spread options (FTR-options), or spread futures (FTR-obligations). The latter, however, has not been used in practice. Use-it-or-sell-it PTRs are financially equivalent to spread options. LTTRs are only issued for zone-to-zone combinations for which a physical interconnection exists. The FCA guideline requires TSOs to auction LTTRs through a so-called single allocation platform (SAP), for which they use a service provider called the Joint Allocation Office. The auction is not linked to domestic forward markets and hence can be thought of as an explicit market coupling. The cumulative auction revenue was €4bn in 2021, jumping to €13bn as power prices skyrocketed during the 2022 energy crisis, according to JAO's annual report.

Spread products. The European Energy Exchange lists "locational spread products". Those are similar to (domestic) futures that are based on zonal spot prices as the underlying asset, but instead the underlying is the price spread between two bidding zones. Buying a spread product of one zone against another is equivalent to buying a domestic future contract in the first zone and selling a future in the other; in fact, spreads are not even outright products. Instead, buying a spread from France to Germany on EEX results in a long position on the French future, and a short position on the German future. Spread products are available in the same durations (years, quarters, months) as domestic futures and with the same profiles (peak, base). Spread products are offered in 23 different combinations, not limited to zones that have physical borders, e.g. a German-Hungarian spread. Spread products are not subject to any specific energy regulation, but are, of course, subject to general financial markets regulation.

Nordic. The Nordic and Baltic market uses a different system of cross-border derivatives that is separate and independent from both spread products and LTTRs. Electricity price area differentials (EPADs) are traded on Nasdaq Commodities, which had bought Nord Pool's forward market in 2008. In June 2023, EEX and Nasdaq Commodities have announced the intention to transfer Nasdaq's European power business to EEX, so EEX will also be the dominant player in the Nordics, pending regulatory approval. EPADs are similar to spread products both in the sense that they are traded on an energy exchange and that they are financial forwards referring to a spot price spread as underlying. That spread, however, is not the spread between two zones, but the spread between the Nordic system price and a zone. The system price is calculated as the hypothetical price in the Nordic region for every hour if network constraints were absent. This is a virtual trading hub, so EPADs are zone-to-hub spread futures. A second difference between EPADs and spread futures is that Swedish TSO Svenska Kraftnät, as a pilot project, provides liquidity to the EPAD market, i.e. is buying and selling the products. Table 2 provides a summary of cross-border derivatives used in Europe today.

Table 2. Properties of cross-border derivatives used today

Product	LTTRs	Spread products	EPADs
Region	Continental	Continental	Nordic / Baltics
Issued by TSOs	Yes	No	No (until 2023) Yes (SvK pilot project)
Type of derivative	• Options (called PTR w/ UIOSI or FTR-options) • Forwards (called FTR-obligations) legally possible but not used	Futures (called spreads)	Futures (called differentials)
Firmness	Non-firm (payout suspended in certain cases, e.g. maintenance)	Firm	Firm

Underlying	Zone-to-zone spread	Zone-to-zone spread	Zone-to-hub (system price) spread
Trading platform	Single allocation platform (JAO)	Energy exchange (EEX), broker	Energy exchange (Nasdaq), broker
Timing of trade opportunities	Discrete auctions	Continuous trading	Continuous trading, SvK: auctions

2.4 Financial Flows

Three financial flows. Financial flows triggered by LTTRs occur in the context of congestion income. There are three kind of payments being made: day-ahead congestion income, long-term congestion income, and LTTR payouts.

Congestion income. TSOs receive congestion income from spot markets. In particular, the day-ahead market coupling algorithm results in congestion income, but also intraday, once intraday actions are introduced, and balancing markets yield congestion income. Under NTC market coupling, these are always payments towards TSOs that occur on each border and can be calculated as "price spread times commercial flow". Under flow-based market coupling, there is no per-border cross-border trade directly resulting from the market coupling. Instead, there are just net positions of bidding zones, such that, mathematically speaking, congestion income does not occur on individual borders but for the whole capacity calculation region. These are then split among TSOs according to a heuristic called "congestion income distribution key".

Long-term congestion income. When issuing LTTRs of the spread options type, TSOs receive an income. This is called long-term congestion income. When selling spread options, the income is always positive since the fair price of an option is never negative. In the case of spread futures, payment flows would likely be defined similarly to futures on domestic markets. Futures are essentially contracts for differences on a fixed volume, in which differences to the price at which the futures contract is entered into are settled at maturity, while as a kind of collateral deposit an initial margin is due in the beginning and a variation margin continuously as price and volatility of the underlying changes. The question of fair pricing vs. underpricing concerns auction proceeds (in the case of options) and the price at which a spread futures is entered into (in the case of spread futures).

LTTR payouts. At maturity, LTTRs result in settlement payouts. In the case of spread options, the payment always goes from TSOs to option holders. In the case of spread futures, the payment may go in either direction. The question of revenue adequacy concerns the question whether congestion income is sufficient to cover LTTR settlement payouts, without considering auction proceeds. LTTR payouts are sometimes also called remuneration of LTTRs.

Rate payers. What ultimately matters is the sum of the three components, which may be called "net income from interconnectors". The use of congestion income is strictly regulated in Article 19 of the Electricity Regulation (2019/943) so that it ultimately benefits ratepayers.

2.5 THE ACER PROPOSAL

Policy papers. In June 2022, ACER and CEER published a joint policy paper on forward markets, specifying a range of reform options for cross-border forward markets. ACER published an updated paper in February 2023. On the one hand, it suggests a number of improvements of existing long-term transmission rights with respect to product definitions, timing of auctions, maturities, firmness of contracts, volumes issued, etc. On the other hand, the paper suggests the introduction of regional virtual trading hubs. In general, ACER's opinion seems to be shaped by the Nordic system of a system price, EPADs, and the Svenska Kraftnät pilot project. The proposal continues to draw significant criticism from market parties and stakeholders.

Problem diagnosis. ACER rests its proposal on the identification of four major problems that concern cross-border forward markets (in addition to other issues that relate to forward markets generally, such as market power and policy interventions that make firms hedge less):

- Poor liquidity and limited market depth of many zonal forward markets while much trading is concentrated on the German zone.
- LTTRs not being useful to be combined with domestic forwards for hedging, because they are options, not continuously available, and are limited to one-year maturities.
- Auction revenues regularly fall short of the payouts during settlement, which is interpreted as underpricing.
- Impacts on forward markets if the German zone would be split.

LTTR improvements. To address these perceived problems, ACERs suggest changing long-term transmission rights with respect to product definitions (moving from PTR and FTR-options to FTR-obligations), timing of auctions (more frequently), maturities (longer than one year), firmness of contracts and volume of LTTRs issued (e.g., "statistical approach"). In principle, all these reforms could be implemented without a virtual hub, even though ACER claims the reduced number of LTTRs with the introduction of a virtual hub allows longer maturities and more frequent auctions.

Virtual hub. On the other hand, ACER proposes the introduction of a virtual trading hub, i.e. the establishment of a composite price index that stretches across several zones ("hub") and the use of the zone-to-hub spread as underlying for LTTRs.

Proposals. Rather than suggesting a fleshed-out, internally consistent reform package, the ACER paper lays out a large set of "reform options" and then provides an assessment of these options. However, it is not always clear which of these options are mutually exclusive, re-reinforce each other, or are otherwise interdependent. Our understanding is that ACER proposes the following specific reforms:

- Replace PTRs / spread options with spread futures

- Replace non-firm products with fully financially firm derivatives
- Increase maturities offered to three years, up from one year today
- More frequent auctions, e.g. every week or every day
- Improving secondary trading and offer local matching on the single allocation platform
- A "statistical approach" to volumes, balancing 3 objectives: maximize volume, minimize revenue inadequacy, and minimize the risk of underpricing
- Define a composite price index that stretches across several zones to serve as an underlying for forward contracts (virtual hub)
- A switch from zone-to-zone LTTRs to zone-to-hub LTTRs

2.6 Not Just "Providing Market Access"

Providing access. It is often suggested that, when issuing LTTRs, TSOs are (or should be) "just providing market access", that they are a neutral entity that helps markets to function without affecting the market outcomes such as prices and volumes. It is said that "TSOs should be facilitators, not traders", that they "should provide capacity, not trade energy", and that they "should support the market, not participate in the market". That also seems to be the spirit of the FCA regulation that stipulates LTTRs are issued to provide "hedging opportunities for market participants". That is, however, an impossibility.

Taking positions. Unless volumes are marginally small, issuing LTTRs will always impact forward markets, influence the forward premium and, hence, forward prices. This is obvious for spread futures because these *are* a pair of domestic futures. Selling a French-German spread is the same thing as selling a future in France and buying one in Germany. Issuing spread futures hence necessarily implies TSO taking a position on forward markets. This is also true for spreads options, even if the link is indirect and works through delta hedging of the option holders (explained in Box 2).

3 Why, What, and How Much? The Fundamentals of LTTRs

This section discusses four fundamental economic questions around TSO-issued LTTRs that turn out to be deeply interwoven:

- Should TSOs provide LTTRs at all? (if)
- What is the objective such a provision aims to achieve? (why)
- What kind of derivative should be issued, options or futures? (what)
- Which volume should, and can, be offered? (how much)

3.1 If and Why? The Forward Market Equilibrium

Hedging congestion income. The reason for firms to engage in forward markets, if they are not speculating, is to hedge against price risk. If TSOs were unregulated companies, congestion income would be just another revenue stream and source of cash-flow, hence one might argue that TSOs should issue LTTRs in order to hedge congestion income. The fact that TSOs currently issue non-firm options indeed suggests hedging as an objective, because these derivatives are a close-to-perfect hedging instrument for congestion income. However, TSOs are regulated entities that have an essentially guaranteed income through network charges, hence there seems to be little economic reason for them to hedge.

Enable market participants to hedge. An alternative plausible objective for LTTR provision is to enable cross-border trade and provide hedging opportunities for market parties. There is demand for cross-border products from market parties who use foreign forward markets for hedging and TSOs are in a position to provide cross-border products, because congestion income provides a natural hedge. In fact, the Electricity Market Regulation states that the objective of LTTR provision is "to allow for market participants … to hedge price risks across bidding zone borders" and the FCA Guideline stipulates that it is to provide "hedging opportunities for market participants". But what exactly does this mean, what does this imply for derivative type, volume, etc.? To clarify these questions, we are introducing a new analytical framework: the forward market equilibrium.

A simple example. The most illustrative case of a forward market equilibrium is a bidding zone that has only consumption and no generation but is well interconnected. In that zone, spot markets are balanced, because buyers (consumers) find sellers (import). Forward markets, however, are unbalanced. Demand does *not* meet supply, because import volumes are not represented in forward markets. Re-balancing forward markets then means bringing the import volumes to the forward market. Only the TSO can do this, the entity that serves as seller on the spot market.

Step 1: Forward equilibrium. The “forward market equilibrium” is an analytical framework to think about the role of cross-border trade in shaping short and long positions on forward markets and the resulting forward premium. We introduce it in four steps. The forward market considered here consists of just one point in time (where in reality it evolves continuously) and comprises all marketplaces and contracts (futures, forwards, PPAs, etc.). Producers of electricity have a natural long position and consumers a short position. If all demand and supply for forward contracts is present in the market, including imports and exports, this results in a forward premium of zero, i.e. the forward price is the expected spot price. We call this a forward market in equilibrium (Figure 5).

