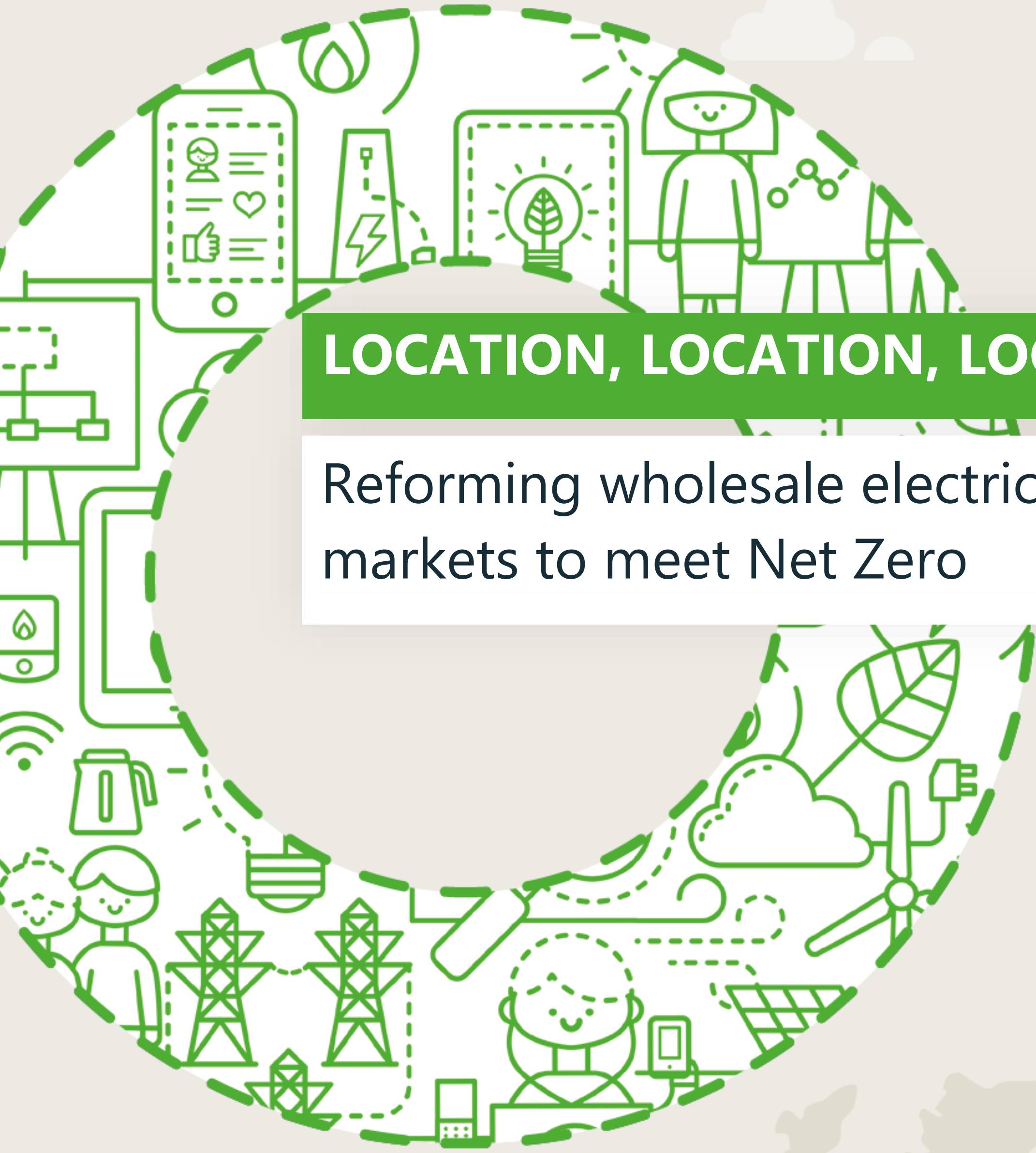
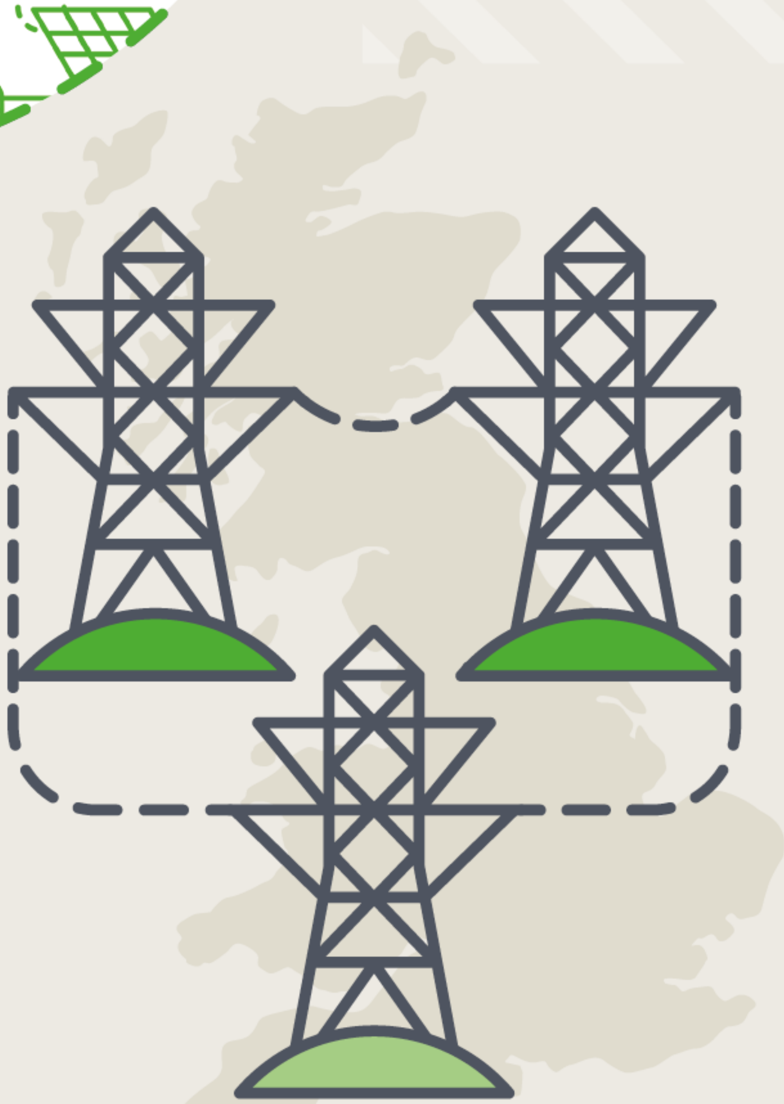


