Review of Electricity Market Arrangements – End User Forum (19th April 2023) – locational signals pre-reading

This End User Forum (EUF) will explore the implications for end users of sending more efficient **locational signals** in electricity markets, and **what a positive outcome of any reform would look like.**

Providing efficient locational signals to minimise system costs is one of the key challenges REMA is trying to address. The locational challenges we see in today's electricity market are typically focused on the supply side. Renewable assets are likely to locate where the requisite natural resources (e.g. wind) are most plentiful and where they are able to obtain planning consents. These locations are often at the extremities of the network, far away from centres of demand. Managing the transfer of electricity between these locations will require rapid expansion of the network. However, we will inevitably see increased periods when there are physical constraints on the ability of the network to transport electricity and when renewables have to be turned down to resolve local imbalances in supply and demand.

To maintain a low-cost system, REMA is developing options **to send more efficient locational signals** that may incentivise generation and flexibility assets as well as sources of demand to build in suitable parts of the network and to operate ways that could lower system costs. Specifically, REMA is focusing on addressing the following questions:

- How can we send more efficient locational investment signals through REMA markets? These signals would incentivise generation and sources of demand to build in suitable parts of the electricity network which can lower system costs. For example, by generation locating in areas of spare network capacity, or incentivising demand in areas of cheap renewable electricity.
- How can we utilise more efficient locational operational signals? These signals would allow generators, flexible assets such as battery storage, and end users to respond to price signals in real time to unlock a more efficient system.

Locational signals could be sent to both supply and demand. But when considering whether end users should be exposed to locational signals we will need to understand in what ways and to what extent different end user groups may be able to effectively respond, and subsequently what fair outcomes would look like. To achieve these aims, the forum will be split into three sessions:

Session 1 - Responsiveness & Barriers: This session will focus on the ability of different end users to respond to locational signals and what other factors may take precedence or effect their response.

Session 2 – Variations of Exposure: This session will focus on the different ways locational signals could either be passed through to end users or how end users could be shielded from them.

Session 3 – Fairness: This session will explore questions of distributional impacts and fairness.

This is a first step to explore these complex issues. No policy decisions have been taken. Ahead of the forum, we would be grateful if participants could review the pre-briefing material below which is split into three sections:

- Section 1: The case for sending more efficient locational signals
- Section 2: How locational price signals could alter end user bills

- Section 3: The potential impacts of passing-through locational signals to end users

Section 1: The case for sending more efficient locational signals

The case for change

The capacity mix of our future electricity system will largely be composed of renewable energy sources. Recently, we have seen increased network congestion (bottlenecks in the network where it is unable to send additional electricity between areas) as wind penetration has increased. This is in large part because new renewable generation is increasingly being built far from our centres of demand, in addition to delays to the necessary network reinforcement.

Managing network congestion carries a cost. Under current arrangements, generators behind congestion points are asked to turn their output down (they are curtailed), receiving compensation for doing so, and generators ahead of the congestion are asked to turn up so that overall demand can still be met. These costs are ultimately passed onto end users.

A future GB low-carbon system is likely to experience periods of increased curtailment even as network infrastructure is built out. An efficient system will have to balance network reinforcement and generation curtailment. It would not be feasible or cost-effective to expand network capacity to prevent all curtailment as some network capacity will have very low utilisation. However, as renewable generation investment has outpaced network reinforcement, constraint costs have increased significantly in recent years, from around £360m in 2015 to £1.2bn in 2021.