Step 2: Dis-equilibrium. If the import and export volumes make no appearance on the forward market, it is out of equilibrium. In an import-dominated bidding zone, the demand for forward contract would exceed supply (Figure 6).

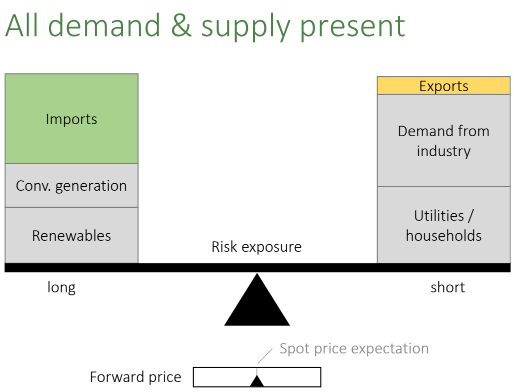


Figure 5. A forward market in equilibrium.

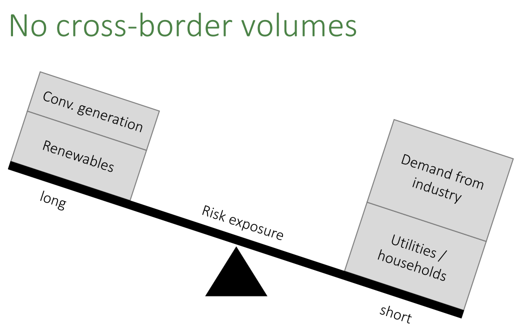
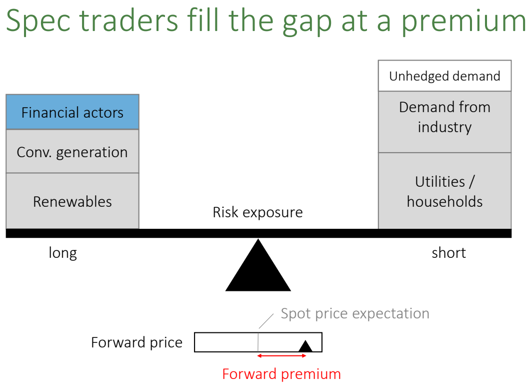


Figure 6. No TSO engagement: Dis-equilibrium.

Step 3: The market rebalances. Like any other market, the forward market finds a new equilibrium through the adjustment of the price. That price is the forward premium, the deviation of the forward price from the expected spot price. The strong demand for forward contracts drives up the forward premium, triggering two types of responses: first, financial actors – speculators – enter the market. They essentially take over risk from consumers and get paid for that service in the form of a forward premium. For that reason, the forward premium is also often called forward risk premium in the literature. In addition, some consumers would reduce their price hedging activities because it is becoming too expensive. In that sense there is unserved hedging demand (Figure 7).

Step 4: TSO volumes. A balanced forward market without a forward premium is reached if import and export volumes are provided to the market. This can only be done by TSOs, because they are the entities that bid those volumes in the spot market, too – in the form of implicit market coupling. Then all fundamental demand and supply – including cross-border volumes – are present in the forward market (Figure 8).



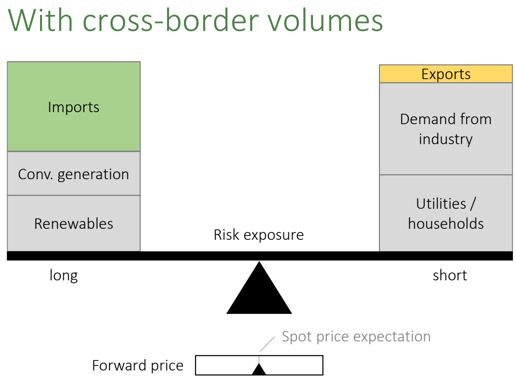


Figure 7. The market rebalances at a premium.

Figure 8. Forward market with TSO volumes.

Generalizations. This simplified illustration can be generalized. Missing import and export volumes distort the forward premium also in the presence of heterogenous hedging preferences (i.e., when the supply side has a greater desire to hedge than the demand side) or in the presence of policy-induced forward distortions (such as from renewable support policies or from fixed power prices for some consumer groups). Also, the effect of missing import and export volumes on the forward market is independent from the marketplace, i.e. whether trading takes place on continuous forward markets, in the form of PPAs or over the counter, as it is about the overall risk exposure in the market regardless of trading venue. To avoid the distortions stemming from the lack of import export volumes, it seems a sensible policy to issue LTTRs.

Cost-benefit. Whatever the objective – hedging congestion income or balancing forward markets – obviously the objective must be weighed against the net costs (if any) of issuing LTTRs. If LTTRs are sold at zero discount and at a fair price, expected auction proceeds are identical to expected congestion revenue, and LTTR provision does not come at a cost. To the contrary, if the option value of the interconnector is captured, LTTR proceeds should, on average, exceed congestion income. However, if LTTRs are issued at excessively long maturities, or if auctions and contracts are poorly designed, or if markets lack competitiveness, there might be a net cost to LTTR provision. For example, the wish to provide hedging opportunities at very long maturities should be traded off against the reduced income that this likely results in.

Conclusions. The "forward equilibrium" logic has at least three important implications: first, it shows that TSOs should issue LTTRs. So, the answer to the if-question is yes. Second, it suggests that ultimately it is forward market volumes that should reach each bidding zone, an objective that can more directly be accomplished by issuing spread futures (FTR-obligations) than spread options (FTR-options). Third, it tells us something about the volume of LTTRs to be issued. To re-balance forward markets, in the case of spread futures, the volume should be equal (or less, if not all demand hedges on forward markets) to expected net imported energy. This is in general (much) lower than selling futures in volumes equivalent to trade capacity ("at capacity"). In the extreme case of two well-interconnected bidding zones where trade goes in both directions and cancels out throughout the year, no spread futures should be issued at all.

3.2 What? Spread Options vs. Spread Futures

Type of derivative. In this section, we discuss what kind of derivative TSOs should issue, i.e. what kind of contract LTTRs should be. This is a surprisingly complex question that is intimately linked with the volume-question. Applying finance tools and theories is not straightforward, because electricity markets trade multi-hour derivatives such as year products. These are effectively bundles of derivatives. For example, a conventional domestic year base futures contract really is a bundle of 8760 futures, each with a different underlying asset – an hourly spot price.

Physical / financial. In principle, LTTRs can be physically or financially settled. Financial derivatives are generally preferred, because physical contracts may result – depending on exact specification – in inefficient trade and under-utilization or simply in added transaction costs, especially in conditions when the owner no longer wishes to import.

Options / futures. There exist two principal forms of defining an LTTR: as an option or a future. What is identical in both cases is the underlying asset: the spread between two spot prices, e.g. bidding zones A and B. A spread option (call option) A->B results in a payout from the option writer (TSO) to the option holder (buyer) if the spot price spread is positive. Otherwise, there is no payout. The reverse option B->A, also called a put option A->B, results in a payout from the writer to the holder if the spread is negative. Hence when issuing a pair of options, there is always a settlement payment from TSO to buyer or no payment, but no reverse payment (Figure 9). This is different for a spread future that results in settlement payments proportional to the spot spread, the reason why it is also called a linear product. The fact that buyers might be obliged to pay a charge is the reason this derivative is also called an obligation (Figure 10).

Spread options

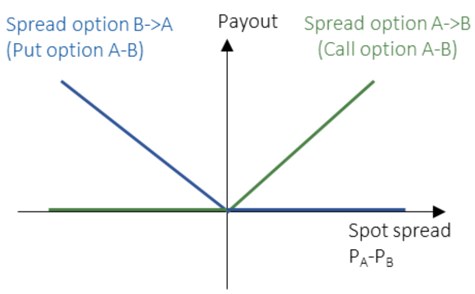


Figure 9. Payout of two spread options.

Spread futures

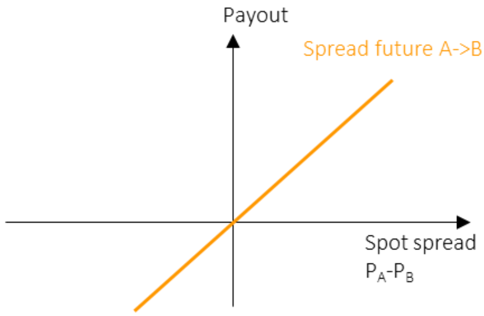


Figure 10. Payout of a spread future.

Market parties need futures. Domestic electricity forward markets are dominated by futures/forward contracts. Options are rarely traded. Market parties such as generation firms and retail suppliers that wish to use a foreign power market for hedging hence need a spread future to "translate" that future into a domestic future: the combination of a foreign future with a spread future is financially equivalent to a domestic future.

Interconnectors are options. For the owner of an interconnector, however, selling (a pair of) spread options will lead to settlement payouts identical to spot congestion income. In other words, it is spread options that provide a good hedge for interconnectors. This is because, financially speaking, interconnectors *are* (real) options. Financial options can be thought of as the financial twins of interconnectors. (If interconnectors are use in flow-based spot market coupling, they are no longer a zone-to-zone option anymore, but more complex.)

Hedging a power plant

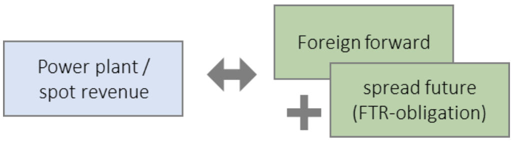


Figure 11. Hedging strategy of a power plant using LTTRs.

Hedging an interconnector

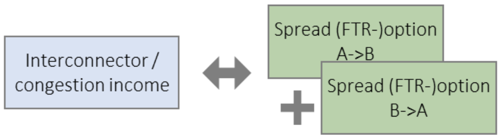


Figure 12. Hedging strategy of an interconnector using LTTRs.

Spread future = 2x domestic future. Issuing spread futures (FTR-obligations) *is* forward trading. This is because "selling a A-B spread future" is identical to "selling a future in A and simultaneously buying a future in B." The same is, of course, true for spread products traded on EEX without any TSO involvement. EEX spreads are not even outright products, effectively just two buttons pressed at once. This implies that if the domestic market is illiquid, one cannot buy a spread product instead – because it is the same thing!

Role of TSO. This has implications for the role of the TSO. Many observers like to think of the TSO as a neutral entity that helps the market to work without affecting prices. We regularly hear statements such as:

- "TSOs should be a facilitator, not a trader"
- "TSOs should provide capacity, not trade energy"
- "TSOs should not speculate on electricity markets"
- "TSOs should support the market, not participate on the market"
- "TSOs should facilitate price discovery, but not impact the price"

This line of thinking seems also to be present in the FCA Guideline, which states that TSO should provide "hedging opportunities for market participants". All of this is, however, impossible. Providing spread futures necessarily means taking a position on forward markets and, hence, influencing forward prices. All this is independent from questions of market platform and auction design: Of course, LTTRs impact forward prices also if they are sold on a separate auction. Moreover, this is also independent of the type of derivative, only that in the case of spread options, the impact is indirect: it is through delta hedging of option buyers that TSOs impact the forward market outcome.