LOCATION, LOCATION, LOCATION

Reforming wholesale electricity markets to meet Net Zero



May 2022

LOCATION, LOCATION, LOCATION

Reforming wholesale electricity markets to meet Net Zero

Energy Systems Catapult worked in collaboration with Octopus Energy to produce this report. We are grateful for assistance from colleagues at Octopus Energy (and also FTI Consulting LLP). This report is a jointly funded collaboration by Octopus Energy and ESC.

1. EXECUTIVE SUMMARY

Energy policy has never been more important.

Surging prices and the war in Ukraine remind us of how central energy is to our cost of living, economic competitiveness and national security.

Clean electricity will increasingly come to dominate our net zero energy system. We will need to invest hundreds of billions of pounds to build the net zero electricity grid.

But our wholesale electricity markets were designed for a different age, with a single wholesale price driving investment and operation of the system across England, Wales and Scotland. This is increasingly out of step with reality in a system that is being transformed.

We need to reform wholesale electricity markets

The clean electricity system will form the centrepiece of our strategy for achieving net zero.

We can reform wholesale electricity markets to make prices reflect the true balance between supply and demand in real time across the grid. Other countries, including many markets across North America, have successfully introduced this approach.

This reform can unlock major benefits for the GB market as we move to a fully decarbonised grid that is more flexible, secure and affordable.

If we fail to reform, we risk spiralling costs to balance the system, and spending billions of pounds of customers' money on generation and new transmission wires that are poorly located and adapted to our needs. We will have less innovation and more expensive energy for decades ahead.

We can unlock benefits for users and build a more balanced system

A study commissioned by Octopus Energy shows that reforms to make wholesale electricity markets reflect local conditions could save around £3bn per annum on average (circa £30bn in total) by 2035, as the UK transitions to a net zero grid.

Key Findings from Octopus Energy study:

- **£30bn of savings** by 2035 from:
  - more efficient location & despatch of generation and storage
  - more efficient use of network infrastructure, including interconnectors to European markets
- Savings for users in **all regions**, but proportionately greater in Scotland & North.
- More investment in grid scale storage & earlier investment in generation supported by carbon capture to complement renewables.
- Estimated benefits are based on conservative assumptions and a simplified representation of reforms. Further savings would be likely under a more refined market design (and modelling exercise) at transmission level, and potentially also from reform of market signals at distribution level.

The results of the study align well with National Grid Electricity System Operator's Net Zero Market Reform project[1], which recommends introducing dynamic real-time locational pricing.

Such reforms would align price signals more closely with physical reality, improving incentives to build the right assets in the right places, and for innovation to make both supply and demand more flexible.

Reform needs to be prioritised and actioned at pace.

The UK commitment to decarbonise electricity by 2035 is laudably ambitious and makes market reform an urgent priority. Delay implies hardwiring inefficiency into the transition and inhibiting the emergence of a more flexible and balanced system.

Both BEIS (through the Review of Electricity Market Arrangements announced in the Energy Security Strategy) and Ofgem (through its analysis of locational pricing) are now starting important work to assess potential reforms in more detail.

Thereafter, implementing meaningful reform will require strong backing from Government, with the resources required to implement at pace.

[1] See https://www.nationalgrideso.com/document/247306/download

The coming dominance of clean electricity

Clean electricity lies at the heart of net zero and long-term energy security. The Government's Net Zero strategy commits us to net zero electricity by 2035.

This clean electricity will be the mainstay in replacing hydrocarbons in the 2030s and 40s, and we will need more of it, as we replace 26 million gas boilers and 36 million petrol and diesel cars and vans with low carbon alternatives. The scale of the challenge is unprecedented:

