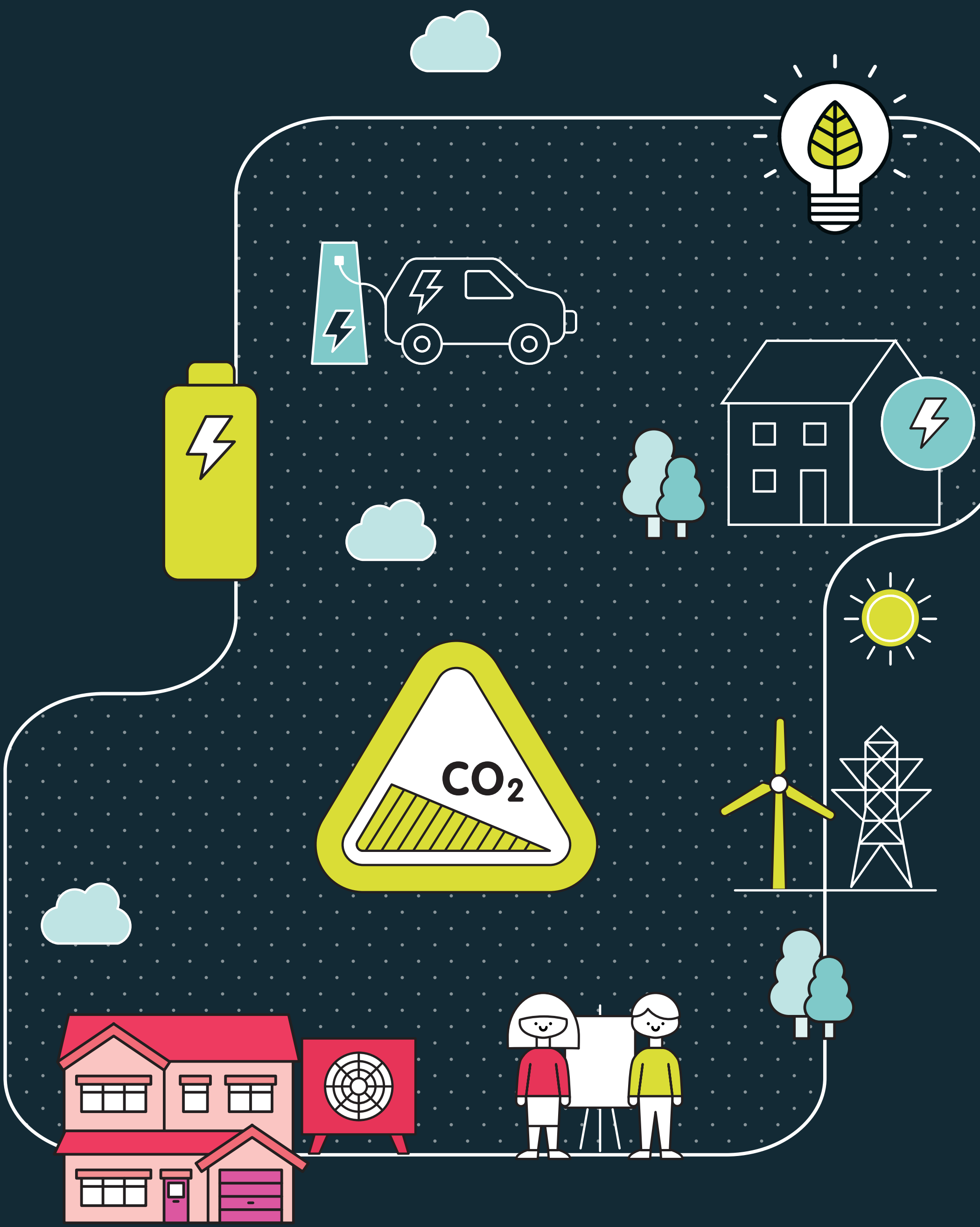

Towards a new framework for electricity markets

A report prepared for Energy Systems Catapult by Poyry

PREFACE

Discussion of electricity sector policy is often focused on design details of particular mechanisms (e.g. network charging, auction mechanisms, capacity markets). There has been less focus on how these detailed mechanisms fit together to signal value, or on the strategic choices around how to 'get prices right' across the system and the value chain.