Box 1: Bundles of derivatives

Bundles. In most financial markets, a derivative has exactly one underlying asset: one stock, interest rate, or commodity price. In electricity markets, spot markets have an hourly granularity. Non-storability implies that spot prices can vary greatly between hours of the same day. This means that electricity is a different economic good, depending on which hour it is delivered. It is the hourly spot price that serves as the underlying asset for financial derivatives (or, in the case of LTTRs, the hourly spread between two spot prices). However, power derivatives are never traded for settlement in a single hour, they are always bundles of hourly derivatives, such as year base or months peak contracts. For example, a year base forward is a bundle of 8760 forward contracts (so it is a swap) and year base option is a bundle of 8760 options (i.e., an option on a swap). While shorter products exist (quarters, months, etc.), hourly forwards do not. The fact that power derivatives are bundles complicates things considerably.

Payout. Conventional "unbundled" options differ from futures only due to uncertainty – under perfect foresight, they would be equal. This is different for bundles: here options differ from futures even under perfect foresight. The payout then is the (net) sum of spreads for a spread future and the sum of absolute spreads for a pair of options (Figure 13).

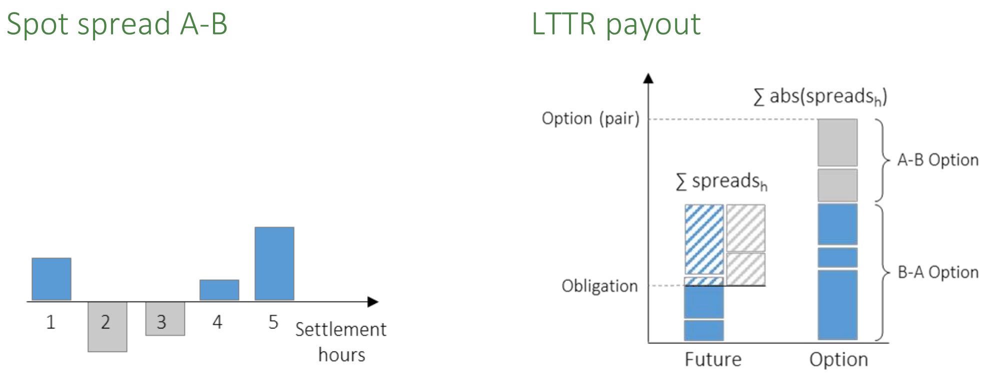


Figure 13. Payout of a spread future and a spread option for a five-hour settlement period.

Shorter products. Bundling also has implications for the forward market equilibrium and the volume of spread futures issued (section 3.3). Complications arise if trade flows of both directions occur within the settlement period flows (which is usually the case). Ideally, TSOs should bring hourly import / export *profiles* to the forward market – but they have to approximate those with existing bundle products. An implication is that additional volumes must be issued once shorter products are traded.

Observations. The fact that power derivatives are bundled also has consequences for delta hedging (section 3.4). Determining the correct forward positions requires empirical data of spreads and volatility of the underlying. But given that hourly future contracts are not traded, those data cannot be observed. Those forward prices that exist cannot necessarily be interpreted as indicating the direction and volume of expected trade. For example, if a net exporting zone features occasional price spikes, it might have positive forward price spreads towards its neighbors. It would be wrong to interpret these spreads as an indication of net imports. Instead, one would need to construct hourly spread forward curves.

Equivalence. Under certain conditions electricity spread futures and options are equivalent: if there is a one-directional flow in all hours during settlement (concerns bundle property) and if the option is deep in the money (concerns uncertainty). Then one of the options would have no payouts and the other option would be identical to the future. This is the case on borders such as SE2-SE3. While much can be learned from Svenska Kraftnät's pilot project on this border, one must be wary of generalizations, because these special conditions are typically not fulfilled on most borders, where electricity regularly flows in both directions during the year and the dominant direction is not known with much certainty ahead of time.

Current setup. Today, TSOs issue spread options. Those are primarily bought by commodity trading houses. These buyers essentially do one of two things with the option: either they hold them as a speculative investment and keep the risk on their books. In this case, they do not have any impact on forward markets, have no price impact, do not contribute to a balanced forward market, and do not improve the hedging opportunities of market parties. The alternative for option holders is to engage in delta hedging.

Delta hedging. Delta hedging is hedging an option by taking a position on the underlying asset. In the case of spread options, it means buying or selling spread futures, or, equivalently, combinations of domestic futures. Hence delta hedging can be understood as "translating" an option into a future. Importantly, delta hedging is not a one-off trade, but a continuous re-adjustment of positions. This is because the relationship between the underlying and the option is non-linear. For us, it is impossible to gauge to what extent the buyers of LTTRs engage in delta hedging today. However, empirical data suggests that it happens: In certain markets, e.g. Austria, one can observe stark spikes in trading activity immediately after the annual LTTR auction in November. It is plausible that this is driven by the initial delta hedge of the buyers of options. An implication of delta hedging is that by issuing spread options, TSOs impact forward markets and forward premiums, too – albeit indirectly.

Box 2: Option Pricing

Option pricing. The financial theory behind option pricing builds on the Black-Scholes model, which revolutionized financial markets in the 1970s. The option value can be decomposed into the intrinsic value that stems from the expected value of the underlying and the time (or extrinsic) value that captures the possibility that the underlying price changes favourably (Figure 14). The higher the volatility of the underlying, the higher is the time value (or extrinsic value) of an option. If TSOs would not issue any LTTRs, they would forego the time value of interconnectors (which are real options). They can capture it by issuing options or by issuing spread futures according to delta hedging.

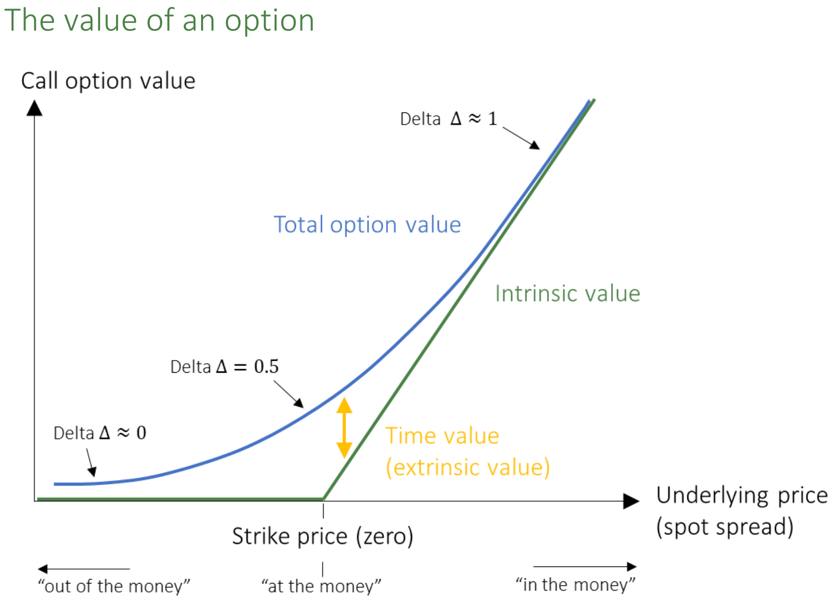


Figure 14. The value of an option as a function of the underlying price.

Delta hedging. One can derive the principal logic of delta hedging from the Black-Scholes model. If an option is deep in the money, it is very likely it will end in a payout. Then a change in the price in the underlying translates one-to-one to a change in the fair value of the option. In contrast, if the option is way out of the money, it is highly unlikely that a payout will occur. Then price movements of the underlying have hardly any effect on the value of the option. The "delta" of an option can be thought of as the probability of an option ending in the money. Because the delta itself depends on the underlying price, the relationship between option value and underlying price is non-linear. Consequently, hedging the option by taking a position on the underlying (delta hedging) requires continues trading, adjusting the position to any changes in underlying prices. Figure 15 illustrates for a simplified case the implied forward position as a function of a spread, for a given volatility. For example, if the spread is 20 €/MWh, a TSO should issue spread futures equivalent to just 40% of trade capacity. Only if the spread reaches 100 €/MWh, it should sell "at capacity".

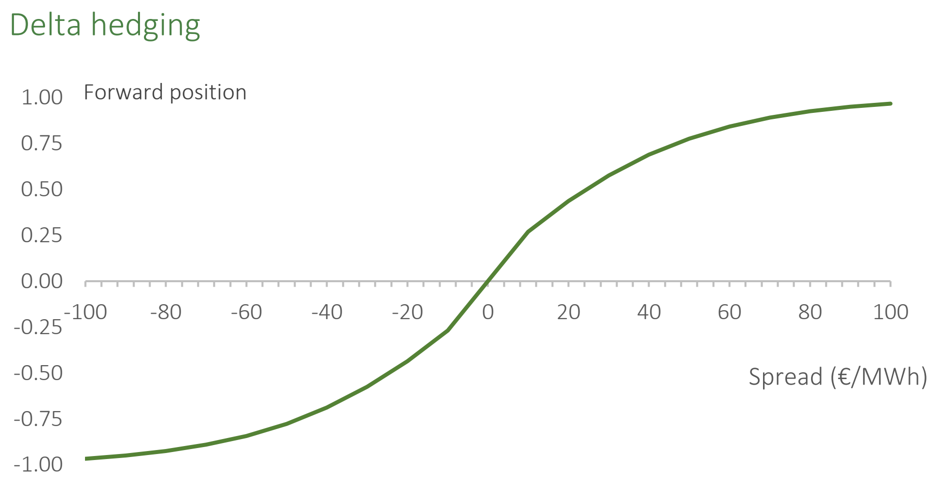


Figure 15. Forward position to delta-hedge an option as a function of the spread according to Black-Scholes, given a certain level of volatility (illustrative/stylized example)

Margrabe options. Strictly speaking, the Black-Scholes model is not appropriate to price interconnectors. Instead, an exchange, or Margrabe, option should be used (Figure 16). A remarkable implication of the Margrabe formula is that it results in domestic forward positions that do not perfectly add up to spreads. For example, at a spread of zero it implies a short position in both markets.

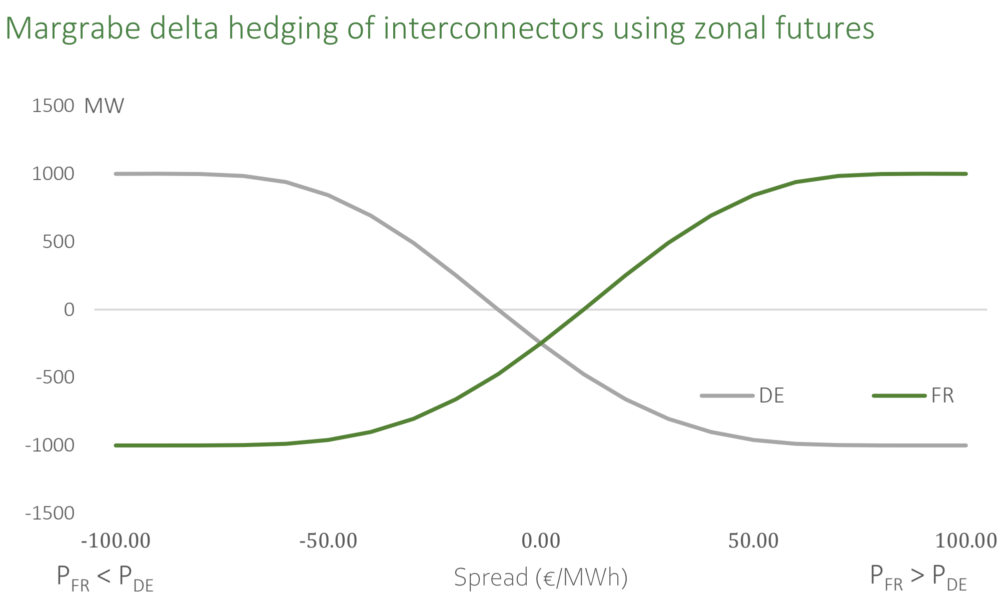


Figure 16. Forward position in zonal futures (DE, FR) to delta-hedge a 1 GW interconnector (option) as a function of the spread of the underlying according to Margrabe, given a certain level of volatility (stylized example).