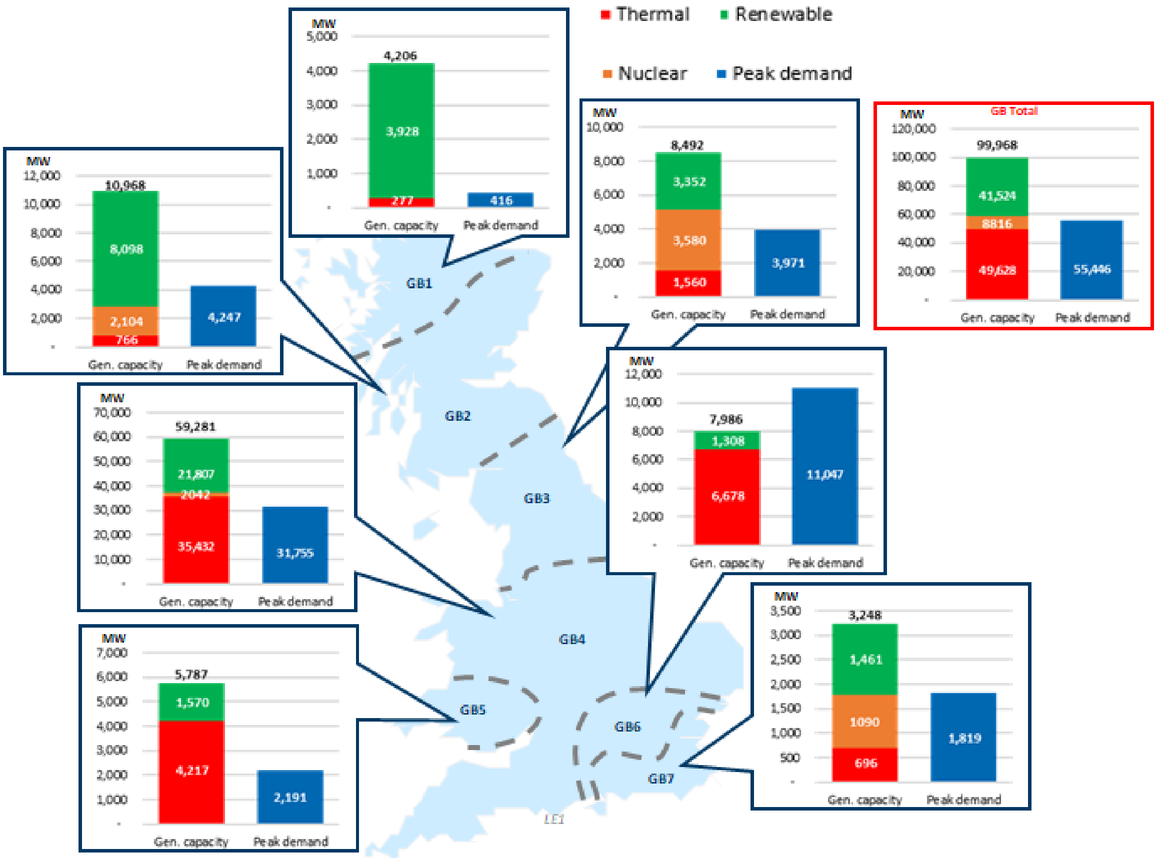
- **completely decarbonising** all electricity generation,
- **doubling** (at least) electricity generation by the 2040s.

Estimates suggest this will require around £1 trillion (£1000 bn) of investment to 2050 in:

- New generation: a mix of renewables, new nuclear plants and carbon capture and storage
- Energy storage at grid scale and below to manage an increasingly variable generation mix
- Major upgrades to electricity transmission and distribution networks
- Digital systems to optimise real time control of millions of new devices, including smart controlled storage and distributed generation, connected to the grid.

Regional diversity in the UK electricity system

The UK's generation mix is regionally diverse – a single price signal across GB masks the underlying reality of major variations in the supply/demand balance across regions. This regional variation is growing more marked as we decarbonise the grid and rely more on renewable generation located further from demand centres.



2. WHY REFORM ELECTRICITY WHOLESALE MARKETS?

The recent surge in energy prices means steep increases in bills for millions of households. The spotlight has naturally fallen on the retail market and the energy price cap over the past few months.

But ultimately wholesale markets shape the majority of costs that consumers must pay in their bills. Current arrangements mean that the gas price is key in setting the wholesale electricity price across the GB market. To deliver net zero affordably and efficiently we must also build strong well-functioning wholesale markets.

2.1. CURRENT WHOLESALE MARKETS NO LONGER WORK

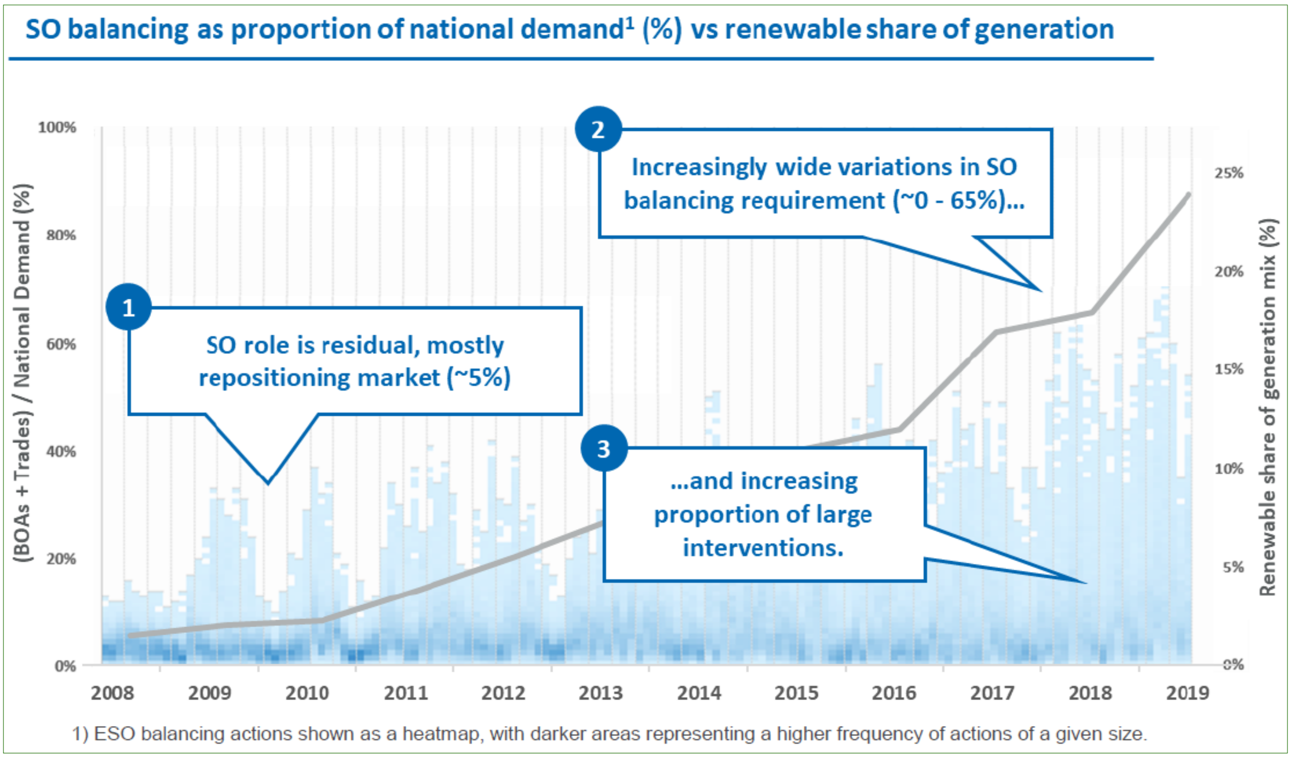
Wholesale electricity trading in the GB market was designed at the turn of the century when large gas fired generators, connected to the transmission network, were expected to dominate.

