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HANDLING CROSS-BORDER ELECTRICITY GRID CONGESTION: THE MAKING OF EUROPEAN ELECTRICITY MARKET COUPLING

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Making Minds Matter

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About Bert den Ouden



Policy brief by drs. Bert den Ouden, Associated Fellow of Erasmus Commodity & Trade Centre; Founder and former CEO of initial Dutch energy exchange APX-Endex; Founding first chairman of Europex (European association of Energy Exchanges)

About Erasmus Commodity & Trade Centre

Erasmus Commodity & Trade Centre (ECTC) is a commodity industry think tank and talent platform offering applied research & advisory, academic education and executive education. ECTC is a part of Erasmus University Rotterdam, a public research university in The Netherlands.

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Introduction

The energy transition requires huge electrification of demand and more intermittent renewable sources of electricity. This causes the current electricity grid to be congested, a serious problem that is impacting business operations. The problem, however, is not new: it occurred earlier. Twenty years ago, the problem of congestion happened on the cross-border electricity interconnectors between neighboring countries. Electricity markets emerged in Europe around the turn of the century, at first on a country-by-country basis. Congested border connections between the countries created a big problem: the market remained fragmented, illiquid, sub-optimal. Nonetheless, a successful integration of these national markets into a fully fledged integrated European market proved to be possible, by introducing a smart market model called 'market coupling'.

This paper describes the origin and establishment of that model, designed and implemented by power exchanges in co-operation with grid companies. This market coupling, started in 2006, is still the basis model for the functioning of the European electricity market today. The model turned a huge problem (the grid congestion) into a big advantage (market liquidity) by applying a smart market solution for the problem. The account written is by Bert den Ouden. one of the designers of the model. The purpose of this historical account on the market coupling by one of its prime designers Bert den Ouden is to provide inspiration for solutions for the congestion problem of today. After all, congestion implies scarcity of transport capacity. And, according to economic theory, scarcity creates prices: it puts value to the congested grids, allowing markets to emerge and balance supply and demand more efficiently.

The origin: liberalizing the monopolized electricity markets

During the 1990s, the urgency was felt in Europe for competition in electricity. The European Commission was already preparing general rules for liberalization of the electricity market in all member states of the European Union. Some countries were already ahead of this. The United Kingdom and Scandinavia had already set good examples. In many other countries the urgency was felt for the creation of a liberalized market as well. This was due to the drawbacks of the old centralized system, namely the following:

- *No competition*. Electricity was generated in most countries by a single monopolist utility company (in many cases, owned by national or local authorities) or by a co-operation of several of these, together coordinating the national electricity production and investment, in fact a sort of oligopoly.
- *No incentive to save cost*. Because of this oligopoly, there was no strong mechanism to save costs. A well-known quote about the electricity system in those years was, that it was an "engineer's paradise". Every investment could be done, all operational costs were allowed, because the costs could be wheeled collectively to the end customers anyway.
- *No choice for the consumer*. The customers had no alternative. Households, offices, factories, industries: they just had to pay the tariff, as decided by the state-controlled utility companies. This became untenable. In order to make European industry more competitive, energy costs should be reduced via competition of electricity supply. Also, households should be offered more choice of supply, the benefits of which were already demonstrated by electricity liberalization projects in some countries.
- *No opportunities for new ideas*. After the oil crises of the 1970s, new technologies came up such as combined heat and power, energy conservation in general, as well as the first renewables projects. It became clear that a monopolistic environment was not conducive for

these developments. A market where new entrants with new ideas and technologies would have an opportunity to provide solutions at scale, was needed to speed up these changes.

Electricity liberalization in each EU country, included day-ahead spot markets

While electricity market liberalization appeared in the European electricity market liberalization guidelines during the 1990s, the implementation (timing and details) was at the discretion of each EU member state. So this appeared one by one, and in different ways, in each member state (at that time 15 states). In many countries, this led to the creation of national power exchanges operating a daily spot market, for matching hourly surpluses and shortages between energy companies, as well as optimizing the hourly fuel mix of production and demand response.