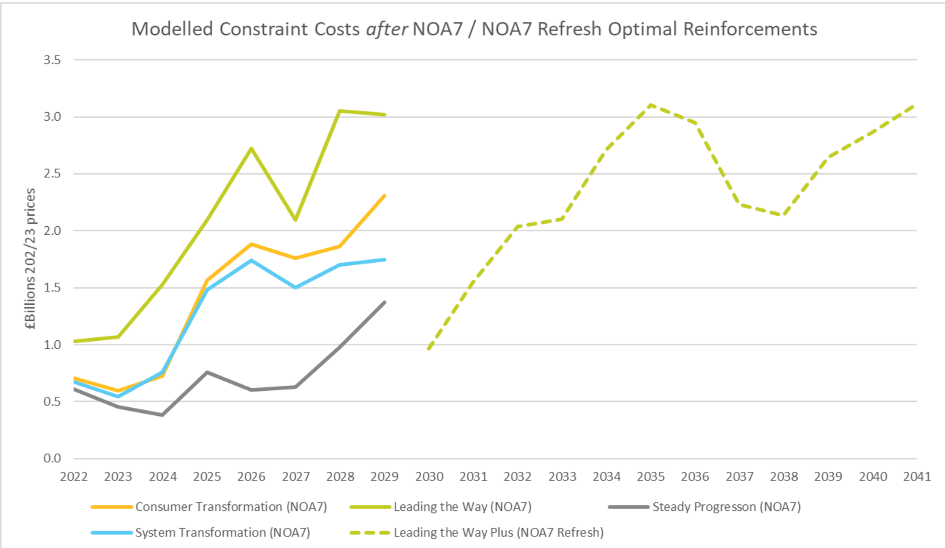

Figure 1- Modelled Constraint Costs after NOA 2021/22 Refresh optimal reinforcements

Looking forwards, National Grid ESO estimate that the cost of managing constraints will rise to around £3bn per year in 2030, before it reduces to around £1bn per year due to the combined effect of a new offshore transmission system and the acceleration of onshore network reinforcement projects[1]. Beyond 2030, it projects that constraint costs will continue to grow again, although there is more uncertainty in the forecasts over this timescale.

Issues with current market design

[1] The dataset used for the NOA 2021/22 Refresh assessment is based on the Future Energy Scenarios published in July 2021, and therefore does not include the recent increase in gas prices and the effect of the war in Ukraine. These higher gas prices have led to increased balancing costs in GB, and an increase in export flows across the interconnectors.

The current wholesale market does not incentivise market participants to adequately consider location in their decision making. The fact that generators are compensated even when the energy they produce cannot be physically utilised by the system means they do not need to consider network capacity and broader system conditions when making investment and operational decisions. In addition, neither of the key mechanisms for driving new generation capacity build - the Contracts for Difference and Capacity Market - are designed to send locational signals, and the effectiveness of the main locational investment signal in our current market structure, network charges (TNUoS), is debated.

REMA's case for change identified several issues with the current market design, which if unaddressed could increase network and balancing costs and therefore end user bills.

Stronger **locational investment signals** would incentivise generation and flexibility assets, as well as potentially end users, to build in suitable parts of the network. This would encourage new assets to consider their impact on the network when deciding where to build, and so may help to minimise spend on network reinforcements and additional generation capacity. This could help incentivise generation such as renewables to locate in areas of spare network capacity (beyond congestion bottlenecks). If demand is exposed to locational signals, they could be incentivised to build in areas where renewable energy is plentiful, and for flexible assets to locate in parts of the network where they could help alleviate constraints. However, this would need to be balanced against the ability of generation and demand to respond to such signals and the other factors which may take precedence.

Once an asset has been built, **locational operational signals** could incentivise the asset to produce or use electricity in a way that benefits the system as a whole, helping to mitigate network constraint costs in real-time. For example, batteries could export energy when the network is constrained, and import to relieve constraints. And, depending on how price signals are passed through, locational operational signals could encourage end users participating in Demand Side Response (DSR) to operate in a way which is more aligned with network needs - potentially increasing the incentives for DSR in some regions.

The REMA case for change concluded that assets need to be better incentivised to locate and operate in ways to minimise whole system costs. However, there remains a need to analyse the degree to which more efficient locational price signals could better optimise investment location (where this is feasible) and enable more locationally-efficient operation. If greater locational signals result in a net benefit, the overall system savings would feed through to end user bills.

The options under consideration for sending more efficient locational signals

We are considering several options for introducing more efficient investment and operational locational signals. For end users, we believe the three options we describe below are of most relevance. These are nodal and zonal pricing, and reformed transmission charging (TNUoS). These options only capture sending locational signals at the transmission level. Options to manage constraints at distribution level are being considered in REMA's work on local balancing models.