Under current arrangements the whole of GB is treated as a single entity for trading purposes, without any consideration of physical transmission constraints.

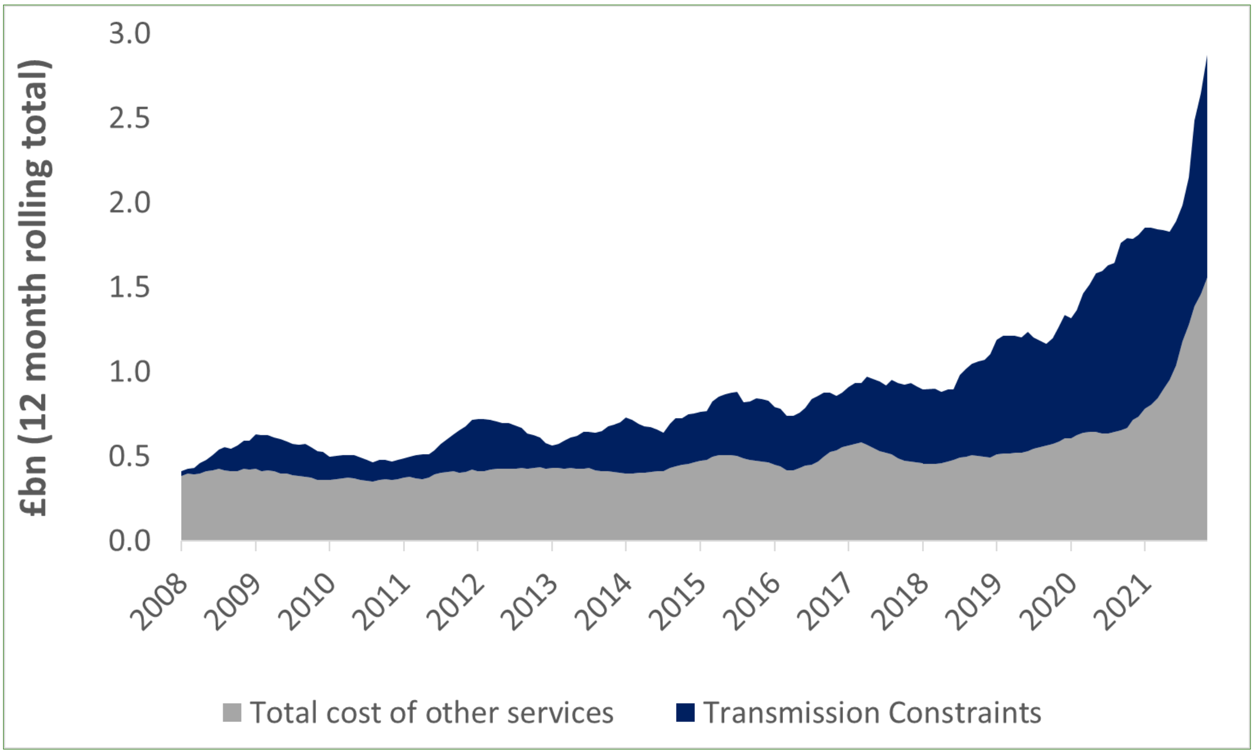
This simplified system no longer makes sense for a changing and more dispersed mix of generation. The result is a growing tension between the wholesale market and physical reality.

This tension must be resolved by National Grid through its role as Electricity System Operator (NGESO). The system operator was originally envisaged to be a small residual role, but now NGESO has to correct the market through balancing actions. These out of market balancing actions (or 'redispatch') regularly exceed 50% of national demand, and their cost is growing rapidly.

The growing role of the system operator in balancing the wholesale market (source: NGESO)



The growing cost of system operator balancing actions (source NGESO)



Without reform the balancing role of the system operator is likely to continue growing, undermining the rationale altogether for wholesale market trading.

There are also a variety of other symptoms of a wholesale market that no longer makes sense. The box below outlines some of these.

Box: Current wholesale market design: signs of strain

- **Constraint payments for foregone renewables subsidies are growing**

  One example of NGESO 'redispatch' is the growing frequency of constraining wind farms behind congested links. In these cases, NGESO constraint payments must include compensation to wind generators for subsidies they have foregone.

- **Perverse incentives for storage and interconnector behaviour**

  NGESO points out in its recent Net Zero Market Reform report that the single national price can create incentives for some flexible assets that actually *worsen* grid constraints. The single national price can encourage interconnectors or batteries to export output behind grid constraints, behaviour that is opposite to that required from a system perspective.