Based on the earlier experience in the Nordic countries, this spot market took the form of day-ahead auction of the hourly supply offers and demand bids (see figure 1). In most cases, the mechanism also contained an iterative mechanism to for including multi-hour bids and offers (block bids), to allow for inflexible demand or supply to be included in the market (see figure 2). Such a spot market day-ahead auction was created in each country implementing liberalization. The design of these spot markets turned out to be more or less the same in each country, yet each spot market covered only its own national area, creating a patchwork of daily prices across Europe, but no real integration.

***Figure 1**: The auction traded market (generally adopted in Europe): Day-ahead spot market, area-based*

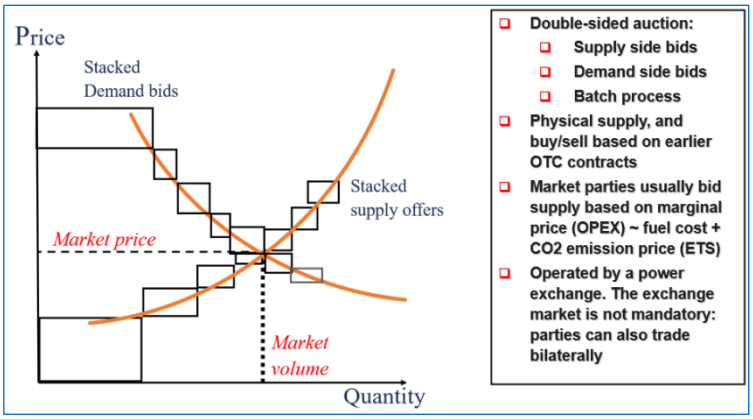
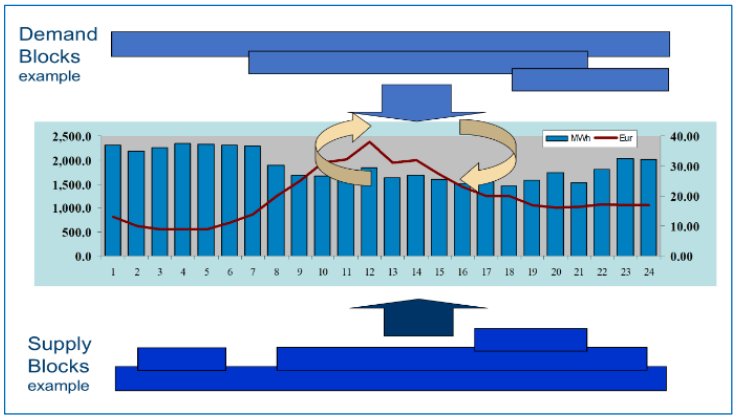


***Figure 2**: Hourly bids and flexible block bids, user-defined e.g. for thermal power: system iteration*



The half-succeeded, half-failed liberalization: market in isolated countries, not European

By 2001, many countries had their own liberalized electricity market, and their own national spot market exchange. These country-based markets were relatively small (size of that country only), with only a limited number of market participants. In some countries, this was the former monopoly incumbent; in some other there were several of these. As a result of a wave of mergers, the number of market participants eventually became smaller. Thus, in each national market there was little competition and limited market liquidity.

The national markets were however connected by the cross-border power lines that could in theory be used for broader international trading. But in practice the trading was still fragmented:

still national markets, illiquid, not achieving true optimization between the multiple national markets. The areas had different spot markets; trading was not shared, even not at moments without physical congestion. There was not a single European electricity market. Rather it was a very fragmented market, a patchwork of isolated markets for each country. And in each country, there were only a few big players active.

This fragmentation was aggravated by the auctions of the transportation capacities on the cross-border interconnectors. By design, the cross-border capacity rights had to be purchased in advance, in the explicit capacity auctions by the Transmission System Operators (TSOs), not knowing the eventual daily area-based spot prices. This implied an inherent market risk and dilemma for the market participants. They could use the capacity rights to bid on price spreads between the different European area-based spot markets, only to often find out that the price spread revenue did not justify their purchased cross-border capacity price, sometimes even in opposite direction (so with negative revenue). Thus, this two-step process (first bidding on the cross-border capacity auctions and scheduling of the border flows, then bidding on the spot markets) led very often to suboptimal scheduling of capacity, under-utilization of capacity or even scheduling of capacity in the wrong direction (opposite to price difference).

