Nodal pricing systems: the US experience and outlook for Europe

Executive summary of the study produced for the French Energy Regulatory Commission (CRE)

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Study background and aims

The European electricity system has engaged for several years in an **energy transition process that is fundamentally changing models handed down from the past**. Decentralised renewable generation connected to distribution grids is increasing, self-consumption behaviours are emerging and the use of power is evolving, with electric vehicles or digital technology. While this transformation offers a wealth of opportunities, it could **generate additional (though partly avoidable) costs for the power system** if badly managed, particularly in relation to the interface between grid, centralised and decentralised generation. These challenges are observed in some countries such as Germany or the United Kingdom that have a level of integration of renewables higher than France. These countries have experienced a significant increase in congestion, resulting in higher congestion management costs that rose by factors of 3.5 and 2 respectively between 2010 and 2016. The rise in loop flows in Central and Western Europe, which restrict import/export capacities and hamper grid management and operational security, are an additional example of these challenges.

The "single country, single bidding zone" approach was adopted in most European Union (EU) Member States in the late 1990s, with the aim of immediately opening up electricity markets to competition. However, given the currently observed changes, this market design might **not be the most efficient way of best using the grid and the generation and flexibility assets**. Furthermore, it may prove to be **inadequate in conveying the right signals to grid users with flexibility in terms of geographical location** -e.g. producers building new power plants or decommissioning old facilities or power-intensive users ready to move to less costly locations for the grid if this reduces their electricity bill.

While this issue was not in the front line over the last twenty years due to the relative stability of the generation capacity set-up, the question of how appropriate it is to send locational signals to grid users is nevertheless arising from a whole new angle. **Alternative market designs**, such as the nodal approach, could provide the means to answer some of the energy transition-related issues. The nodal design has been used in the United States (US) for close to twenty years, but also in other countries worldwide such as Canada and New Zealand, based on recommendations from researchers or regulators.

In this context, the aim of the study was to focus on the **theoretical and practical implications of the nodal approach reflecting on the US experience** and to **assess the outlook for the European power system**.

The nodal approach: from theory to practice

What is the theory underlying the nodal approach?

In the zonal system currently used by most EU Member States, the markets set **a price country by country**. Each producer follows a decentralised approach to schedule its generation capacity based on portfolio bidding. **Network operators manage internal congestions** on **their national power system** through redispatch measures, whose costs are passed on to the network users *via* network tariffs. Similarly, network operators offset electricity losses by purchasing energy on the markets, with the costs being passed on to the network users. As such, there is no incentive for producers to alter their production schedules to reduce grid losses.

By contrast, in a nodal approach, the network operator uses a centralised process to determine how much each plant must generate based on the generators' bids. It subsequently sets **a price for each of the grid's physical nodes** based on supply and demand and taking **operating constraints over the entire network** (including congestions and losses) into account. As such, the price associated to a node is allocated to each generation capacity that is connected to this node. A nodal approach allows **making best use of existing infrastructures** by taking into consideration actual operating constraints.

Schematically speaking, the nodal approach applies the principles of cross-border electricity transactions in Europe by replacing countries (or zones) with grid nodes. Furthermore, while redispatching entails a cost for the network operators, price differences between nodes between which transactions take place constitute a source of **income for network operators** that can be used, for example, to fund investments to reduce congestions. This income corresponds to services provided by the transmission system -much like a motorway toll- or interconnectors between different European countries.

The economic literature endorses the nodal approach

Researchers have studied the nodal approach as far back as M. Boiteux's work in the 1950s as well as throughout the 1980s and 1990s and there is a **very broad academic consensus about its benefits**. A nodal approach helps **minimising the global power system operation cost**, i.e. both demand-led generation costs, losses' costs and ancillary services' costs, by using the network as efficiently as possible. From a competition point of view, problems linked to some generators' local market power are mitigated compared to zones.

The nodal approach also fosters **long-term signals** that help guide generators to locating their investments, while enabling network operators to improve or develop network infrastructure. Although these signals can be volatile and are based on a certain number of assumptions (such as access to information, perfect predictability or perfect competition), they can incentivise producers and consumers to hedge with long-term contracts and financial transmission rights.