Clearing. Options (if stock-style) trigger settlement payments always from seller to buyer. Futures instead may trigger payments in either direction. This is the reason for another important difference between spread options and spread futures: the need for clearing. In the case of options, counterparty (credit) risk is asymmetric and TSOs do not need to worry about solvency of buyers. In the case of obligation, market party credit risk becomes an issue for TSOs. This requires collateral (margining), including variation margins, i.e. additional margins if volatility or level of spreads change. To avoid extensive due diligence, using existing clearing infrastructure seems recommended, i.e. outsourcing this task to clearing houses such as European Commodity Clearing or Nasdaq Clearing. This is true regardless of the trading platform, that is, both for energy exchange and OTC-traded LTTRs.

Underpricing. Underpricing refers to the proceeds when auctioning LTTRs and occurs if revenues fall systematically short from the fair value. Sometimes it is argued that underpricing occurs, because in past years settlement payouts significantly exceeded auction revenues. Such an ex-post comparison is inappropriate to detect underpricing. During 2021-22, electricity prices moved up dramatically and unexpectedly, and so did the value of LTTRs issued earlier. The opposite was the case when prices dropped after August 2022 (Figure 17). To empirical evaluate underpricing, one must assess the fair value of a spread option *at the time of the auction*. This is a difficult task, because of the complicated nature of the contract: options are more difficult to price in the first place, these options are bundles of 8760 options, and in addition most of them are non-firm. A consequence of the complex pricing is that only highly skilled commodity trading houses are likely to buy such derivatives. The limited number of potential buyers itself, of course, gives rise to concern of lack of competitiveness – a possible reason for underpricing. To sum up, there are reasons to be concerned about underpricing, but the available evidence is inadequate to assess this question empirically. Such an assessment is also out of scope of this study. An advantage of a switch to spread futures is that a much broader group of firms can be expected to participate in such auctions and estimating a fair price is much easier.

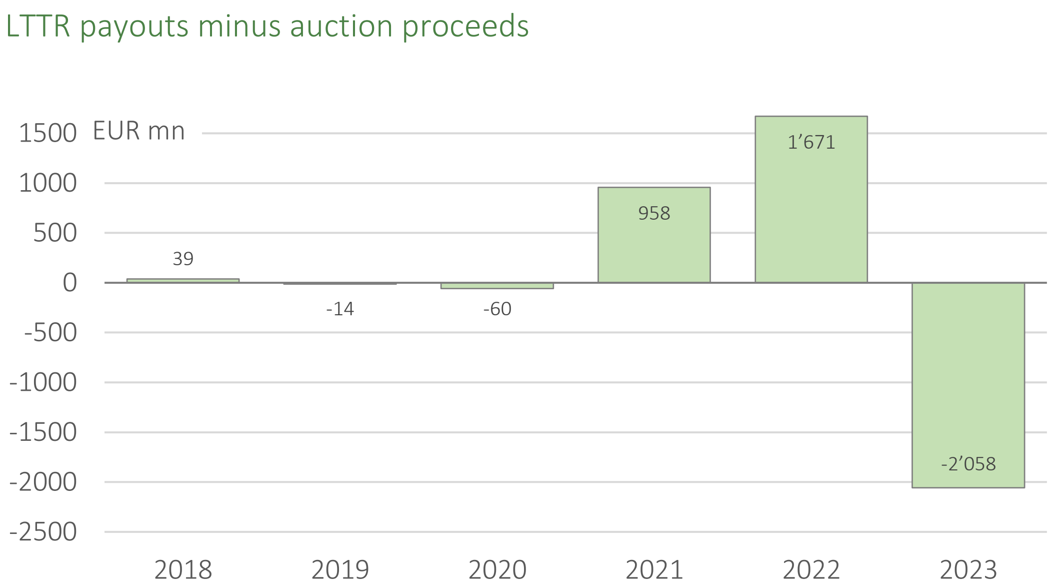


Figure 17. Historical LTTR settlement payouts minus auction proceeds. Data source: JAO.

FBMC. In the discussions of derivative types, we have so far ignored the fact that cross-border spot trade is handled through flow-based market coupling. Under FBMC, the market coupling does not directly result in zone-to-zone trade, but in net positions of each bidding zone; zone-to-zone trade may be ex-post calculated using heuristics. Hence, mathematically speaking, there is no zone-to-zone congestion income, only congestion income of the entire capacity calculation region which then is distributed to zones using an ex-post distribution methodology. If the objective of LTTRs was to hedge congestion income on capacity calculation region level, the ideal derivatives would actually not be zone-to-zone options, but something like "congestion revenue rights" (in the meaning of the word), a contract that entitles to a certain fraction of the annual congestion income across the region.

Conclusions. The question of derivative type is linked to the objective of LTTRs. If the objective was to hedge congestion income, non-firm spread options, or possibly congestion revenue rights, would likely be the first choice. Given that we think the objective should be to re-balance forward markets, spread futures immediately seem appropriate, because imports / exports volumes become directly available on forward markets. Options could also achieve this goal, but only if buyers fully engage in delta hedging, as we discuss in more detail in section 3.4.

3.3 How Much? Volume

How much? In this section we discuss how much LTTRs TSOs should issue, i.e. how many MW of contracts they should auction. Some seem to suggest "the more, the better" and indeed ACER states "maximize available LTTR volume" as one of its objectives. In our view, this is generally not true – it fundamentally depends on objective and type of derivative.

Option volumes. If spread options are issued to hedge congestion income, the volume question becomes rather trivial, at least in theory: TSOs should issue options in both direction in the amount equal to expected zone-to-zone trade capacity. Issuing more than that would turn TSOs into financial speculators and is not advised under any circumstances. In reality, preloading, interconnector outages and maintenance as well as decoupling means trade capacity is neither constant nor known in advance, and this uncertainty might impact the choice of volume. More fundamentally, if spot markets are coupled through a flow-based algorithm, zone-to-zone trade capacity does not exist and the optimal volume of zone-to-zone spread futures becomes a much more complex question.

Spread futures volumes. If spread futures are issued, the volume-question becomes much more complex. First and foremost, one cannot apply option thinking to futures, because they are fundamentally different derivatives. One MW of a spread option is something completely different from one MW of a spread future, because they may result in completely different payouts (in fact, selling a 1 MW future is equivalent to selling 1 MW of one option and *buying* 1 MW of the reverse option at the same time). Second, selling futures "at capacity", i.e. in a volume equivalent to expected spot trade capacity, is generally not sensible because it would introduce a new distortion of the forward market (Figure 18), which also depresses LTTR prices and reduces congestion income to the detriment of ratepayers. Instead, futures should be sold according to expected net imports, i.e. expected spot traded energy (or possibly even less, if not all demand wishes to hedge). Unless a border is used just in one direction, this is less than capacity, often much less. If flows on a border cancel out over the course of a year, no annual spread futures should be issued at all! Third, there is a whole range of volume-related aspects, including the following:

- Splitting volumes across auctions and maturities
- Changes in volumes when trade flow expectations change
- Additional volumes when trade flow expectations reverse
- Additional volumes of shorter products (quarter, month, etc.)

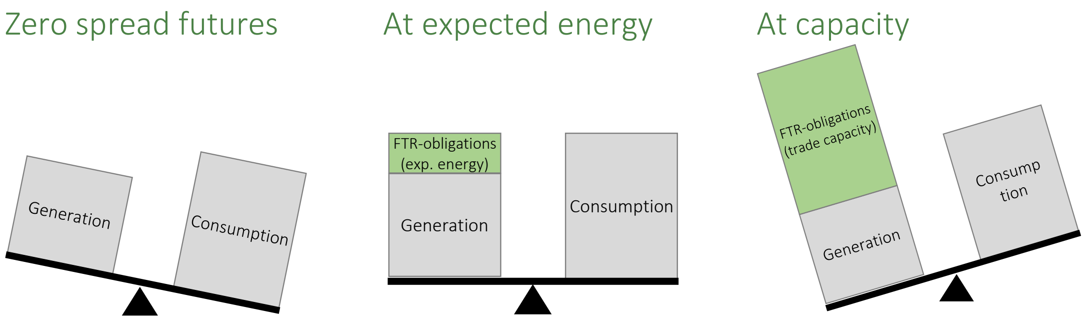


Figure 18. Spread futures sold at three volumes: zero (left), expected net imports (middle) and at capacity (right). Issuing spread futures at capacity does generally not lead to balanced forward markets but introduces a new distortion instead.

Frequency of auctions. ACER has proposed to schedule auctions much more frequently, potentially every day rather than once a year (for year products). However, there is a trade-off regarding frequency of auctions (regardless of the type of derivative): both hedging needs of market parties and the goal to benefit from price movements (delta hedging) suggest frequent auctions. But concentrating liquidity and the conventional minimum tick size of 1 MW lean towards less frequent auctions. A sensible strategy could be to start with quarterly auctions and then move towards monthly and possibly weekly schedules.

Maturities. Maturities are another trade-off, which also applies both to spread futures and spread options. A learning from the 2021/22 energy crisis is that longer-term and more widespread price hedging among consumers has benefits to society, because the social and economic impacts of price spike are mitigated. On the other hand, pushing large volumes of futures into the market when there is little demand will depress prices and hence comes at a real cost for rate payers. One possible approach is to issue 10% of the volumes three years ahead, another 30% two years, and the remaining 60% during the last year.

Example. Figure 19 shows an illustrative trading schedule for spread futures, assuming for monthly auctions with expected net imports of 1000 GWh and a split of volumes across maturities by 10/30/60. Note that these volumes are drastically smaller than selling "at capacity", because expected net trade is much smaller than the expected spot trade capacity.

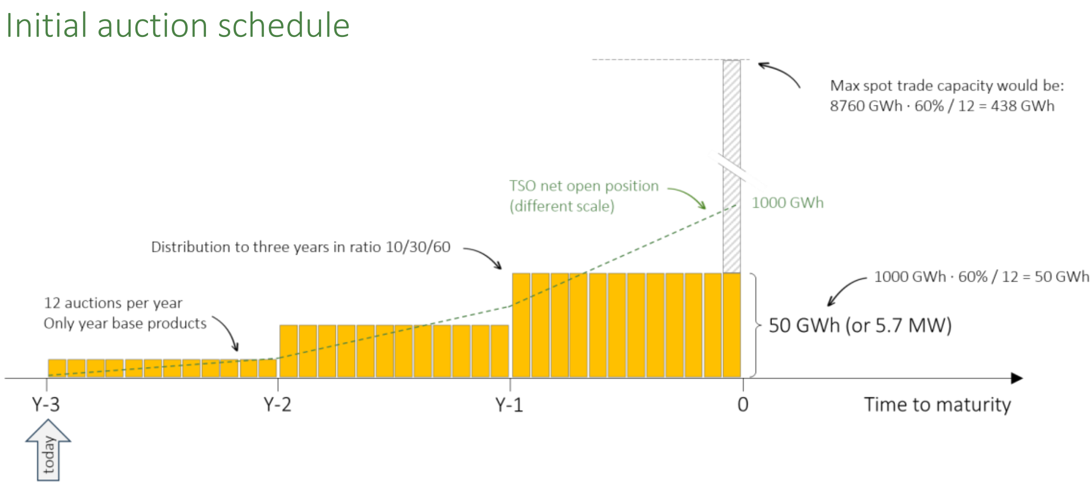


Figure 19. Illustration of a spread futures auction schedule for monthly auctions, trade capacity of 1 GW, expected net imports of 1000 GWh, and a split of volumes across maturities by 10/30/60.