Incomplete utilization and adverse scheduling

The cross-border capacity available for trading was underutilized or even wrongly utilized in practice. There were huge price differences between the various pricing areas, while the capacity between these areas remained partly unused (if it had been, the prices could have been closer together). This happened very often, for instance in the early days of the Amsterdam Power eXchange (APX), the initial Dutch spot market, of which I was the managing director at the time. Although the price in the Netherlands was often relatively high and while we could have imported more, there was often import capacity not fully used. Sometimes the Netherlands could have exported more, but that did not happen either despite available export capacity. The same happened in many other countries and country-based spot markets.

> Many policy makers said: *"there is too little cross-border capacity, we have to invest in new power lines". I responded: "You don't know how much, because the current power lines are so under-utilized, they are used so ineffectively".* My reasoning was*:* building of power lines takes a long time; a smart solution for utilizing the power lines more efficiently could work much faster. Begin with the fastest fix: improve utilization**.**

Finding a solution: combining and integrating trading in areas and on borders

The solution of the fragmentation problem was easy in theory: combine and integrate the daily trading in the pricing areas and the border areas, all in one go. Fortunately, a model to do that already existed in the Nordic countries. In the liberalised electricity market of the Nordic, the bids on the spot markets in the areas were also used to establish the flows on the area borders and the value of the border capacity. This was a one-step process involving all areas and all the cross-border capacity. The outcome of this process was solid, proven by in multitude of years of operation.

The transfer of this Nordic model to the whole of Europe was however not straightforward. This was because the Nordic solution was operated by a single exchange operating the market in all the countries (Norway, Sweden, Denmark, Finland), whereas in Central and Western Europe there were already different spot exchanges for each country. How to operate an integrated system across all these different markets? This was seen as an enormous hurdle, as often

quoted in the European discussion between the parties involved. The various stakeholders (TSOs, exchanges, grid companies, European Commission) did recognise the value of the Nordic system, however they also perceived it to be very difficult to implement for all of Europe with all these different exchanges: “First merge all the exchanges together in one” I remember participants saying, thereby pushing the prospects far into the future.

A co-operative effort: market coupling

Around that time, in the early 2000s , the prospect was discussed within Europex, the association of power exchanges in Europe, of which I was the first chairman. The consensus among the Europex members was not to rely on a time-consuming pan-European merger of exchanges. This was unlikely to happen soon, and a fast European market integration and quality improvement was very urgent. Instead, it was decided to work out a cooperation between the existing exchanges. This was proposed to the other actors (grid companies, transmission operators, traders, regulators, industrial offtakers, European commission) at the annual European regulatory forum (the “Florence Forum”).

The proposed model was branded “Market Coupling”. This wording was coined during a meeting between me and the chairman of the European Federation of Traders. The name market coupling seemed appropriate for what we wanted to achieve: an integration of the market areas in Europe, also by a cooperation of their exchanges instead of a single model with split zones as an outcome. The wording also symbolized the objective of European integration.

A mixed model of exchanges, TSOs and bilateral trade

The market coupling model was different from the Nordic model in more aspects. How much of the cross-border capacity should be involved? The Nordic model involves all the cross-border capacity to be allocated through the market splitting algorithm on a daily basis. Consequently, there was no long-term physical capacity to be auctioned for bilateral cross-border trading to the market parties themselves. Intra-zonal trading could only be done financially.

It was felt especially among traders that the Nordic model was too radical, and by the grid companies, who had their own cross-border term capacity auctions established. In a series of meetings, a compromise was reached: a part of the cross-border capacity should be auctioned directly to the market parties long-term, and another part of the cross-border capacity would be made available on a daily basis for the market coupling through daily scheduled area bids in the market coupling algorithm. This compromise, mainly negotiated between Europex, European Federation of Traders and the European grid companies, was eventually presented in the Florence Forum of 2004. This was felt to be the right mix between the role of exchanges, grid companies, and bilateral trading. This outcome was then endorsed by the European Commission as the way forward. Throughout this process and thereafter, the highly skilled support from representatives and staff at the European Commission proved to be very important, stimulating the market development: a real public-private co-operation, pushing the development forward.