Wholesale pricing options (nodal and zonal pricing): These options send a locational price signal through the wholesale price. Currently the single national wholesale price is determined by the cost it takes for generators to produce the next unit of electricity. Nodal and zonal pricing would factor in not only the cost to produce the next unit of electricity into the wholesale price, but also the locational value of that electricity (whether it can be transported to demand or not). This would mean that different geographic regions would have different prices of electricity. Whether demand is exposed to these price differences is an open design choice and a question we will explore in this Forum.

The key difference between nodal and zonal pricing is the granularity of the locational signal and complexity. Zonal pricing could split GB into for example a dozen geographic zones each with their own wholesale price, while nodal pricing would generate a different wholesale price at 100s of different supply points across the country.

Non-wholesale-pricing options: as well as locational wholesale pricing, we are also exploring a package of options to introduce locational signals into other markets and mechanisms. The main option in this package that could impact end users is reforms to transmission charging (TNUoS). Under this option the locational signals that TNUoS charges provide could be strengthened and/or made more granular. This is something that Ofgem are looking into as part of their TNUoS Taskforce. We are working closely with Ofgem to ensure that their review fits with our REMA objectives.

The rest of this paper primarily focuses on the impacts of locational pricing (nodal and zonal) as it could send a locational operational signal to end users which absent from todays arrangements. However, potential reforms to TNUoS could also impact the existing locational signals sent to end users, and we would want to understand how effective current arrangements are in sending locational signals and how reform might change this.

Section 2: How locational price signals could alter end user bills

Currently, the locational signal end users see in their electricity bills come from transmission and distribution network charges. These hypothetically send long term investment signals over where to locate - though their effectiveness has been debated and in some cases this is not their primary aim – and they do not send signals over operational, real-time timescales.

The combined effect of these variations for domestic end users is shown in the table below, which shows how the current default tariff cap varies by region for domestic consumers on direct debit for the cap level from 1 April 2023 to 1 June 2023.

Region, *i*	**Single-Rate Metering Arrangement (benchmark consumption per annum, *k*)**	**Single-Rate Metering Arrangement (benchmark consumption per annum, *k*)**	**Multi-Register Metering Arrangement (benchmark consumption per annum, *k*)**	**Multi-Register Metering Arrangement (benchmark consumption per annum, *k*)**
	Nil kWh	***m* (3,100kWh)**	**Nil kWh**	***m* (4,200kWh)**
North West	£178.73	£1,658.37	£179.06	£2,147.81
Northern	£198.25	£1,654.45	£198.58	£2,140.59
Yorkshire	£193.28	£1,662.47	£193.61	£2,155.52
Northern Scotland	£205.02	£1,679.95	£205.35	£2,172.61
Southern	£172.41	£1,675.65	£172.74	£2,174.23
Southern Scotland	£214.37	£1,699.63	£214.70	£2,191.88
N Wales and Mersey	£214.90	£1,754.88	£215.22	£2,259.13
London	£132.73	£1,670.42	£133.06	£2,173.14
South East	£164.11	£1,686.75	£164.44	£2,184.82
Eastern	£151.76	£1,668.71	£152.10	£2,166.71
East Midlands	£174.88	£1,645.12	£175.21	£2,138.09
Midlands	£187.59	£1,669.95	£187.92	£2,166.94
Southern Western	£202.59	£1,684.31	£202.92	£2,174.82
South Wales	£187.11	£1,683.40	£187.44	£2,179.84

Figure 2- The current default tariff cap for direct debit domestic consumers by region, source - https://www.ofgem.gov.uk/publications/default-tariff-cap-level-1-april-2023-30-june-2023

The first and third columns show how the standing charge varies by location and the second and forth columns show how the annual cost of energy for a typical domestic consumer varies by location.

How locational pricing could affect wholesale prices and system costs

Firstly, it is worth noting that end users and retailers can be shielded from locational price signals and there are several different approaches for doing this (as is discussed in the next section). In other words, it is a policy decision as to whether, how, and which end users could have locational signals passed through to them, if at all. **Ahead of discussing these points, this section explores how locational pricing could potentially affect prices in the wholesale market and system costs**.

Locational pricing would change how wholesale market prices are formed in different regions. Broadly, the balance between supply and demand in each region and the ability of the network to transfer electricity will determine prices. We would typically expect electricity to be cheaper in the north when compared to the south. This is due to the high levels of cheap renewable generation in the north, the distribution of demand across GB, and constraints in the network limiting transfer to the south which would mean more expensive generation must be used to supply southern demand.