Energy Systems Catapult's Rethinking Electricity Markets initiative aims to fill this gap by focusing attention on the options for reforming the current complex mix of market and policy arrangements so that they stimulate innovation and investment in a flexible and resilient mix of zero carbon electricity.

This means addressing issues such as policy fragmentation, integration of electricity into the wider energy system (heat/ transport), and interaction between regulatory and policy instruments. A key emerging theme is the need for more granular price signals in both time and space, to ensure that markets reward actors who deliver flexibility in locations where it is most valuable.

This report is a part of Energy Systems Catapult's Rethinking Electricity Markets initiative to develop proposals to **reform electricity markets so that they best enable innovative, efficient, whole energy system decarbonisation**. The work has been informed by a number of discussion sessions with stakeholders in the GB market.

EXECUTIVE SUMMARY

The report summarises key project findings to date and puts forward an initial approach for developing a future market framework that better reflects the true value to the system of different resource types.

Conceptual framework and GB mapping

We developed a simplified conceptual framework for classifying different value components that can be provided by resource connected to the electricity system. Those value sources are:

- Commodity (value of energy)
- Capacity (value of reliability or availability
- Capability (value of flexibility)
- Carbon (value of avoided carbon emissions)
- Congestion (value of easing network congestion or offsetting network investment)

There are clearly interactions and overlaps between some of the value components, which creates complexity for overall market arrangements seeking to provide coherent price signals across value sources. The basis for value across the five identified sources varies across several dimensions, including time, space and technological capability. A key emerging theme in GB context is the need for more granular price signals in both time and space, to ensure that markets reward actors who deliver flexibility in locations where it is most valuable.

Case studies

Applying the framework to a selection of other jurisdictions (Germany, Nord Pool, New York, and New Zealand), we found that key strategic choices for market design emerge in the areas of time-related price signalling, locational signals, low-carbon incentives, and degree of centralisation of coordination mechanisms and security of supply responsibility. Our main observations include:

- Electricity market designs are diverse and underpinned by different philosophy for market development.
- Nodal and zonal pricing approaches allow for better locational differentiation in pricing at wholesale level. They are likely to rely on financial tools to enable risk hedging for market participants.
- Nodal pricing tends to rely on centralised algorithms for decisions about dispatch and trade. This is at odds with current GB practices.
- There are inevitably trade-offs between nodal, zonal and national approaches. They cover areas such as efficiency of use of network and generation resources, market power, locational investment choices and price credibility.

Towards a potential future framework

Our preliminary assessment suggests the following key areas necessitate further attention to improve market signals in GB, while retaining decentralised trade as key coordination mechanism:

- enhancing value reflection through dynamic short-term pricing, enabling market-led innovation and risk management;
- creating options for locational differentiation within market operation and pricing, along with complementary hedging mechanisms;
- evaluating options for the decentralisation of the responsibility for delivering reliability and security of supply;
- evaluating options for a carbon intensity obligation to support carbon pricing.

We will investigate the aspects of this market framework further in next stage of the project.

The report is structured as follows:

- Section 1 sets the context for the work;
- Section 2 considers value sources conceptually before then considering value sources in GB and some aspects of international market designs;
- Section 3 sets out strategic choices for improving market signals and a potential framework;
- Section 4 considers types of changes that could be progressed to enhance the current arrangements;
- Annex A contains a working paper focused on value frameworks and the GB approach prepared for one of the discussion sessions held during the project; and
- Annex B contains another working paper focused on approaches taken in a selection of other markets prepared for another of the discussion sessions held during the project.