Proof of the model: trilateral market coupling as a pilot

Despite the positive outcome of the 2004 Florence Forum, a lot of scepticism remained. Could it be done operationally? Would cooperation between the exchanges really work? And what would be the regulatory embedding of the new mechanism? So many practical questions remained. A practical real-world demonstration of the new model was therefore required.

Around that same time, talks had started between electricity exchanges and grid operators in France, the Netherlands and Belgium regarding the initiative for a market coupling pilot between the three countries. Stakeholders included were the Dutch APX and the French Powernext and the TSOs of the three countries TenneT, Elia and RTE. Each of the countries involved had its own reasons to engage in the project. The Netherlands had the oldest spot market with competition and innovative ideas, but as a small country it needed more interaction across the borders to add liquidity. For France as a large country with an almost single supplier, the border integration would bring additional competition and a European perspective. For Belgium as a small country with an almost single supplier, the market coupling would generate the needed liquidity and kickstart a Belgian spot market. The Trilateral Market Coupling (abbreviated TLC) project was put into motion. The teams of exchanges and TSOs started to work together, preparing the model.

Sharing the order books, maximize and optimize the border flows

The project faced the challenge of creating a new operative model, as there was no example of a multi-exchange electricity market anywhere in the world. The coupling model started to be developed quickly by the joint teams of Powernext, APX and also Belpex, the new Belgian exchange. The idea was the sharing of order books: the exchanges would share their (24-hourly) order books based in the bids and offers from their market parties on a daily basis. They would also receive the information from the TSOs about the hourly available cross-border interconnection capacity to match and integrate the markets. Then the exchanges would calculate the market outcome in the three price zones, using all of the cross-border capacity as much as possible.

Depending on the amount of capacity and the market circumstances, the result could be either:
- *Constrained*: Different area prices with all the border capacity used to the maximum to bring area prices as close together as possible, generating also a cross-border capacity auction income from the remaining price difference (so-called implicit auctioning);
- *Unconstrained*: if enough border capacity, it resulted in one integrated price for the areas combined, with the border flows scheduled exactly to equal the prices: using border capacity optimally to create a single market with a free cross-border flows at zero border price (See figure 3: the mechanism illustrating the model for two price areas; it works in the same way for three or more price areas, with more borders involved).

***Figure 3**: Cross-border interconnector constrained: Market Coupling at partial*

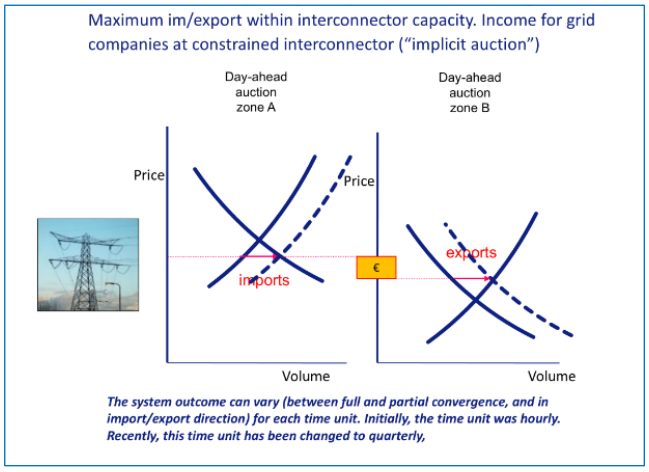
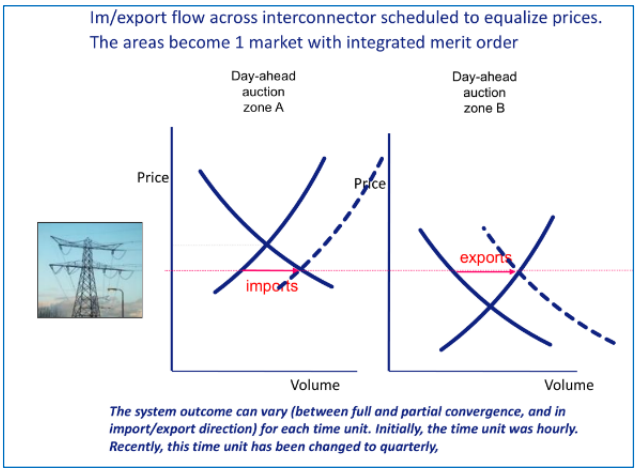