Prices may also vary over time. For example, in Scotland, prices may be closely linked to wind availability, with prices becoming low when wind turbines are generating, whereas in Cornwall there could be lower prices in the middle of the day when solar panels are generating. It could be possible that some regions have price signals which are more volatile or harder to predict. The price discrepancy between locations could also change over time as the generation mix changes and network reinforcements alter how much electricity can be transferred from one location to another. So, costs could begin to equalise over time. As well as this, we would expect price variations to be more granular under nodal pricing when compared to zonal pricing.

As noted above, the costs to manage system constraints are socialised across end users. Locational pricing could lower these constraint costs as the ESO would not have to pay generators to turn up or down due to locational imbalances. More widely, locational pricing could mean less network infrastructure and generation capacity needs to be built which would further lower system costs. However, depending on how this is introduced, retailers may face more risks and challenges in managing a more complicated and varied system. There would also be costs for implementation, and potential knock-on impacts for some market participants which would need to be considered when determining the overall system savings which are passed onto end users.

It is unclear how the potential net benefit of introducing locational pricing could feed through to individual end user's bills and further modelling would be needed to understand this point. This will be affected by how locational pricing alters the underlying costs of supplying different end users i.e. in different regions or with different usage profiles, how retailers may hedge across regions and whether/how end users are shielded from these signals.

It is therefore worth considering for this forum both the potential that the cost of supplying all individual end users will reduce, but the reduction varies across the country, and the potential that it costs less to supply some end users, but it costs more to supply others. We believe this discussion would aid understanding of any potential benefits and questions of fairness.

The options for passing through or shielding end users and retailers from locational signals

As discussed, it is possible for locational pricing to be introduced without end users being exposed to these signals. This could allow some of the benefits of locational pricing to filter through to end user bills without bringing different prices to end users in different regions. However, doing this could also reduce some of the potential overall benefits of locational pricing as end users would not be responding to more granular locational price signals.

It is important to consider these options within the context they could be introduced within. If it were pursued, at the time locational pricing could be introduced, we would expect Market-wide Half Hourly Settlement (MHHS) to be in operation, for there to be an increased number of flexibility propositions for end users, and for there to be greater uptake of smart appliances. Additionally, wholesale market prices may become more variable compared to today as more variable renewable generation is brought online.

REMA is also being carried out alongside energy retail market reforms aimed at making the retail market work better for end users, be more resilient and investable, and better support wider system transformation. Both programmes are essential for delivering the right outcomes for end users. We are aware that the future of the retail market has clear interdependencies with the discussion below on the potential impacts of exposing end users to locational pricing. We are working closely across these work programmes.

There are several ways for how end users could be shielded from locational signals, and a national price provided for them. Many countries with locational pricing use these types of approaches. Firstly, the wholesale market can be set up so that some participants sell/buy at a locational price and others sell/buy at a national price. Secondly, retailers could be required to provide some tariffs where the wholesale market component is consistent across regions - this would require them to take the different prices of supplying different end users and create an average tariff for their consumer base. Finally, steps could be taken at settlement so that some participants receive the locational price and others a proxy national price. This option also includes the potential for a separate component of end user's bills to be altered, so that average bills are consistent across regions. For example, an end user in a region with lower wholesale prices would have a higher standing charge than end users in high wholesale price regions. This would result in retailers having a full locational price and therefore being able to potentially respond efficiently to this, whilst the average bill remains consistent across regions[2].

At a high-level, the table below shows the potential end outcomes for end users from either nodal or zonal pricing considering this potential for price signals to be levelised by either settlement or retailers, or for some costs to be passed through. Note that different approaches could be taken with different end user groups and approaches could potentially be phased. The potential benefits and risks for different end user groups is something we would like to discuss, and therefore which options might be preferable.

Wholesale market pricing approach	Potential end outcomes for end users
Single national price	- The **wholesale market portion of a tariff is consistent across the UK**. There are still variations due to network charges (TNUoS). There are also potentially variations due to locational ancillary services and local markets.