- **Transmission investment is proving costly and difficult:**

  Projections suggest the need for major transmission upgrades – not surprising given the growth in clean electricity required. But transmission improvements remain expensive and challenging to deliver, and delays result in costs. Recent major delays in delivering the Western Link subsea cable project are testament to that. While major new transmission investment is undoubtedly required, the current market does not help to manage demand or alleviate costs ahead of investment completion.

- **Plans for new renewables will impose more strain on the network:**

  25GW of potential new offshore wind emerged through the recent Scotwind leasing round, implying £billions of new transmission lines to connect to demand, mostly located south of border. Under current market arrangements project developers focus on maximising generation resource, taking much less account of the cost of transporting output to market. This means that the pipeline of new renewables projects will impose more future strain on the system and be less likely to deliver a least cost solution.

- **Flexible demand and storage are not keeping pace:**

  Investment in unlocking flexibility in demand and storage is not keeping pace with renewables investment (backed by Contracts for difference). The government has published a 'smart systems and flexibility plan' but, without stronger market signals at both transmission and distribution level, progress is unlikely to keep pace with what is needed. Meanwhile evidence from US markets points to greater motivation to invest in and deploy storage assets.

- **Network pricing signals are complex and too weak:**

  Current market arrangements rely on administered charges for using transmission networks to incentivise efficient location of capacity. Electricity buyers in the south pay higher transmission charges, reflecting the cost of importing electricity from areas where generation is more abundant.

  Network charging methods have proved hugely time-consuming and complex to reform since Ofgem's creation. Despite multiple methodology revisions network charges do not provide operational signals and locational signals for investment are weak (sometimes perverse for storage assets).

2.2. OPTIONS FOR REFORMING WHOLESALE MARKETS

Many other jurisdictions around the world have adopted wholesale market designs that more closely reflect the physical reality of their transmission systems.

These provide strong evidence of how it is possible to operate with alternative market designs – and to resolve implementation challenges.

There are two main options for reform to introduce better locational prices (at transmission level):

- Splitting the market into a number of bidding zones (zonal markets)
- Forming wholesale prices at multiple locations or 'nodes' across the grid (nodal or local pricing or the more technical term 'locational marginal pricing')

Options to reform locational price signals at transmission level

Zonal markets	**Nodal pricing** **('local pricing' or 'locational marginal pricing')**
System divided into zones reflecting key constraints in transmission networks. Each zone clears with its own price, reflecting zonal supply and demand conditions.	System is divided into a larger number of nodes, each with its own individual price. Market prices reflect the marginal costs of consumption at each node.
Pros	
Locational signals to investors and market players (both supply and demand sides) stronger than current GB market design.	Market prices reflect the physics of the transmission grid and balance between supply and demand. This provides accurate and efficient signals for operation and location of generation, storage and demand side actions.
Cons	
A system operator must still intervene to resolve constraints within zones. Zonal boundaries are awkward to adjust as the system evolves, due to potential risk and uncertainty for market players and investors. Zone boundaries may become outdated.	Potential costs arising from disruption and transition to a new regime. Concerns often centre on potential impact on price risk and liquidity, which could affect investor sentiment.
Examples	
Australia, Italy, Denmark, Sweden, Norway	Most of USA; Canada, New Zealand.

3. ESTIMATING THE BENEFITS OF REFORM

Reforming markets so that price signals better reflect physical reality has an intuitive appeal, given the scale and complexity of the investment required for net zero. But how big is the potential prize in terms of what energy users will be asked to pay?

Modelling what the system would look like – and cost - under different market designs can give a sense of:

- the nature of potential benefits,
- how benefits could arise and
- how much they could be worth.

3.1. MODELLING RESULTS

A study for Octopus Energy suggests that organising markets to better reflect the locational value of electricity could realise cost savings for electricity users of **£30bn to 2035**.

At circa £3bn, size of the estimated annual savings is very material. By way of comparison, it is greater than the total annual cost of system balancing actions under current market arrangements[2].

Summary of Modelling Results

(further details of the modelling approach used are set out in Annex 2)

Benefits for Electricity Users	• Total **savings for electricity users worth £30bn** (NPV to 2035).
	  ◦ Equivalent to over £1000 per household
	  ◦ Savings would also benefit businesses and industrial energy users.