***Figure 4**: Cross-border interconnector unconstrained: Market Coupling at full convergence*



The market outcome could be different for each hour: constrained in one hour, and unconstrained in another hour; also, with different combination of borders being constrained or unconstrained. To make it work, a thorough algorithm design was required, also to allow for the multi-hour block bids to be fully integrated in this mechanism. Sophisticated ICT skills were needed to solve this consistently.

Thus, the project to implement this idea in an operating system was very intense, perhaps the most intense I have ever seen. It not only involved the change of the systems of all three exchanges, but also a mechanism and schedule to rotate the practical operation of the central algorithm between these exchanges. This way, each of these exchanges remained in equal position, also providing contingency: they could be the back-up for one another. Very important because the daily schedule of international flows across TSO interconnectors, would be essentially determined by the exchanges. The TSOs were also involved: they had to make sure that the maximum cross-border capacities for each hour of the next day would be sent to the exchanges (and transparently published to market parties on the website) and thereafter receive the proper interconnector schedules and auction revenue back from the exchanges.

In the end it was a concerted effort, done with enormous dedication and faithful co-operation, by teams of highly dedicated and motivated staff. It delivered also very fast: the Florence Forum had given the green light in 2004; and after just two years of dedicated design, building, testing and training. the Trilateral Markt Coupling started on 21 November 2006.

An immediate strong result beyond all doubt

The market was of course well-informed about the new system. It went live very smoothly, with flawless technical operation right from the start. After a small adjustment time, the amazing results started to appear (see figure 4). The new system delivered a truly integrated market between the three countries. Before, there was a substantial price-gap between the countries. After the introduction of trilateral market coupling, the prices converged, becoming the same or with only very small differences. This included all three markets: the French spot market, the Dutch spot market and the newly established Belgian spot market. All spot markets had added liquidity due to the cross-border flows integrated with their trading, and the market converged much more than before, due to the optimal scheduling of the imports and exports between countries across interconnectors.

***Figure 5**: Price convergence France, Netherlands, Belgium after introduction of first market coupling (trilateral market coupling) in 2006*