Updates. Ahead of every auction, trade expectations must be re-evaluated, and volumes adjusted accordingly. If an expected import turns into an expected export, not only are the new volumes to be sold in the remaining auctions, but also the previously sold spread futures should be "bought back" (Figure 20). Such back-and-forth trading mirrors delta hedging and will generally yield profits. Those profits represent the time value of the (real) option that the interconnector is. Failing to do so would be a destruction of social welfare.

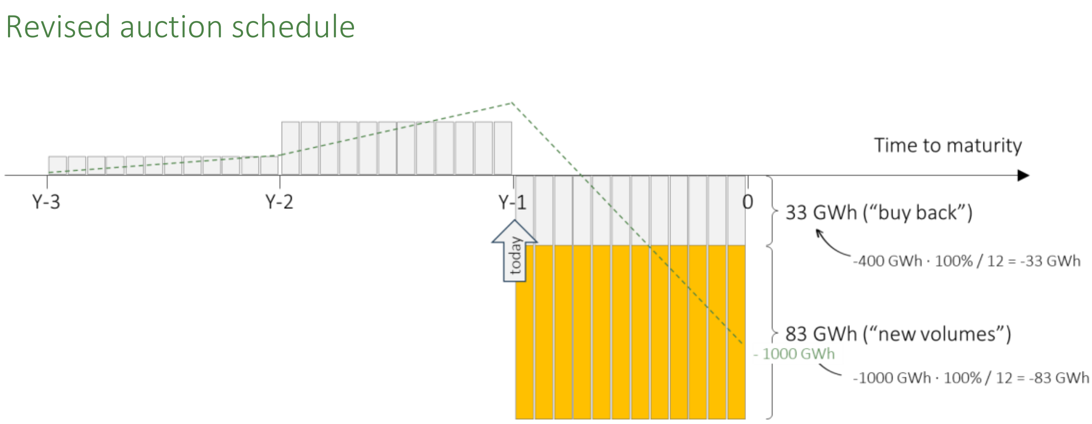


Figure 20. Updated auction schedule if at Y-1 the expected import of 1000 GWh suddenly turns into an expected export of 1000 GWh.

Expectations. Expected trade cannot be directly observed from market data but would need to be taken from electricity market optimization models. Forecasting market outcomes such as trade flows is difficult in any context, the even more so in the case of LTTRs:

- Expected trade flows need to be updated frequently, ahead of every auction of spread futures. Daily auctions would mean daily model runs.
- Many TSOs are involved, requiring substantial coordination.
- This can become highly political, as it is an easy way to depress/inflate forward prices (recall the 2022 energy price discussions about policy interventions to depress electricity prices).

Hedging preferences. Expected net traded energy would be the appropriate volume to issue in terms of spread future LTTRs if 100% of demand and supply wanted to hedge forward. However, if only a certain share of demand and supply prefers to hedge forward and the remainder prefers staying exposed to the spot price, then issuing only the share of expected net traded energy that corresponds to the share of overall hedged demand in total demand could be appropriate.

Shorter products. Actual trade on the spot market takes place at an hourly granularity, and it is the hourly spot price spread that serves as the underlying asset for LTTRs. However, forward products are bundles of derivatives: a year spread future is really a bundle of 8760 hourly spread futures. Such bundling is unproblematic for borders where trade always goes in the same direction during the entire settlement period. It causes, however, additional complexity in the much more usual case of bi-directional trade flows. Ideally TSOs should bring import / export *profiles* to the forward market – but they must approximate those with existing (year / quarter / month – base / peak) products. This needs to be considered when determining volumes, as the following example illustrates.

Example. As a simple example with perfect foresight, assume that Germany exports 10 TWh in Q1 if a future year, and France exports 10 TWh each in Q2, Q3 and Q4 to Germany. According to the forward market equilibrium logic, TSOs should hence offer annual spread futures worth 20 TWh (buy 20 TWh in France and sell the same amount in Germany). Once quarter products become available, however, they issue additional volumes: an additional 5 TWh each in for Q2, Q3, Q4 products and 15 TWh for Q1 in the reverse direction (sell FR and buy DE).

Flow-based. We have famed the above volume discussion along zone-to-zone trade expectations. Under flow-based coupling of spot markets, there is no zone-to-zone trade, but just zonal net positions. That does not pose a problem, however, for the volumes of spread futures. One would simply bring expected net positions to the forward market. For example, if Germany is to be expected to import 50 TWh of electricity, TSOs should sell German futures equivalent to that volume. If France is expected to export 20 TWh during the same year, TSOs should buy French futures worth 20 TWh. In other words, regardless of the type of spot market coupling, net imports (i.e., net positions) need to be forecasted – flow-based does not introduce additional complexity here. Note that this refers to *spot* markets being coupled through a flow-based algorithm. The question if introducing a flow-based logic to the determination of zone-to-zone LTTRs, something that is currently under implementation, is a different topic that is beyond the scope of this study.

Box 3: Why Not Volumes According to Correlation?

Logic. Sometimes it is proposed to provide less LTTRs at borders where prices are highly correlated, and in turn issue larger volumes where correlation is low. At first sight, this might appear sensible, as the quality of proxy hedging depends on price correlation and hence the welfare created by LTTR provision can be thought of as highest there. In this box we explain why "volume allocation according to correlation" is nevertheless a bad idea. First, we explain this for the case of spread futures and at the end we cover the case of spread options.

Correlation of what? First of all, it is not always clear which electricity prices are referred to: hourly spot prices or monthly/year forward prices. It is the correlation of the latter that determines if a foreign forward market can serve as a close proxy hedge for a domestic forward market, i.e. if cross-border proxy hedging is feasible. The correlation of hourly spot prices within the settlement periods is of no interest for this question.

Extreme case. For the sake of the argument, assume Malta and Germany had poorly correlated electricity forward prices. "Volume allocation according to correlation" would lead to bizarre results when applied spread futures: It implies the volumes for this pair should be large, even though the lack of trade between the two countries implies TSOs are not physically hedged to provide such contracts (Model A) and buying / selling large volumes of Maltese forwards would greatly distort forward prices, i.e. lead to an unbalanced forward market (Model B).

Forward imbalance. Furthermore, even if forward prices of two bidding zones are highly correlated, forward markets can be way out of balance (i.e. demand-heavy or supply-heavy) in the absence of cross-border volumes. Therefore, even these markets benefit from LTTR provision. Although in this case a lack of LTTRs would be less severe because proxy hedging is more feasible, proxy hedging leaves a remaining basis risk, which might seem small in normal times, but can materialize strongly in crisis times. This could be observed in the gas market, for example, when the usually strong correlation between British NBP and Dutch TTF broke down during the energy crisis of 2022.

Volume swings. The idea would also result in large volume swings near zero spreads for countries with little correlation (and therefore large volumes, according to the logic). A positive +0.01 €/MWh spread then results in massive opposite volumes to a negative -0.01 €/MWh spread. This results in imbalanced forward markets and therefore in a forward discount in the import area and a premium in the export area. Effectively, forward spreads would be "nailed to the zero" – but the spot market would remain unaffected, and thereby artificially depressing congestion revenues. That would yield profit opportunities for commodity traders at the cost of rate payers.

LTTR options. Sometimes it is also argued that the volume of the "option" product type of LTTRs should be increased for borders with little correlation. The idea here is that options become more valuable the higher the volatility, given that it increases their time value (also called extrinsic value, see also Box 2). However, in our view even for options it is not justified to artificially increase volumes for borders with low correlation, as it is physically limited by expected interconnector capacity. It is true that the value of options increases for such borders, but issuing more than expected trade capacity would lead to imbalanced forward markets. These, in turn, would lead to depressed LTTR prices (below efficient prices) at the expense of ratepayers.

Supply function. Today, LTTR volumes are fixed and price inelastic. We are convinced that a price-sensitive supply curve is preferrable. A supply curve means that the volume of LTTRs sold depends on the bids and a high auction price leads to additional volumes sold. This has two benefits:

- It mitigates potential market power among LTTR buyers and reduces the risk of underpricing (regardless of the derivative type).
- It effectively uses market information in face of the uncertainty of future trade flows, because a high willingness to pay tends to indicate large, expected trade (spread futures only).

Supply function

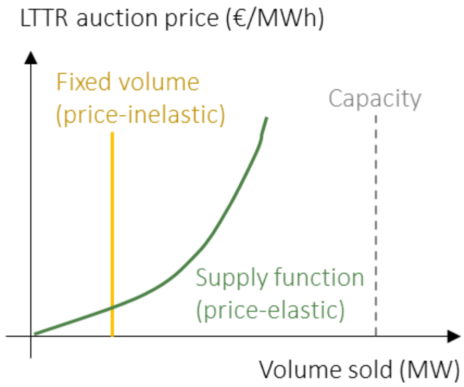


Figure 21. Fixed volume vs. supply function (illustration).

Conclusions. The volume question – how many MW of LTTRs to issue – cannot be separated from the objective and derivative type. If spread options are issued to hedge congestion income, the volume should be (roughly) expected spot trade capacity. If spread futures are issued to balance forward markets, the volume should be expected trade. The latter is complex, because it requires market modelling, coordination among TSOs, frequent re-adjustment of volumes in light of forecast changes and shorter products. Effectively, TSOs would need to evolve into some sort of commodity trading house. On top of all that, one must expect significant politization of that process.

3.4 Symmetry: Delta Hedging

Symmetry. In this chapter, we show that under certain restrictive assumptions the two models A and B are essentially the same. Under these conditions both objectives – hedging congestion income and balanced forward markets – can be fulfilled at the same time. This is because both models are connected through delta hedging. Delta hedging is the art of hedging an option by trading its underlying, and here, hedging congestion income by trading the spread future (recall Box 2). In that sense there is a deeper symmetry between the two models.

Assumptions. Strong assumptions are needed for this symmetry. Forward market prices and their volatility must be observable at all times, markets need to be competitive and forward markets would need to be in hourly resolution, rather than the yearly or monthly bundles of hours which forward products to date are specified as. With these assumptions, the following thought experiment is possible.

TSO as delta-hedger. Assume the TSO wanted to hedge congestion income by issuing not spread options but spread futures. Because, financially speaking, an interconnector is a (real) option, by doing so they engage in delta hedging. Which volumes of LTTR options would they sell? It turns out, delta hedging mathematics yields something close to net expected energy.

Market data. Applying the delta hedging equations, TSOs would use market data to determine the two main parameters that determine volumes: the spread on forward markets ("price of the underlying") and the volatility of that spread as it is traded over time. Roughly speaking, the volume of spread futures issued would be close to capacity if the spread is large and stable, because this indicates a clear market expectation of direction and certainty of flows. In turn, only small volumes would be issued if the spread is small and/or volatile, since this signals small net traded energy and high uncertainty.