The US experience shows that the nodal approach performs well, provided that some practical arrangements compared to the theory are implemented

All **those US states that have liberalised their power systems** have designed their markets **using the nodal approach** with a central dispatch. The pace of the transition to this system has varied depending on the region. While PJM and NYISO adopted it rapidly after establishing their markets in the late 1990s, Texas and California chose to design their markets differently before revising their approach in the late 2000s. In California, the 2000-2001 crisis, which resulted from various manipulations of the then existing redispatching system, was one of the main triggers for the transition.

Several studies have highlighted the practical benefits for the system of using a nodal approach, particularly the **improvement of the use and location of generation capacity**, a **greater transparency** of system requirements, or the **better use of flexible resources thanks to the co-optimisation** of energy and reserves. The benefits also stem from close and often *ex ante* market monitoring measures to guarantee competitive market behaviours.

Network tariff regulation in the US is **similar to the European approach**. The tariff is based on the network operators' allowed revenue (needed to cover their costs and allocated between the various network users) and congestion income is deducted from the tariff paid by users. In practice, nodal pricing is used as a locational signal for grid users and an investment planning guide, more than a fully-fledged source of income for the network operators.

Nevertheless, in contrast to Europe where power exchanges and network operators manage electricity markets and the power system, respectively, in liberalised US markets these two functions are centralised by non-profit entities referred to as Independent System Operators. These entities are also responsible for planning grid developments, while network ownership is separate and has generally been kept by the incumbent operators.

In the US markets, the financial risk linked to volatility of nodal prices can be controlled through **products enabling a hedge against temporal variations** -which are traded on futures markets- **and against locational variations**. **Congestion income** (linked to price differences between nodes) **is partly redistributed** to grid users through its subtraction from the tariffs to mitigate the impact on existing players. This avoids, for example, generators historically located at a node where energy is cheap from being prejudiced by the switch to a nodal system. Still, large industrial users located at sites where electricity is cheap are generally offered the option to benefit from this reduced cost of electricity, while a **tariff equalisation system is maintained** for those users that want to benefit from it.

Finally, as in Europe, the short-term signals conveyed by nodal pricing are **complemented to improve long-term signals**. Most liberalised markets in the US have subsequently introduced capacity mechanisms. Some of these give regional capacity prices to boost the locational signal and add greater stability or strength over time. Over the last few years, scarcity pricing mechanisms have also been developed in various US markets to reinforce investment signals.

What is the outlook for France and Europe?

In theory, as in practice, the nodal approach helps minimising power system operation costs and delivers efficient investment signals. In the current context of the energy transition processes initiated in many Member States, introducing the nodal system in Europe could **help addressing some issues faced in the development of a European market model**, for example, linked to managing cross-border flows and flow-based market coupling.

However, the nodal approach raises **a number of questions and implementation issues**, especially concerning the integration of European markets or the governance and separation of network and power markets' operation tasks. Introducing this approach in France, or even in Europe, would also require assessing mechanisms that could mitigate the effects on existing market players.

This study has nevertheless allowed identifying **several areas for further reflection and research, building on the nodal theory and its application in US markets**, in relation with the challenges that this market design aims at addressing.

- *In terms of managing grid constraints*, it would be useful to continue analysing the nodal approach by more in-depth research, particularly by modelling applied to France and Europe to **assess the tangible costs and benefits of a nodal system**, as well as related redistribution effects. This research might be conducted by RTE and its European partners and may initially focus on simulating and publishing historic and/or close to real-time nodal prices. Furthermore, on a more pragmatic note, the potential role of local trading platforms that optimise local capacity for the grid could also be studied.
- *As concerns reducing network losses*, introducing a location-based network charge for feeding electricity into the grid could be studied to provide producers with an incentive to cut their losses' costs.
- *As for locational investment signals,* **alternative mechanisms** could also be evaluated to support better locational investment and targeted closure of power plants on the grid. This could, for example, involve connection charges or network tariffs.
- *Finally, other areas could be explored to boost short-term price signals* independently of locational issues. For example, research could be conducted on developing an **energy/reserves co-optimisation mechanism** in the existing decentralised market or introducing a **scarcity pricing mechanism**.