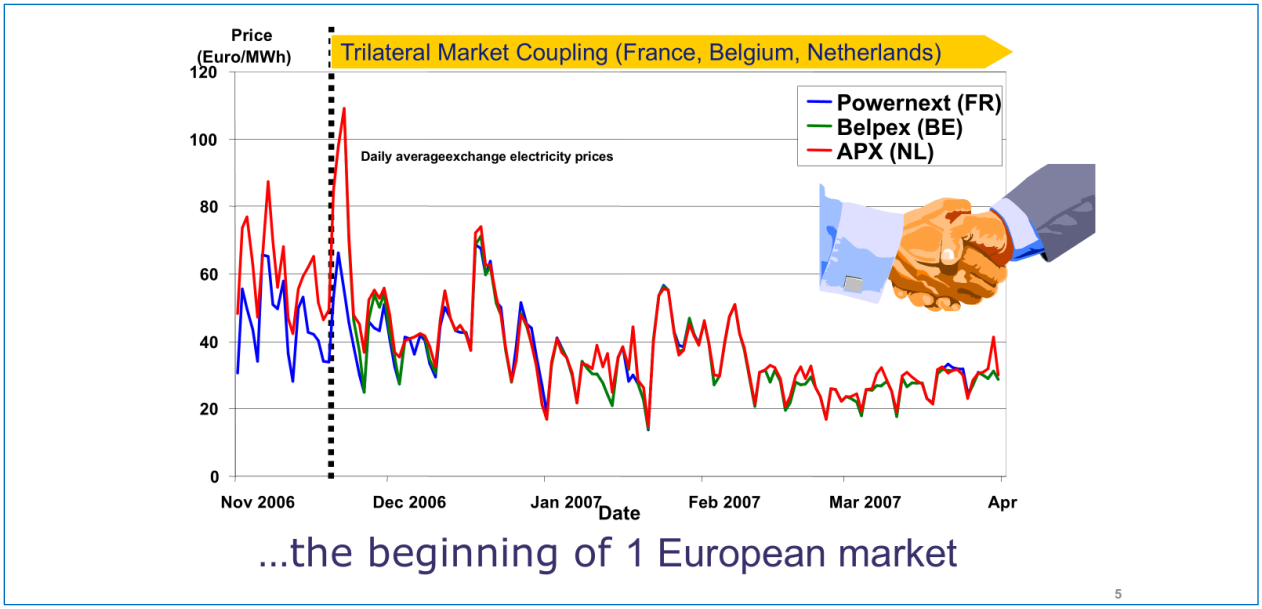
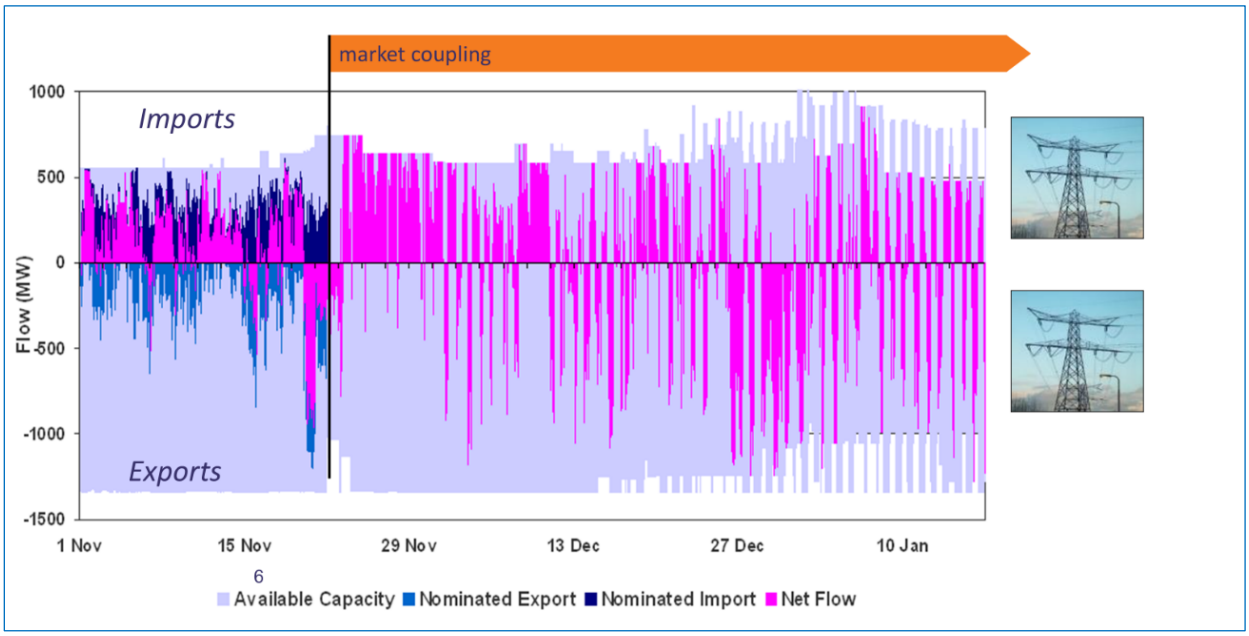