Approximately net energy. The volumes needed to delta hedge an option are similar to net expected energy. Essentially, it can be seen as a different, empirical way to determine these, by harnessing market information like spread and volatility from observed prices. Large spreads and low volatility at borders indicate a high certainty about traded energy, so selling spread futures in large volumes (at capacity) is indicated. Vice versa, small spreads and/or high volatility indicate that market actors have low certainty in which way trade flows will turn out. TSOs should thus sell only few spread futures. The delta of an option can be thought of as approximately the probability of an option ending in the money. For the case of interconnectors, this means the probability of energy being traded at capacity.

Implications. This symmetry means that when hedging congestion income through options (Model A), forward markets become balanced as a side benefit. Vice versa, when striving to re-balance forward markets through spread futures issued at expected energy (Model B), congestion income is hedged as a side benefit.

Outsourcing. In essence, the choice between Model A and Model B (i.e. between issuing options or spread futures) then becomes more of a question of "who does the translation from options to futures?" In Model B it is done in-house by TSOs while in Model A, it is outsourced to commodity traders.

Supply function. TSOs can use this symmetry to derive (or at least get inspiration for) a "supply function" of spread futures as suggested in section 3.3. Under the strong assumptions introduced above, it would even be possible to derive a supply function of spread futures that does not require the TSO to do the difficult and contestable task of estimating net expected energy. Assuming the TSO has no (reliable) expectations on net imports at all, it could instead let the market decide how much obligations it needs. The higher the price spread, the more volumes, and the more certain the market is of a certain flow direction (i.e. the less volatile the spread is), the more volumes also. In this sense, the delta hedging function can be interpreted as such a supply function.

Theoretical differences. The symmetry of models A and B, however, does not hold, due to several theoretical and practical differences. First and most fundamentally, electricity forwards are bundles of derivatives rather than individual hours, hence forward price and volatility for an individual hour's future are not observable. Second, the option delta does not equal the probability of an option to end in the money (i.e. energy being traded at capacity), despite being a close approximation. Third, the delta of the Margrabe exchange option (see Box 2) yields somewhat asymmetric volumes of domestic futures. Therefore, for effective delta hedging of interconnectors not only spread futures, but the individual zonal futures would be needed in asymmetric volumes.

Bundles. To picture the consequences of forward contracts being bundles, consider the following example. Assume that German spot prices are higher than French spot prices in 99% of some future year. In those hours, the price spread is 1 €/MWh and Germany imports at capacity. In the remaining 1% of the hours, there are price spikes in France, resulting in spreads of -1000 €/MWh and imports to France. The perfect-foresight base year forward price absent a forward premium would be -9.01 €/MWh, while Germany will be a massive net importer: in this case, the forward price does not even indicate the dominant direction of flows, let alone trade volumes. This is because of the uneven price patterns across the individual hours during the year-long settlement period. If we would let the market decide which (annual) spread futures to sell, we would buy futures in France, and sell in Germany – increasing the forward imbalance rather than re-balancing it. None of this would occur in case of hourly forward contracts.

Hourly spread curves. Since we cannot observe hourly forward prices and their volatility, the delta hedging formula to determine volumes cannot be directly applied. A possible solution to this would be to construct "hourly spread forward curves". Those could be constructed from two (consistent) domestic hourly price forward curves from bottom-up or econometric estimation models and could be used to estimate hourly spreads. To apply option pricing formulas, however, one would also need estimates of "hourly volatility", too.

Practical difficulties. In addition to these theoretical difficulties, there are several practical problems, too.

1. The first concerns data availability. For less liquid forward markets, spreads and volatility may not be observed, in particular for longer maturities. The entire option pricing theory rests on the assumption of observed prices, but LTTRs are particularly relevant for markets where liquidity is limited.

2. Second, models A and B differ in their transparency. While in Model B the TSO offers public auctions of spread futures, which provide transparent price signals about zonal electricity prices to all market participants, commodity traders who won LTTR options in an auction could offer these volumes back to the market less transparently, i.e. in OTC trading in the case of zones with illiquid futures markets so that no transparent price signal materializes.
3. Third, the business of commodity trading may not be perfectly competitive – thus pricing power can result in differences. A particular consequence may be that the buyers of spread options do not engage in delta hedging at all but keep the options in their books instead. To the extent that this is the case, Model A does not help at all to re-balance forward markets or provide any hedging possibility for generators and utilities.
4. Fourth, the two models differ in their susceptibility to political influence. When TSOs directly engage in forward markets and thereby raise or lower forward power prices, there is a higher risk of influence, especially because it is harder to determine the right amount of spread futures than it is to determine an appropriate amount of spread options.
5. Lastly, there are also differences with respect to the necessity of trading skills. Reaping the full option value of interconnectors means complex trading and TSOs are not as well positioned to do so as commodity traders are.

Pre-existing distortions. The models also cope differently with pre-existing distortions in forward markets, such as contracts for differences between generators and governments, other support policies, or instruments that fix power prices for demand entities. To the extent such policies provide a hedge against price risk, the affected market parties are no longer interested in hedging on forward markets. If volumes are determined from bottom-up computer models of energy flows and spot markets, they are independent from forward prices. But forward market prices are influenced by other policy distortions to forward markets. Delta hedging is based on observed prices – and thereby result in different volumes in the presence of pre-existing forward market distortions.

Conclusion. Under perfect theoretical and practical assumptions, in particular single-hour futures, models A and B differ only in *who* does the delta hedging – TSOs or commodity trading houses. But in reality many theoretical and practical differences remain. Therefore, models A and B remain separate choices. How different is hard to judge, because many of the differences are hard to quantify.

3.5 LTTR Fundamentals: Conclusions

Conclusions. The objective of LTTRs, derivative type and volume must be discussed and decided jointly. Table 3 maps the objective, derivative type and volume to two consistent models of LTTR provision: Model A (Hedging congestion income) and Model B (Balanced forward markets). Our opinion and also our reading of the FCA Guideline is that balanced forward markets are the objective. This speaks for Model B.

Table 3. Two models of LTTR provision

	Model A Hedging congestion income	Model B Balanced forward markets
Objective (why?)	Hedging congestion income / Making congestion income available to market parties	Balanced forward markets / Making import/export volumes available to forward markets
Derivative type (what?)	Spread options (FTR-options) (Or, under FBMC: congestion revenue rights)	Spread futures (FTR-obligations)
Volume (how much?)	Spot trade capacity (adjusted for unavailability and uncertainty through de-rating or non-firmness)	Expected spot traded energy (net imports)

Model B challenges. However, implementing Model B is complex, because it requires market modelling, coordination among TSOs, frequent re-adjustment of volumes in light of forecast changes and shorter products. Effectively, TSOs would need to evolve in commodity trading houses, and lawmakers as well as regulators would need the corresponding understanding, skills and tools, too. On top of all that, one must expect significant politization of that process.

Delta hedging. Financial mathematics, in particular the theories of option pricing and delta hedging, suggest there is a certain symmetry between the models. Under perfect theoretical and practical assumptions, including single-hour futures, they effectively are the same. But in reality, many differences remain, such that A and B remain separate choices. But financial theory also suggest two variants of Model B:

- Rather than forecasting traded energy, use a supply function derived from option theory ("supply function")
- Rather than selling spread futures, sell options and hope commodity trader will take care of delta hedging while acknowledging this is unlikely to lead to balanced forward markets ("outsourcing delta hedging")

Choice. The choice among the three variants of Model B – futures at expected energy, futures according to a supply function, or options at capacity – will crucially depend on the confidence one has in TSOs, regulators and lawmakers on one side and commodity traders and financial markets on the other side.

4 Other Economic Questions on LTTRs

In this section, we discuss the following three questions:

- Should congestion income always exceed LTTR payouts? (revenue adequacy)
- Who should organize auctions and clearing? (marketplace)
- Should forward products refer to spot prices of bidding zones or a composite price index? (virtual hub)

4.1 Revenue Adequacy

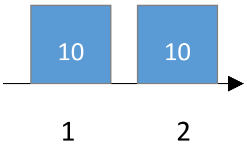
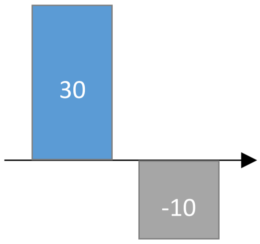
Revenue adequacy. The term revenue adequacy describes that congestion income suffices to cover LTTR payouts during settlement. It has hence nothing to do with the proceeds when selling LTTRs and the question of underpricing but refers exclusively to the time frame of settlement. A revenue gap, i.e., a lack of revenue adequacy, implies that payouts exceed income, which could be a concern for cash-flow. A more holistic perspective on cash-flow from congestion income should ideally cover all three flows: revenues from spot congestion income, revenues from selling LTTRs, and payouts (and revenues) from LTTRs settlement.

Granularity. To discuss revenue adequacy, one must clarify at which granularity. Achieving revenue adequacy is easier on a larger scale, because stochastic fluctuations smooth out the revenue gaps of individual hours. For example, there may be a significant revenue gap for a single interconnector in some hours but over longer time periods, congestion income always exceeds payouts and the revenue gap closes. The same holds for the geographical scope: the revenue gap in the entire flow-based area is smaller than the revenue gap of a single bidding zone or of an individual border.

Need for revenue adequacy. Hourly revenue adequacy is not required but on a more long-term horizon it is. Revenue adequacy is important because congestion income may be used to finance new projects. Hence, revenue gaps increase the cost of liquidity management. Means to improve revenue adequacy are non-firm LTTRs, LTA inclusion, a reduction in the auctioned LTTR volumes and a compensation account that works as insurance against revenue gaps.

Theory. If spot trading capacity is firm and known in advance, revenue adequacy is a non-issue. Table 4 exemplifies this. For spread options issued at capacity, congestion income is always mathematically identical to payouts, in every hour and at every border (revenue equality). In other words, an option is the financial representation of the value of an interconnector. For spread futures (FTR-obligations), if capacity is known, revenue adequacy is always archived, because congestion income either equals payout (if trade flows are one-direction, e.g., case A in Table 4) or exceeds payouts (if flows go in both directions during the settlement period, e.g., case B).

Table 4. Revenue adequacy for options and spread futures in theory

	Case A	Case B
Hourly spreads (in €/MW)		
Average spread	10 €/MWh	10 €/MWh
Congestion income	20 €/MW	40 €/MW
Option payout	20 €/MW	40 €/MW
Spread futures payout	20 €/MW	20 €/MW

Reality. In reality, revenue adequacy is not guaranteed. This is because spot trade capacity sometimes falls short of the auctioned LTTR volume. Reasons for reduced trade capacity are the pre-loading of interconnectors and critical network elements, flow-based market coupling, maintenance and outages of interconnectors, and de-coupling. When trade capacity is reduced, less congestion income is generated. A reduced trade capacity also leads to increased price spreads between bidding zones, inflating LTTR payouts. In these situations, payouts may exceed congestion income by far. For instance, the two partial decoupling events in 2022 and 2023 resulted in a revenue gap of approximately EUR 1.9 Mio and EUR 1.2 Mio. EUR, respectively. This may be problematic for small bidding zones with one or a few large interconnectors, where a single technical failure has relatively large financial implications. However, the revenue gap resulting from both events was well below 1% of the total monthly congestion income.