[2] Note: this option was proposed within *Powering Net Zero, Policy Exchange, 2020*.

Zonal pricing and nodal pricing	- End user tariffs include the **zonal or nodal price** and therefore vary across regions. - End user tariffs include a proxy **national or zonal price (under nodal pricing)**. - The default is for end user tariffs to include a proxy **national price, but there is the option for** end users to opt-in to the zonal or nodal price. - End users have the operational signal of locational pricing, but a process is undertaken to ensure the average price of a bill is the same across regions (i.e by weighting another component of the bill based on a consumer's location).[3]

This table highlights that there are a large number of potential options for how locational price signals could be managed for end users. It also highlights that with all these options, bills could vary across GB due to wider factors - as they currently do, though there is the potential that locational pricing could affect these differences.

These different options could potentially be phased and it could also be possible to take different approaches for different end users depending on their ability to effectively respond to locational signals. Ultimately, we would want to ensure a positive outcome for end users.

There are several implementation questions around these approaches, for example whether they cause any distortions to system incentives, how predictable each approach would be and whether end users with different profile types are affected differently by each approach. For all options, a solution would need to work with the arrangements in places for Demand Side Response Service Providers (DSR SPs).

The table also shows several 'opt-in' approaches. These could potentially be very valuable, as they could shield some end users from locational signals, whilst enabling end users seeing lower prices to benefit and enabling improved operational decisions from DSR. This does however raise questions about how this may operate in reality. For example, if end users opt-in to the more granular price in areas where prices are cheaper, tariffs for the remaining end users could increase above what is purely the average national price. Also, end users providing flexibility could choose to not opt-in if this would make them more revenue (i.e. in regions with relatively flat price signals). This would reward some DSR for operating in a way which doesn't support the network.

The final option within the table enables end users to receive locational operational signals whilst the average end user bill does not vary across the country. This could potentially enable end users to react to the correct operational signals but levelise bills across end users.[4] We need to understand how practical this would be and whether it could be introduced in a way which does not distort incentives. There may also be fairness considerations with some end users effectively subsiding other end user's bills.

We would also need to take into account different policies which may sit alongside these market designs, for example, policies to support those in fuel poverty. Impacts on different end user groups is explored further below. At this stage of the process, we are interested in understanding the potential implications of these different approaches for passing through locational signals as well as what a good outcome would look like for end users. Questions

[3] [3] *Powering Net Zero,* Policy Exchange, 2020.
[4] ibid

around fairness and distributional impacts will be key determinants when deciding which option is most appropriate. Some key considerations include:

1. Variations in prices across regions – Is it fair for price signals to vary across regions? Is it fair for end users in some regions to subsidise those in others?
2. How benefits will be split across end users – How will the benefits of locational pricing be split across end users under each model? Are there differences based on usage of an end user, their engagement with the retail market or their access to flexibility assets? What would be an acceptable outcome?
3. Whether some end user groups will be negatively impacted by these changes – Will specific end user groups be negatively impacted by these changes? Is this okay if these are not vulnerable end users and if so, what variation is acceptable? Could wider policies, such as support for end users in fuel poverty change these considerations?

As well as this, as discussed in Chapter 1, REMA is also considering options for sending more efficient locational signals outside of the wholesale market. Reforms to TNUoS could make the locational signal they send stronger or more granular. In this case, we would also want to explore the impacts this could have on the decision making of end users.

Section 3: The potential impacts of passing-through locational signals to end users

Determining which of the options above is the best approach requires an understanding of the potential impacts of passing through locational signals to end users. It is possible that passing through locational signals could allow end users to make decisions which further minimise the costs of the electricity system, reducing both their own and fellow end users' bills.

Understanding the potential 'size of the prize' of these actions, at which times these benefits may accrue and how this varies across end user groups, will help assess how policy should evolve in this space. Alongside these potential benefits, we are aware that some end users could potentially be negatively impacted by these changes, or that even though end users are better off than they would have been overall on average, it is seen as unfair that prices vary by location. As discussed above, there are potential design choices, or wider policies which could be introduced alongside this mechanism, to mitigate or remove these negative impacts.