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1. WHY THINK ABOUT ELECTRICITY MARKET DESIGN NOW?

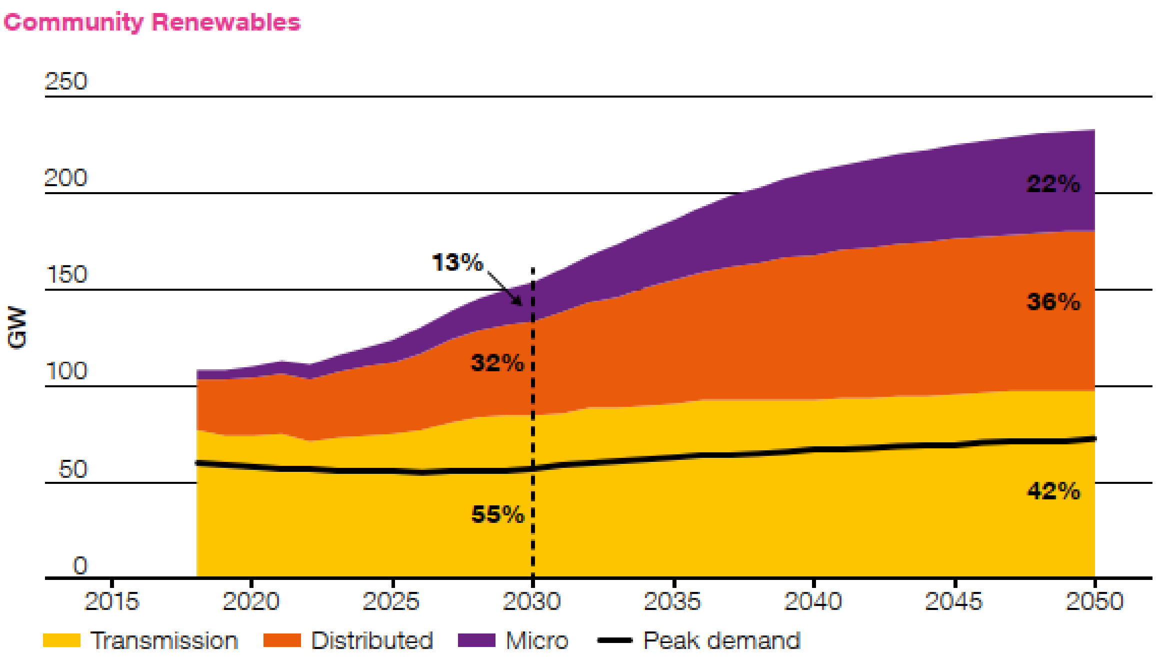
1.1 System evolution

Decarbonisation, decentralisation and digitalisation are driving a profound change in GB's electricity resource mix.

In 2019, renewables already account for over 30% of the capacity mix. Looking forwards to 2050, National Grid scenarios suggest that solar and wind capacity could grow by over 300% and storage capacity by over 700%[1].

This is being accompanied by growing resource decentralisation, with Figure 1 highlighting the anticipated increase in smaller scale distribution-connected or micro-scale (<1MW) projects. This highlights the potential for 45% of installed capacity to be at lower voltages by 2030 increasing to 58% by 2050, in comparison to 29% today. This emphasises the scale of the anticipated transformation linked to behind the meter resource, such as rooftop solar, and distribution-connected projects.