Quantification. We conducted an analysis of 25 European bidding zone borders between 2020 and 2023 to evaluate the effect of fluctuating trade capacity empirically.[1] Our results show that congestion income exceeded LTTR payouts by far. In the case of spread futures, only 39% of congestion income would have been paid out, compared to 82% in the case of options. While revenue adequacy was achieved in both cases on average, LTTR payouts exceeded

[1] We used historical data from ENTSO-E transparency to calculate congestion income and LTTR payouts. Congestion income is based on the scheduled commercial exchanges. The volume of each option was set to the (annual) average of commercial exchange in hours with flow in respective direction. The volume of spread futures is assumed to equal the average commercial exchange. Note that this ex-post calculation disregards ex-ante uncertainty and accounts for LTA inclusion but not for non-firmness in products.

congestion income for some borders and some months. In the case of options, this would have been the case in 35% and in the case of spread futures in 9% of the analyzed months.[2] This example shows that revenue adequacy is not a major concern over long time periods, especially because revenues from the LTTR auction have not even been considered. In addition, switching from options to spread futures further improves revenue adequacy.

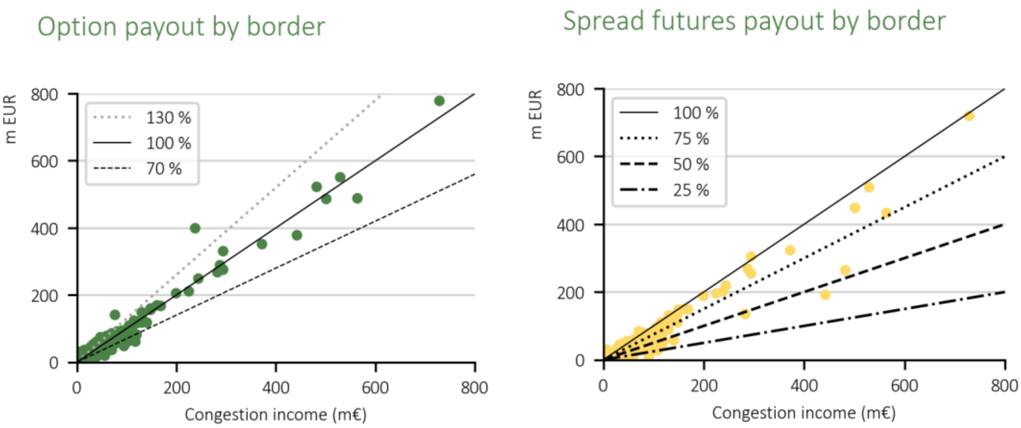


Figure 22: Payouts of options (left) and spread futures (right) by border in relation to congestion income

Mitigation measures. We briefly discuss four measures to improve revenue adequacy. First, non-firm LTTRs suspend the payout in case of technical failures of interconnectors. While improving revenue adequacy, non-firm LTTRs come at the cost of lower LTTR auction revenues: because buyers have difficulties estimating the risks of technical failures, they value non-form LTTRs significantly lower than firm products. Second, is LTA inclusion. It guarantees that interconnector capacity at the day-ahead market stage is not lower than the issued LTTR volume. LTA inclusion comes at a significant cost: it results in suboptimal trade patterns and affects the dispatch of generators and clearing prices. Third is the reduction of the auctioned LTTR volume, i.e., a derating of interconnector capacity. Issuing less LTTRs implies a larger security margin between congestion income and LTTR payouts and thus increases the likelihood of revenue adequacy. The downside is that derating interconnector capacity also reduces cross-border hedging opportunities for market parties. The fourth measure to address the challenge of revenue gaps is a compensation account. This could for example be a European account that compensates TSOs for revenue gaps, e.g. when markets are decoupled. The approach is economically least distortive, but there might be legal and political challenges. Hence, we encourage further exploration in this direction. While the first two measures are currently implemented in Europe, the latter two are not, at least not explicitly.

Conclusion. To conclude, we are somewhat skeptical about the need to mitigate revenue inadequacy for every point in time and suggest that from a social welfare perspective, this

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[2] For this analysis, we assumed congestion income occurs at each border and is not redistributed. ENTSO-E already proposed an adaptation of the congestion income distribution methodology, notably to compensate TSOs for unintuitive flows. This does not affect the overall congestion income but its distribution among TSOs.

should be regarded as a secondary objective. Revenue adequacy on an hourly basis for each border is certainly not necessary. Instead, a high likelihood of revenue adequacy on an annual or monthly basis for each TSO seems to be sufficient. We recommend scrutinizing the current approaches to improve revenue adequacy, namely non-firmness of LTTRs and LTA inclusion. Instead, we recommend considering alternative approaches, in particular a central compensation account to smooth fluctuations in cash-flow. Besides, the occurrence of revenue inadequacy would be significantly reduced if LTTR products were changed from options to spread futures: our estimates suggest the average payout would be reduced by more than half compared to options.

4.2 Marketplace and Clearing

Marketplace. When TSOs issue LTTRs, they need to choose a market platform on which to sell or auction them. If the product type is spread futures, then they additionally need to choose how to clear the products, as payment flows can go both ways. In terms of marketplace, TSOs could use existing platforms such as power exchanges, outsource the task to brokers, or use their own facilities such as a single allocation platform (SAP) like the Joint Allocation Office (JAO). If existing platforms should be used, a question is whether using continuous trading makes sense or whether auctions are better suited. Lastly, we address the question if "local matching" should be offered.

SvK pilot. Before diving into each of the questions and to illustrate these choices, it is helpful to look at the choices made by Svenska Kraftnät in their pilot project launched in 2023 in which they auction electricity price area differentials (EPADs). They decided for an auction run by a broker and used standard products, cleared through an established commodity clearing house, Nasdaq Clearing. For the kind of LTTR products offered, all of these seem reasonable choices to us.

Margining. It is important to note that for spread futures (FTR obligations) initial and variation margins and regular margin calls are necessary because the payment flows can go both ways and enough liquidity on the side of the counterparty must always be ensured. It is not conceivable that TSOs themselves fulfill this role. Therefore, if spread futures are to be issued, then there is a reliance on a clearing house. The European Commodity Clearing (ECC) is by far the largest player in the EU in this field. Therefore, there is some dependence on the ECC regarding this question.

Cleared standard products. TSOs can choose whether to create new proprietary products or rely on pre-existing standard products if appropriate products already exist in the market. If the format of LTTRs is options, then relying on pre-existing privately traded products is usually not possible, because such options are not usually traded on commodity exchanges. This is different for spread futures. As these are products that are also traded on commodity exchanges, TSOs can choose to rely on these pre-existing products. This enables easy secondary trading and builds on existing infrastructure, e.g. for clearing (e.g. margin calls). Note that even if standard products are used, the marketplace (power exchange, broker, etc.) can still be chosen separately.

Continuous trading. One marketplace to trade electricity futures is the continuous trading on power exchanges such as EEX or ICE. At first glance, it might appear attractive for TSOs to sell spread futures directly on such exchanges, as it would simply use the existing marketplace and increase liquidity on such markets, benefiting a wider set of market actors. However, continuous trading comes with several downsides for the specific use case. When TSOs sell LTTRs, they will do so in pre-determined quantities or at least clearly specified supply functions. The behavior of TSOs is thus very predictable. This is also necessary, as they are regulated entities that must follow a certain rulebook. However, such predictable action would put the TSO (and in consequence, the ratepayer) at a disadvantage. In continuous trading, all bids are visible in the order book. Expecting the TSO to come in at a pre-determined time, market parties could coordinate on an unfavorable price level for the TSO. Therefore, continuous trading is not well suited for this use case.

Discrete auctions. Auctions are much better suited for the use case of TSOs selling LTTRs. This is because here a "sealed bid" procedure could be used, where market participants cannot see the other parties' bids and therefore coordination to the detriment of the TSO cannot happen as easily. In other words, auctions with pay-as-clear and sealed bids are incentive compatible, in so far as they incentivize market parties to reveal their willingness to pay. They are therefore likely to perform better in a regulated context like this.

Auctioneer. Another question is who should run the auctions. In our view, much speaks in favor of tendering the auctioneering as a service contract. Then both energy exchanges such as EEX or Nasdaq, but also brokers and platforms such as Trayport, Enmacc or Svensk Kraftmäkling could bid for the job. A blueprint for such an approach is the auctioning of European Emission Allowances (EUA), where there are government-contracted primary auctions and then voluntary secondary trading. An alternative option is for TSOs to do it themselves or appoint a TSO-owned body, such as the single allocation platform JAO. Synergies are likely larger in using private existing platforms.

Local matching. In the context of LTTRs, local matching refers to whether bids and asks from the same bidding zone should be matched (i.e. brought together) during LTTR auctions of TSOs. While this could potentially yield efficiency gains, it is unclear whether they exist or how large these would be. It would also create additional supply competing with that of the TSO and thereby potentially drive down prices (spreads). Furthermore, TSOs would enter in competition with exchanges and brokers for domestic (zonal) products then, which is not their role as regulated entities. In any case, further analysis of this question seems warranted. If spread futures are auctioned by an auctioneer that also offers continues trading, such as a broker platform or a commodity exchange, an additional question is if order books should be integrated, e.g. if open orders from the continuous market should be regarded as bids into the auction (and vice versa).

Conclusion. We recommend LTTRs to be sold in dedicated auctions. Regardless of the type of derivative, participation in continuous markets is not recommended. The auction service should be procured in competitive tender, in which all possible auctioneers can participate, such as energy exchanges, brokers, and platforms, as well as JAO. Spread futures must be cleared as they come with counterparty credit risk for TSOs, and clearing should be handled by an established clearing house (such as ECC or Nasdaq Clearing).

4.3 VIRTUAL HUB

Virtual hub. We use the term "trading hub" as a forward market that is not (or not only) used by market parties with direct exposure on that market, but also for proxy hedging, usually because it is more liquid than the domestic forward market. A regional virtual trading hub is a composite price index that serves as the underlying asset of financial derivatives, in particular forward contracts. While one might think the term refers to a location, an institution, or a marketplace, that is not the case. A virtual hub is a price index to base forward contracts on. The concept does not exist in spot or balancing markets and hub prices are not used to settle any physical electricity contracts. The hub price index can either be calculated as the weighted average of a number of spot prices or as the hypothetical price that would emerge if the trade between bidding zones in an area was unrestricted. It is "virtual" in the sense that no physical generation and consumption are settled with the price index. The opposite of a virtual hub is a physical trading hub, where the underlying spot price *is* used to physically settle production and consumption, i.e., a bidding zone. Cross-border derivatives such as spread options or spread futures are said to be zone-to-hub products if the underlying asset is the price spread between a bidding zone and the price index rather than the spread between two bidding zones (zone-to-zone). This section discusses the potential benefits and risks of introducing a virtual hub and alternative price index methodologies.

Regulatory approach. The proposed EU legislation does not force market participants to use hub-based forward contracts, nor does it prescribe power exchanges or any other marketplace operators to offer such contracts. It does, however, regulate the supply of LTTRs by TSOs, possibly requiring them to be zone-to-hub contracts. The idea is that market parties in smaller bidding zones in the future will hedge by using hub-based forward contract in combination with such zone-to-hub LTTRs. This is supposed to shift forward trading away from zone-based towards hub-based contracts, even if not legally mandated. The trade of domestic forwards continues to be allowed but might fade away.

Questions. In our view it is important to carefully distinguish three separate questions:

- What would be the consequences (benefits and risks) if forward markets increasingly shift to a virtual hub?
- What would be the consequences if LTTRs are defined as zone-to-hub?
- To what extent does the latter trigger the former, i.e., what is the role of LTTRs in shifting forward trade towards a virtual hub?