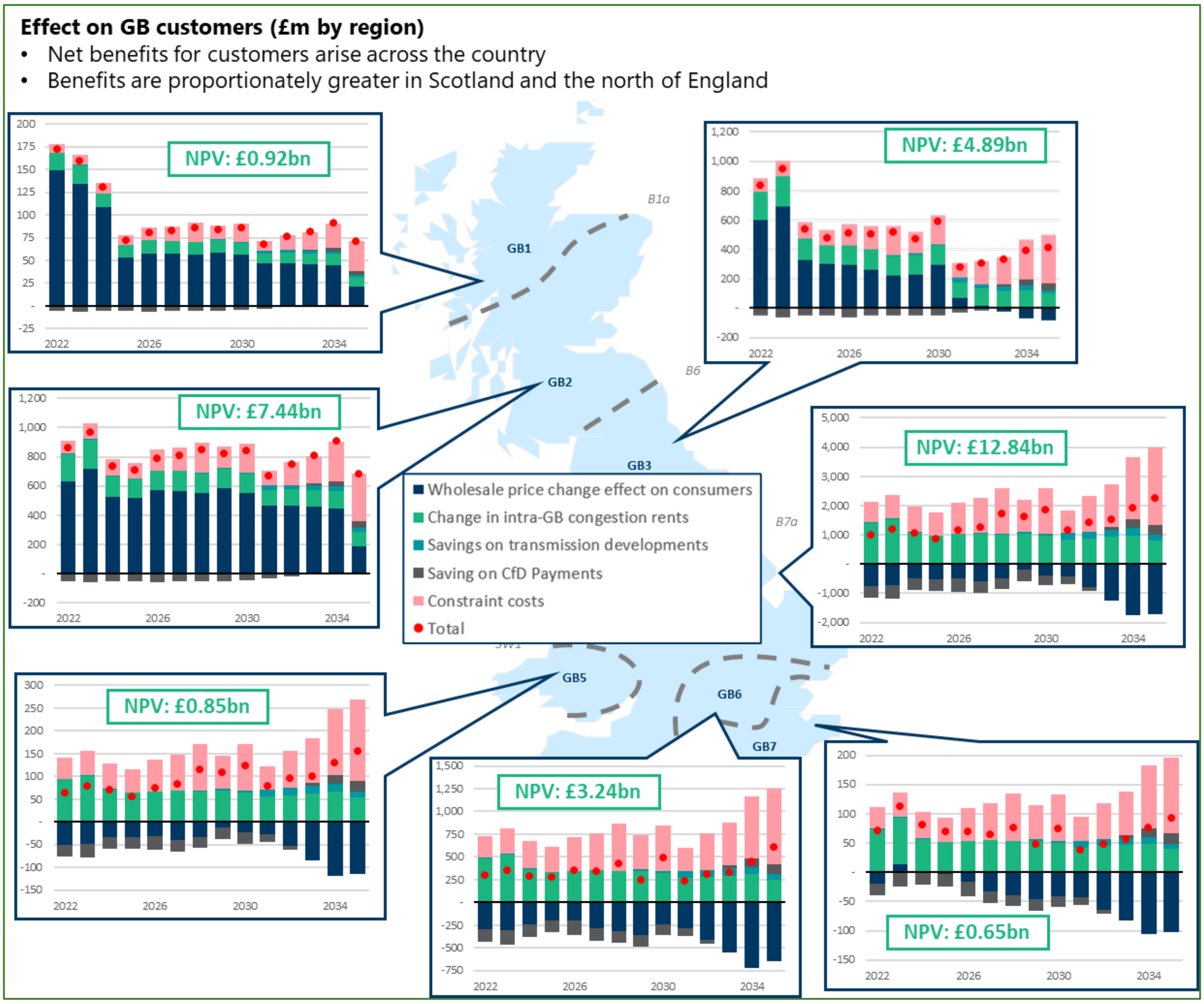
Regional impacts	• **Consumers across the country benefit, with biggest gains in Scotland and the north** • Industrial and commercial customers would benefit also from lower energy costs (particularly in north and Scotland in line with levelling up objectives).

Impacts on the system	• Annual **reduction in system costs of circa £3bn per annum** in the period to 2035, compared with status quo arrangements.
	• Savings beyond 2035 not estimated – but benefits could be expected into the 2040s as the system expands to meet transport and heat demand.
	• The savings reflect:
	  ◦ more efficient location and despatch of generation and storage across the system (and therefore lower balancing costs / constraint payments)
	  ◦ more efficient use of network infrastructure, including interconnectors to European markets

Impacts on the generation mix	• Locational pricing incentivises **a more efficient generation mix** with:
	  ◦ more investment in storage technologies to complement renewables,
	  ◦ earlier investment in CCS plants in England and
	  ◦ major expansion of offshore wind is still required but located (on average) closer to demand in England.

[2] See Elexon's recent analysis of system balancing costs: https://www.elexon.co.uk/article/bsc-insight-increasing-costs-for-balancing-the-gb-system/

Initial modelling results point to benefits spread across the country from improving locational pricing



3.2. OTHER POTENTIAL BENEFITS

The modelling approach used to estimate benefits is conservative in some respects:

- Improved locational price signals were modelled at a relatively low resolution (7 zones) – much higher resolution could be achieved in practice, potentially delivering greater benefits than those modelled.
- The modelling does not quantify 'dynamic efficiency' benefits that may arise from sharper incentives for innovation in technology, project design or operation arising from more accurate price signals.
- The modelling adopts conservative assumptions about the potential availability and future development of demand side flexibility/response.
- Improved market signals at distribution level may also make it possible to address constraints at lower voltage levels more efficiently. These benefits are likely to grow in importance with greater uptake of low carbon technologies like heat pumps. The modelling only estimates benefits realised at transmission level, but further benefits may also be realisable by improving market signals at distribution level.

In short, the estimated benefits do not take account of innovations by numerous companies active in this space (many supported by ESC) that could reasonably be expected to arise as market players respond to more accurate price signals.

More broadly the changes resulting from more accurate wholesale markets, would:

- help to address risks around the future operability of the system[3]
- enable the UK to transition to net zero efficiently with wider benefits for UK economic competitiveness, bearing in mind that we spend around 6% of GDP on energy and
- position the UK on the leading edge of clean energy innovation[4].

[3] The operability challenges associated with a net zero energy system are discussed in ESC's report "A Zero Carbon Energy System: The Operability Challenge" https://es.catapult.org.uk/report/zero-carbon-energy-system-the-operability-challenge/

[4] For further details on the potential benefits of innovation-friendly market reform see ESC's report "Rethinking Electricity Markets EMR2.0: a new phase of innovation–friendly and consumer–focused electricity market design reform" https://es.catapult.org.uk/report/rethinking-electricity-markets-the-case-for-emr-2/