Figure 1 – Expectations of increasing decentralisation



Source: National Grid ESO 'Future Energy Scenarios', July 2019

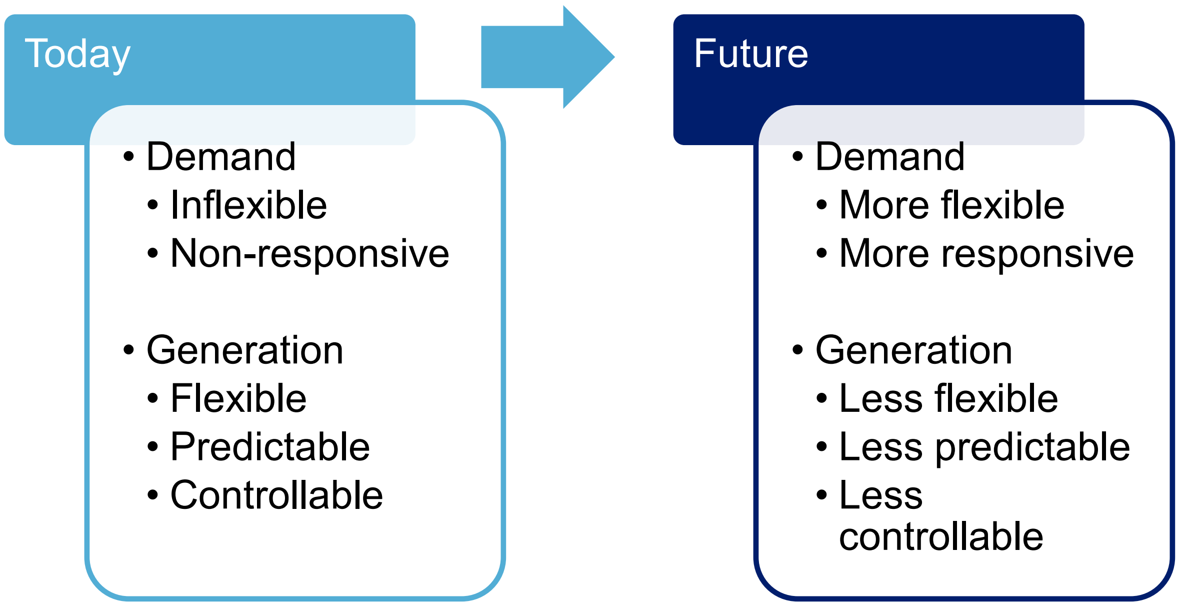
Rapid advances in IT and comms are, under the banner of digitalisation, complementing the above and helping to enable contributions from a wider range of sources. For example, aggregation business models are increasingly in evidence, using software platforms to combine disparate, small scale resources into a portfolio that can interact with and provide services to the market. These types of application are also altering the

1 FES 'Community Renewables' scenario.

demand side dynamics of the market, increasing the scope for demand side flexibility to be accessed and allowing for greater controllability of demand.

As a result, historic electricity supply and demand characteristics will not apply in future. As illustrated in Figure 2, the transition is expected to deliver greater demand flexibility and responsiveness and, from a supply side perspective, to result in a generation fleet with less flexibility, less predictability and less controllability. Future market design needs to reflect and take advantage of these changes.

Figure 2 – Supply and demand characteristics transformation



1.2 Business model development

The transformed resource mix and market characteristics present opportunities for development of different business models and service offerings that can utilise the new technologies, data access and control functionality. In particular, there is potential for a revamp of business models for retail activities and offerings to consumers, with service providers tailoring energy offerings (across electricity and heat) to their customers based on a deep understanding of their requirements in terms of desired levels of warmth and home comfort, including reliability. The offerings made by service providers may, therefore, be far more differentiated than retail offerings today, leveraging the power of digitalisation along with much greater data availability to, and detailed understanding of, consumer preferences by the service provider.[2]

In this context, service providers and consumers will be able to agree tailored service level agreements specifying service standards, including in relation to reliability requirements. Based on these agreements and its knowledge of its customer needs, a service provider will have freedom to determine how best to deliver the agreed performance metrics. A service provider can then secure the reliability it needs from upstream resources as well