Hub-based forward markets. Today, European electricity forward trading is concentrated on three physical hubs, the German, French and Hungarian bidding zone (in this order). Anyone, e.g. an exchange, a broker, or a group of traders, could define a new composite price index and in that sense introduce a virtual hub. What would be the consequences? Putting aside the question of LTTRs for a moment, there would be two potential benefits and two potential downsides / risks if a virtual hub is introduced compared to the status quo, where Germany serves as the main physical trading hub. They concern the correlation of hub prices with domestic prices and the impact on liquidity:

- Correlation benefit: The price index is likely to be better correlated with domestic forward prices of many small bidding zones than the German price, i.e. a better hedging product for market parties here. The correlation in question is not the correlation of hourly spot prices, but the correlation of forward prices such as year base prices. If the new market has the same liquidity and market depth as the German forward market today, the virtual hub will hence offer the better proxy hedges.
- Correlation downside: The price index is less than perfectly correlated with German forward prices, i.e. a worse hedging product for German market parties. The same might be true for some other bidding zones that today are well correlated with the German price.
- Liquidity benefit: If the virtual hub is successful in displacing other forward contracts, one common regional electricity forward market is established, potentially attracting more liquidity than any of the multiple existing forward markets today. This is sometimes referred to as "liquidity pooling".
- Liquidity risk: If the virtual hub attracts some but not all of the trading activities, liquidity might be split across more markets and overall liquidity might decline.

Cost-benefit. While acknowledging the lack of any hard empirical evidence on that matter, in our opinion the relative weight of costs and benefits of introducing a virtual hub depend on the alternative, i.e. the existence of a liquid physical hub. The big advantage of a virtual hub is that it works in a setting with many small bidding zones. In the status quo, where Germany is a very liquid market, the risks seem to outweigh the benefits. If the German bidding zone were to be split in several small zones, the physical hub would disappear, and the establishment of a virtual hub seems reasonable. All this, however, may have less to do with LTTRs than many believe.

Hub-based LTTRs. ACER seems to suggest that defining LTTRs as zone-to-hub will kick-start hub-based forward markets. This might not be the case, because zone-based forward markets are perfectly compatible with hub-based spread futures. This is the case because spread futures can be "chained" and "decomposed": a spread future A-C is mathematically identical to the pair of two spread futures A-B and B-C, because the middle price cancels out:

$$P_A - P_C = (P_A - P_B) + (P_B - P_C)$$

This is also true if B is a hub price, of course. A, say, Belgian market party that wished to hedge using the German forward market in combination with LTTRs would then simply buy two spread futures (DE-Hub and Hub-BE) instead of one (DE-BE).

LTTR volumes. How would the volume of spread futures to be issued by TSO be determined if they are defined as zone-to-hub products? Given that the virtual hub does not exist in spot markets, bidding zones have no spot trade vis-à-vis the hub, so the "net traded energy" rule cannot be applied. However, this apparent problem is easy to solve: TSOs can simply issue *pairs* of spread futures in identical volume (like Svenska Kraftnät does today). For example, instead of issuing DE-FR spread futures equivalent to the expected German-French electricity trade, they would issue both DE-Hub and Hub-FR spread futures of the same quantity. As a result, TSOs would have no position on the hub price but also not introduce any net liquidity to the hub. For that reason, it is not clear to us if zone-to-hub LTTRs would trigger any hub-based forward trading. It is hence a possible outcome that the introduction of zone-to-hub LTTRs have zero impact on forward markets and the virtual hub effectively remains nothing else than a technicality of LTTRs.

Number of products. ACER argues that with zone-to-hub LTTRs, a much smaller number of cross-border derivatives are needed, essentially just one per bidding zone. The smaller number of LTTRs, it is argued, will improve the liquidity of LTTR trading. This argument ignores two important aspects: first, spread futures are identical to a pair of domestic futures, so LTTR liquidity cannot be thought of as independent from domestic forward market liquidity. Second, if Germany serves as the physical hub of Europe, markets parties do not need all possible zone-to-zone combinations, but just a zone-to-Germany spread. The possibility to "chain" spread futures holds regardless of the hub being virtual or physical. Both a physical and a virtual hub result in the same number of spread futures needed.

Hub with options. Spread options cannot be similarly chained or decomposed. It is unclear to us how the volume of spread options could be determined in the context of a virtual trading hub. Also, market parties cannot use a pair of zone-to-hub options to construct a zone-to-zone option. For these reasons, we are doubtful if a virtual hub makes much sense if LTTRs are defined as options.

Price index methodologies. The virtual hub price index can be defined in three principal ways:

- A weighted average of zonal spot prices with ex-post weights
- A weighted average with constant ex-ante weights
- The unconstraint price

Weighted average. Using ex-post weights such as day-ahead trading volume, would make any derivative based on this price index an incompletely defined contract, because the underlying will only be known ex post. This is something that should be avoided. A more sensible approach is to use ex-ante defined weights to average spot prices, such as long-term average consumption. In our view, stability of definitions is more important than an accurate match, so the weights should ideally not be changed, or just every couple of years. This is the price index definition that we recommend.

Unconstrained price. The third alternative is to define the hub price as the hypothetical price that would emerge if all zonal buy and sell bids on spot markets would be aggregated, in other words if cross-border trade was unconstrained. This is how the Nordic system price is determined. The advantage of this approach is that it is robust against reconfigurations of bidding zones (which do change spot prices and hence also change the weighted average). The fundamental problem with this approach is that it is prone to manipulation, because the hub price generally depends on bids that are not executed. Market parties may strategically issue bids and offers for that sole purpose, i.e. bids that for sure will not be executed in the actual, constrained coupled spot market but do affect the hub price. For this reason, we advise against this methodology.

Conclusions. In our view, any cost-benefit assessment of virtual hubs should carefully distinguish between "a virtual hub being established and actively used" and "LTTRs being defined as zone-to-hub". If TSOs issue zone-to-hub spread futures, they do not take any net position on the hub, and hence might not trigger the use of hub-based futures by market parties, so the two questions might have less to do with each other than commonly thought. In our view, the net benefits of introducing a virtual hub are linked to the potential split of a German bidding zone: only if that physical hub disappears, a virtual hub seems needed. If a virtual hub is introduced, we recommend defining it as the weighted average of spot prices. Weights should be stable for at least multiple years and could reflect long-term average electricity consumption.

5 Conclusions

Two models. The objective of LTTRs, derivative type and volume must be discussed and decided jointly. Table 3 maps the objective, derivative type and volume to two consistent models of LTTR provision: Model A (Hedging congestion income) and Model B (Balanced forward markets). Our opinion and our reading of the law is that balanced forward markets are the objective. This speaks for Model B.

Table 5. Two models of LTTR provision

	Model A Hedging congestion income	Model B Balanced forward markets
Objective (why?)	Hedging congestion income / Making congestion income available to market parties	Balanced forward markets / Making import/export volumes available to forward markets
Derivative type (what?)	Spread options (FTR-options) (Or, under FBMC: congestion revenue rights)	Spread futures (FTR-obligations)
Volume (how much?)	Spot trade capacity (adjusted for unavailability and uncertainty through de-rating or non-firmness)	Expected spot traded energy (net imports)

Model B challenges. However, implementing Model B is complex, because it requires market modelling, coordination among TSOs, frequent re-adjustment of volumes in light of forecast changes and shorter products. Effectively, TSOs would need to evolve in commodity trading houses, and lawmakers as well as regulators would need the corresponding understanding, skills, and tools, too. On top of all that, one must expect significant politization of that process.

Stakeholder impacts. In Table 6 we summarize the impacts of the models on consumers on the one hand and on regulators and TSOs on the other hand. For consumers, Model A comes with a higher risk of underpricing due to the complexity of options and the resulting limited competition in the auctions. If LTTRs are underpriced, higher network charges for consumers result. Furthermore, the models have implications for consumers in their role as market parties. The hedging possibilities provided through Model A are less direct, as the volumes from LTTRs are passed through to forward markets only if the buyers of LTTRs choose to engage in delta-hedging. Model B on the other hand provides volumes and liquidity directly through the TSOs' auctions. For regulators and TSOs, however, a disadvantage of Model B is its higher complexity and resulting risk of political influence. Model B is more complex because many decisions need to be made such as forecasting of net traded energy, timing of auctioned volumes, and as well as a frequently readjustment of positions. Such complexity can in turn also negatively impact consumers, because it can result in imperfect execution of Model B, impairing its outcomes.

Table 6. Effects on stakeholders

	Model A Hedging congestion income	Model B Balanced forward markets
Electricity consumers (as network charge payers)	Higher risk of underpricing due to complexity of option pricing	Lower risk of underpricing
Electricity consumers (as market parties)	LTTR volumes become available on domestic forward markets if and the degree by which option buyers engage in delta-hedging	LTTR volumes become available on domestic forward markets immediately
Regulators / TSOs	Lower complexity	Higher complexity (forecasting net energy, frequent re-adjustment of positions, coordination among TSOs, political influence)

Delta hedging. Financial mathematics, in particular the theories of option pricing and delta hedging, suggest there is a certain symmetry between the models. Under perfect theoretical and practical assumptions, including single-hour futures, they effectively are the same. But in reality, many differences remain, such that A and B remain separate choices. But financial theory also suggests two additional ways to aim for balanced forward markets:

- Rather than forecasting traded energy, use a supply function derived from option theory ("supply function")
- Rather than selling spread futures, sell options and hope commodity trader will take care of delta hedging while acknowledging this is unlikely to lead to balanced forward markets ("outsourcing delta hedging"). This would resemble Model A in the choice of derivative and volume (options at capacity), but the underlying objective is different.

Choice. The choice among the three possibilities to achieve balanced forward markets – futures at expected energy, futures according to a supply function, or options at capacity – will crucially depend on the confidence one has in TSOs, regulators and lawmakers on one side and commodity traders and financial markets on the other side.

Revenue adequacy. We are somewhat sceptical about the need to mitigate revenue inadequacy and suggest this should be regarded as a secondary objective. Revenue adequacy on an hourly basis for each border is certainly not necessary. Instead, a high likelihood of revenue adequacy on an annual or monthly basis for each TSO seems to be sufficient. We recommend scrutinizing the current approaches to improve revenue adequacy, namely non-firmness of LTTRs and LTA inclusion. Instead, we recommend considering alternative approaches, in particular a central compensation account to smooth fluctuations in cash-flow.

Marketplace. We recommend LTTRs to be sold in dedicated auctions. Regardless of the type of derivative, participation in continuous markets is not recommended. The auction service should be procured in competitive tender, in which all possible auctioneers can participate, such as energy exchanges, brokers, and platforms, as well as JAO. Spread futures must be cleared as they come with counterparty credit risk for TSOs, and clearing should be handled by an established clearing house (such as ECC or Nasdaq Clearing).

Virtual hubs. In our view, any cost-benefit assessment of virtual hubs should carefully distinguish between “a virtual hub being established and used” and “LTTRs being defined as zone-to-hub”. If TSOs issue zone-to-hub spread futures, they do not take any net position on the hub, and hence might not trigger the use of hub-based futures by market parties, so the two questions might have less to do with each other than commonly thought. In our view, the net benefits of introducing a virtual hub are linked to the potential split of a German bidding zone: only if that physical hub disappears, a virtual hub seems needed. If a virtual hub is introduced, we recommend defining it as the weighted average of spot prices. Weights should be stable for at least multiple years and could reflect long-term average electricity consumption.