Below we explore some of the potential responses to passing through locational signals to end users. Within the session we wish to get your input to develop and refine this thinking on how end users could potentially be impacted, who would need to be protected, and to understand your views on the relative importance of each factor.

Potential impacts of exposing end users to locational pricing

There are three ways different types of end users can potentially respond to locational pricing to reduce the cost of the electricity system. These are:

1) Making more economically efficient siting decisions.
2) Taking investment decisions on their existing site which closer aligns with system needs in their area i.e. investing in solar panels or energy efficiency in areas of relatively high prices and/or DSR systems in areas with more variable prices.

3) Changing consumption patterns or asset operation to reflect price signals in their area.

For each category there will be potential positive and negative impacts. The potential impacts will vary across end users groups, the year being considered (due to the state of network build, generation mix, access to smart technologies and specific weather) and the impacts in a specific region.

Below we discuss some of these key considerations, and for these purposes we have split the discussion into the potential impacts on domestic and non-domestic consumers.

Domestic consumers

We expect domestic consumers are highly unlikely to be able to, or willing, to move home in response to locational pricing and the existing housing stock is already in place. We also think it unlikely that developers of new homes would take this into consideration, though we will explore this further. It should be considered whether there will be any boundaries where electricity prices vary considerably over a small distance. In this instance there is a chance renters may take this into their considerations though there are other factors which would likely take precedence.

More widely, there is potential for some consumers to take action which will reduce both their costs and overall system costs, by making more economically efficient investment decisions due to their exposure to sharper price signals. This could be through consumers in higher price areas installing energy efficiency measures or solar panels and consumers in lower price areas switching from gas to (now) locationally cheaper electricity or buying an electric vehicle. There is also potential that consumers could invest in batteries. The change to locational pricing could possibly accelerate the business models for these assets in specific regions, supporting decarbonisation and reducing whole system costs. It is worth considering that changes in electricity price may affect the appeal of each of these assets to a different degree. For example, an improved pay-back period may increase the likelihood of someone buying solar panels, but the decision to buy an electric vehicle may be mainly driven by different factors.

There is also potential for locational pricing to increase the incentives for consumers to operate flexibly. Being exposed to locational signals could improve the efficiency of how this flexibility is activated ensuring that DSR actions are in line with system needs, reducing whole system prices and not accidently compounding network problems. That said, a large capacity of domestic energy usage may not be suitable for shifting. The extent to which consumers may respond would depend on their access to certain technology, as well as their engagement with the retail market and the quality of the propositions incentivising them to behave flexibly. Retailers and aggregators could help boost this engagement and optimise assets in response to specific locational needs.

However, there are also potentially negative impacts from introducing locational pricing for domestic consumers. For example, households who use more energy or consumers who cannot invest in new technologies and live in areas where the wholesale price could be expected to increase will be more affected by price increases. So, we would need to ensure that these end users are not disproportionately impacted.

Non-domestic end users

The majority of existing assets may be unlikely to move due to locational pricing and for many new-build assets it is other locational factors, such as local needs (e.g. hospitals, schools), skills, and infrastructure which will determine siting decisions. However, there may be some industries (e.g. energy intensive sectors with less infrastructure requirements, such as data centres) which may take energy price into consideration when determining where they locate. Though there could be benefits for new industries locating in places with lower electricity prices, if an existing industry were to relocate or other local businesses were to be negatively impacted by price changes, this could have negative impacts. Therefore, we wish to understand which sectors may be particularly impacted by potential price changes.

As above for domestic consumers, sharper locational operational price signals could lead to some industries making improved investment decisions which reduce both their own and overall system costs. This includes sites potentially choosing a more economically efficient decarbonisation pathway based on the price of electricity in their region. For example, sites could choose to electrify where there are cheaper local electricity prices or to install a battery where a region has high variations in prices. This will be considered within the context of industrial decarbonisation to understand the implications this could have for different sites. It may be that some non-domestic sites may be more likely than domestic consumers to invest in new assets based on their business models, so may react more effectively to changes in price signals.

Non-domestic DSR could potentially be a large source of low carbon flexibility. Operational locational price signals could increase the incentives for industry to engage with flexibility (likely via a supplier or aggregator), as some regions may see increased price variability, and could ensure these assets are operated in a way to maximise their value within the energy system.