ANNEX 1: WHY WHOLESALE ELECTRICITY MARKETS ARE IMPORTANT

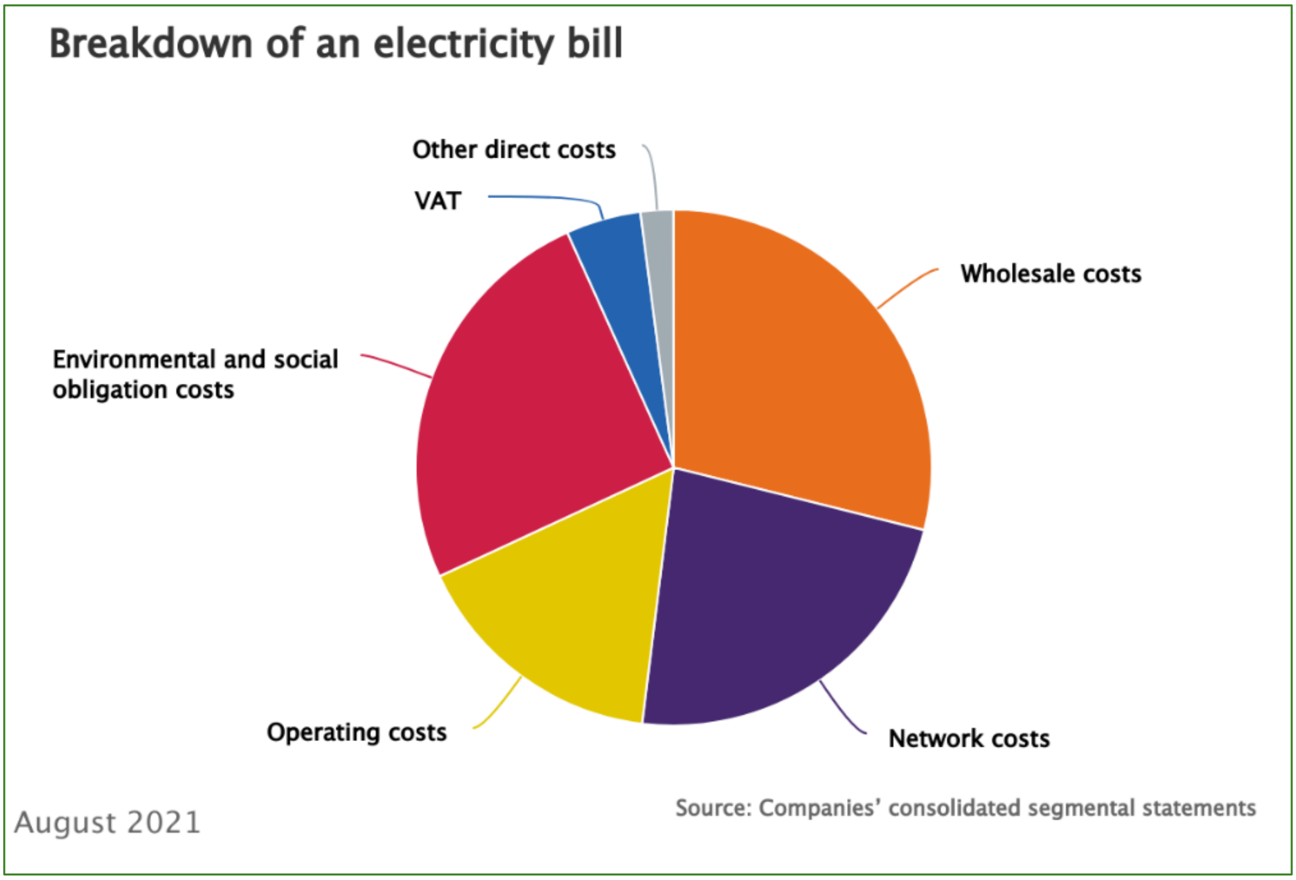
This annex sets out some basic reminders on why wholesale electricity markets are key in determining the overall cost of electricity to users.

Wholesale markets and the costs that users pay

Most of the cost stack that ends up in a retail bill is shaped by how well wholesale markets function.

- Wholesale markets clearly determine wholesale costs – which constitute the biggest (and in recent months the most rapidly growing) single element in an average electricity bill.
- Network costs: price signals from wholesale markets determine where investors will locate new generation plant. This in turn determines the cost of the network. Better locational price signals from wholesale markets will help to minimise expensive investment in networks.
- Environmental and social obligation costs: a major portion of these costs is to support low carbon generation. Well-functioning wholesale markets can also play a key role in minimising the cost of decarbonising the system.

Typical breakdown of household electricity bill (source: Ofgem based on 2020 data)



Markets to shape the mix of investment

The cost and efficiency of the clean energy future depends crucially on getting the right mix of investment and locating it in the right places across the country. Otherwise we risk building a more expensive and less reliable grid that imposes bigger bills on households and makes our economy less competitive in a net zero future.

Well-functioning wholesale electricity markets have a crucial role to play. Market signals need to reflect the physical reality of a more dynamic emerging system. In future the system will need to integrate and harness renewables and storage, and incentivise millions of new EVs, heat pumps and controllable devices to shift demand out of peak periods and reduce the need for costly network reinforcement.

Investors, project developers and innovators respond to market signals, designing technologies and projects to capture revenue. These revenue opportunities should reward projects and innovations that help the system to serve its users better. This should mean better rewards for generation that can locate close to a demand need, or for a battery that can operate to match variable generation with demand.

The UK was a global leader in liberalising electricity markets thirty years ago, but our wholesale electricity market has now fallen behind global best practice. Some key features of our wholesale markets remain largely unchanged since privatisation: a single wholesale price across the GB, which is reset half hourly according to bids submitted by generators.

This simplifies the physics of the real electricity grid. Other jurisdictions in North America, New Zealand and Europe have adapted their markets to more accurately reflect the dynamics and balance of supply and demand across their grids.

The Electricity Market Reform programme introduced a decade ago by the coalition government was actually a misnomer. The new policies it introduced to drive low carbon investment and secure energy supply left the underlying design of wholesale electricity markets in GB largely untouched (see text box).