***Figure 6**: Market Coupling Maximizing imports and exports on cross-border interconnectors*

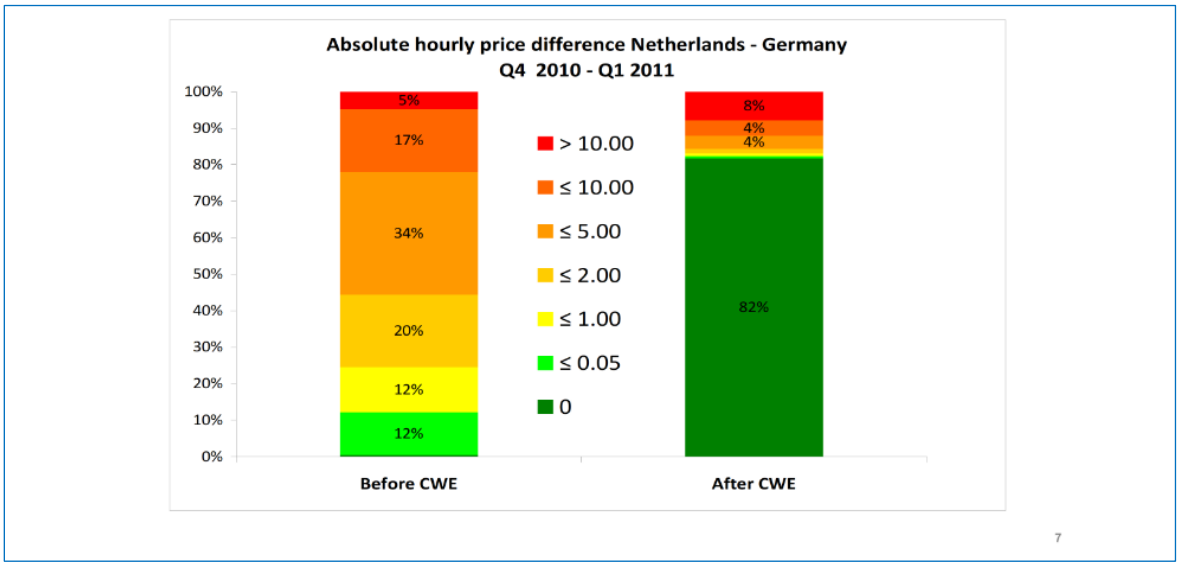


Physically this cross-border capacity remained the same as before, but it was now scheduled in an optimal way, maximizing imports and exports, with a much better utilization of the interconnectors (see figure 5). The sudden improvements, in reducing the price gap, and in improving interconnector utilization, were very striking; it became soon clear that the model was a great success, even more than anticipated.

The market coupling as a target model

The success of the trilateral market coupling was hailed by the European Commission together with all the partners. The model was proclaimed as the desired model for the whole European electricity market. Subsequently, a series of projects was started to extend the market coupling to include more countries. Firstly, Germany and Austria, transforming the TLC into the Central West European Market coupling (CWE). Once operational in 2010, this also showed the same type of benefits (see figure 6).

***Figure 7**: Next success: Convergence of prices Netherlands-Germany after CWE Market Coupling in 2010*



The project went further, integrating the CWE with the market splitting system in the Nordic countries, followed by UK and Ireland, the Iberian Peninsula and Italy plus Slovenia. Further extensions and integrations of eastern European countries followed in the years thereafter.

Meanwhile another improvement step was made in the CWE area, involving a “flow-based” model: instead of fixed border capacities, this was a more advanced TSO model whereby the maximum flow on one border could be dependent on the other borders, opening up a wider optimization of the market coupling with even better economic outcomes.

Today: 20-year anniversary, reliable operation, building further, new challenges

We are now in 2026, the market coupling has been with us for 20 years. Reliable operations in a ever expanding system that is by now covering most of Europe’s electricty demand can be considered a true successtory of European integation. A system that was also recently upgraded, with integration of quarterly 15-minute operations (so 96 prices on a day), a major effort. With this additional time resolution, the market coupling is more ready for the new electricty market influenced by the energy transition: higher volatility due to faster variations in supply and demand.

The daily market coupling goes into its third decade of existence: now more needed than ever, with new challenges ahead. The call for additional price zones is growing, as grid congestion is

ramping up. New price zones in the market coupling is possible. Possibly more price zones and a more dynamic price pattern requires recalibration and optimization of the market coupling.

Maybe the market coupling could also provide inspiration for solutions for today's domestic congestion problems such as experienced nowadays in the Netherlands. The energy transition generates huge electrification of demand and more intermittent renewable sources of electricity. This causes the current domestic electricity grid to be congested which constrains the energy transition ambitions.

Could there be also market solutions for those new congestions? After all, congestion implies scarcity of transport capacity. According to economic theory, scarcity creates prices: it puts value to the congested grids, supporting the most optimal market outcome, allowing for the most efficient solutions to handle the situation. The market coupling provides a good example of how these types of problems can be solved in a lasting and efficient way.

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