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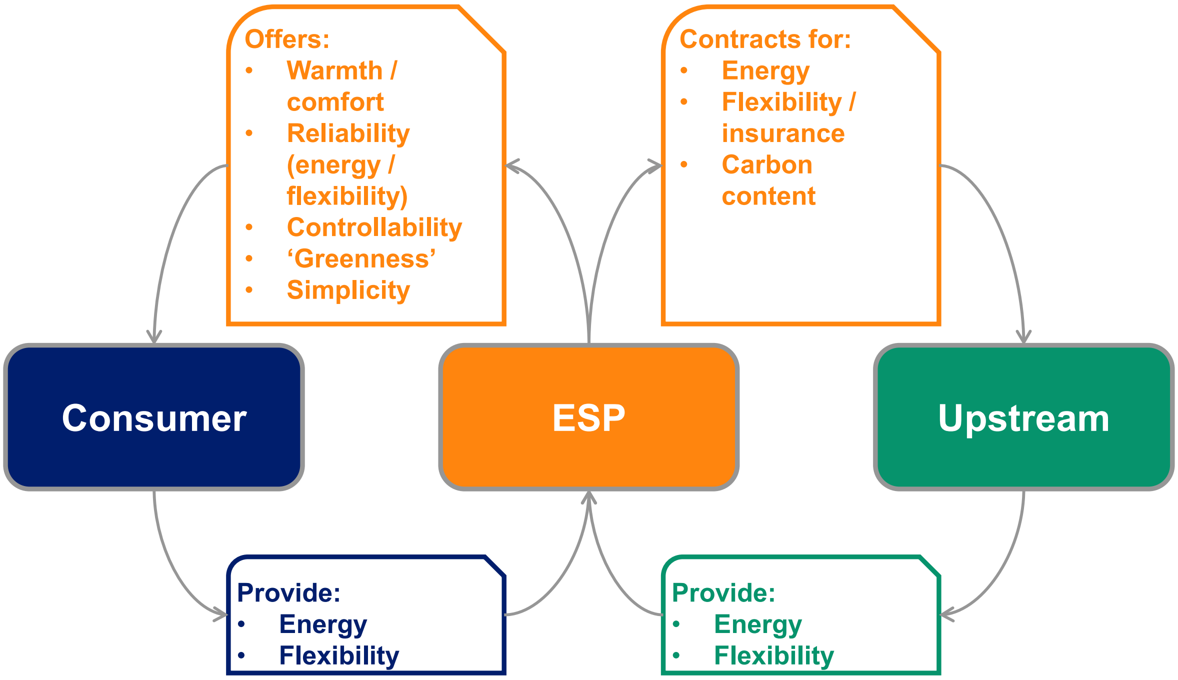
2 This type of service provider model is considered further in a separate piece of work prepared by Pöyry for ESC, which is summarised in a report entitled 'Broad Model for Capacity Remuneration in an ESP-Led Market' that is available on the ESC website.

as by harnessing flexibility within its own portfolio from, for example, flexible appliances, rooftop solar, heat storage and electric vehicles.

The service provider can, therefore, be the nexus between the consumers and the wider sector and vice versa, providing services to consumers from the market, as well as from its consumer base to the market. This is illustrated in Figure 3.