Although 'new electricity trading arrangements' were introduced in 2001 (and a GB-wide market created in 2005), some key features of the design have remained largely unchanged since privatisation:

- Electricity is traded or 'settled' in half hourly periods reflecting how the schedule of generation and demand varies through the day
- Buyers and sellers contract freely in forward markets and through power exchanges, but these operate on a whole GB basis and so are essentially blind to location
- One hour ahead of each trading period the system operator takes over responsibility for balancing the system, mainly by buying short term changes in generation or demand to ensure they are physically matched in real time across the system – this is required to keep the system stable
- The system operator effectively 'reworks' the outcome of wholesale markets to reconcile it with physical reality in real time.

The status quo arrangements are demonstrably leading to inefficient operational and investment decisions by market players as price signals do not reflect local conditions. Without reform these inefficiencies are likely to grow over time and require the System Operator to 'redispatch' the wholesale market more often to balance the system. Market players are responding to inaccurate price signals both in short term operational decisions and longer-term innovation or investment choices

ANNEX 2: MODELLING APPROACH TO ESTIMATE BENEFITS

Overview

To illustrate the impact of more granular locational price signals in the GB wholesale electricity market, FTI Consulting ("FTI") developed a model that split the current single GB price zone ('national market') into seven individual price zones ('zonal market'), following six major GB transmission network boundaries. These boundaries have been selected by FTI on the basis of publicly available historical data on transmission congestion as published by National Grid ESO. This approach aims to capture a significant proportion of congestion on the GB transmission network (while keeping the modelling tractable).[5]

FTI modelled the outcomes (including, wholesale electricity prices and network congestion) under the seven-zone model and compared them to the counterfactual single price model to estimate the impact of more granular locational price signals in the GB wholesale market.

This Annex sets out further details on FTI's methodology in terms of the input assumptions, power market modelling methodology and the quantification of consumer impacts.

Input assumptions

FTI's inputs have been based on public datasets and assumptions, including:

- **Generation capacity:** NG ESO's Future Energy Scenarios ("FES") 2021 data and the Platts power plant database. To inform the allocation of renewable capacity between zones FTI also used BEIS' Renewable Energy Planning Database and Crown Estate leasing rounds;
- **Demand:** NG ESO's FES 2021 data (for annual demand) and a combination for FES 2021 and ENTSO-E's demand pattern forecasts for region-specific demand curves;
- **Climate conditions for GB zones:** ENTSO-E's European Climate Database (PECD); and
- **Transmission capacity:** NG ESO projections (Network Options Assessment and Electricity Ten Year Statement [NOA/ETYS]), with some delays to the planned build-out.[6] FTI have also applied seasonal availability factors to the transmission network, based on historical data.

Power market modelling methodology

FTI have used a well-known and widely accepted power market model that runs on the Plexos® platform to forecast, on an hourly basis, wholesale electricity prices in GB (and wider Europe) both in the single-zone and in the seven-zone market.

This forecast reflected an optimised build-out of capacity from 2022 to 2035 (targeting, in line with the latest policy statements, a full decarbonisation of the power sector by 2035), and a least-cost dispatch of available resources. Both the total volume of generation capacity and its location vary between the single-zone and seven-zone models to reflect the re-optimisation of new generation siting in response to wholesale electricity price signals. In addition, in the seven-zone market, the model forecasts the electricity flows across zonal boundaries.

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[5] FTI did not seek to identify an optimal way to introduce locational signals (e.g. through optimal configuration of zones or through nodal pricing). The analysis was limited by publicly available information

[6] In the single zone scenario, transmission capacity between the GB zones is modelled as an unconstrained network to reflect how wholesale market operates in practice (i.e. 'blind' to the transmission network limits).

Consumer impact

To estimate the impact of more granular locational price signals from the wholesale electricity market, FTI have calculated five elements:

- **Wholesale market impact on consumers:** In zones where supply tends to exceed demand electricity, prices tend to fall relative to the national market, which in turn leads to reduced costs to consumers (and vice versa for zones where demand tends to exceed supply). FTI estimated the aggregate impact on consumers from this effect in each of the seven zones;
- **Intra-GB congestion rents:** In the zonal market, the wholesale price differentials between the zones create arbitrage revenue ('congestion rents') on transmission lines between zones. FTI have assumed that these rents are allocated to transmission owners and can be used to reduce network charges in consumer bills;
- **Constraint costs:** FTI estimated the reduction in constraint costs[7] using historical Balancing Mechanism data, together with a forecast of dispatch from the power market model, and assumed that these savings are passed on to consumers;
- **Savings in transmission investments:** FTI calculated the reduction in transmission network charges resulting from the assumed delay in network build-out relative to the NOA/ETYS projections (noting that these savings represent a very small share of the total benefits); and
- **Changes in Contract for Difference ("CfD") payments:** Lower wholesale prices would increase CfD payments from consumers to generators (for a given strike price) and vice versa. FTI calculated the impact on transfers between consumers and generators under the national and seven-zone markets, based on assumptions on grandfathered CfDs and future strike prices for renewables.

  The wholesale market impact was calculated for each zone separately, while the other effects have been calculated in aggregate for GB as a whole and split proportionally to annual demand between the zones.

[7] In the national market, market participants do not observe transmission constraints when participating in the wholesale market. As a result, resources need to be constrained on and off by NG ESO to balance the system, the costs of which are ultimately borne by consumers. A zonal market would resolve a significant proportion of constraints without such payments.

OUR MISSION

TO UNLEASH INNOVATION AND OPEN NEW MARKETS TO CAPTURE THE CLEAN GROWTH OPPORTUNITY.

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