Figure 3 – Energy Service Provider interactions



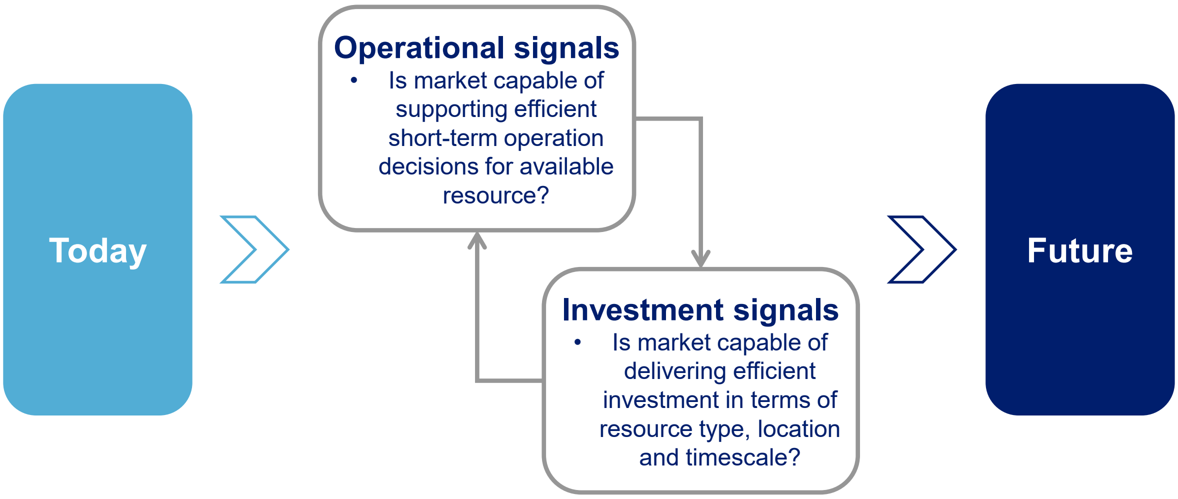
1.3 Importance of market signals

The evolution in the resource mix is changing the dynamics of the system in real time, with, for example, a growing need for flexibility to complement increasing intermittent renewables. Getting an appropriate response to short-term conditions relies on appropriate and visible near-term price signals. In turn, having the right resources available to respond to the short-term conditions relies on provision of signals to support investment decisions to deliver an appropriate resource mix.

The goal of efficient real time operation and investment relies on the market and supporting arrangements being capable of providing signals to drive operational and investment decisions in a manner that supports overall system efficiency. There is, therefore, a need for 'good' market signals that reflect the true value to the system of different resource types, with different characteristics. This cycle is illustrated in Figure 4. If there are shortcomings in short-term price signals, this cycle can breakdown.

This objective is not without challenges. Characteristics of resource types that can provide value to the system as a whole are multiple and varied. The current arrangements in GB cater for these characteristics through a variety of mechanisms and with differing levels of effectiveness.

Figure 4 – Signals needed for delivering and operating in envisaged future mix



2. WHAT DRIVES VALUE IN ELECTRICITY MARKETS?

2.1 Value stems from multiple sources

Investment decisions will be driven by the ability of the resource in question to realise value. The value that different resources connected to the electricity system can deliver to the market can be grouped into five main ‘sources of value’, as illustrated in Figure 5.

While stylised to some extent, these categories provide a straightforward and coherent breakdown of the sources of value that different types of resource can provide to the system and which resource providers can seek to capture in their business models.

If value from one or more of these sources is not realisable or if the market signals are inefficient, then the investment outcome may be ’wrong’, potentially increasing system cost and/or the risk of non-delivery against climate objectives.

Figure 5 – 5Cs framework for value

Commodity
- Value of MWh energy delivered to the system

Capacity
- Value of reliability or availabilty in support of security of supply

Capability
- Value of supporting system operability in operational timescales

Congestion
- Value of easing network congestion or offsetting network build

Carbon
- Value of avoided carbon emissions

The intended coverage of the five value sources introduced in Figure 5 is as follows, which is what we refer to as the ‘5C framework’:

- **Commodity**: this relates to the value of MWh of energy delivered to the system through, for example, generation or demand response and used by consumers. This is the value of energy for meeting consumption requirements.
- **Capacity**: this relates to the value of resource for supporting security of supply requirements. This can be focused on the value for availability or reliability, for example, recognising the contribution of such resource attributes to meeting defined security standards.
- **Capability**: this relates to the value of resource for supporting system operability. This can be focused on the value for flexibility, meaning the ability for resource to provide response in specific (often short) timescales to support real-time system

balancing (e.g. response/reserve products) and system stability (e.g. voltage support products).

- **Congestion**: this relates to the value of resource that is able to alleviate network congestion issues in operational timescales or, with a longer term perspective, to offset or delay network investment.
- **Carbon**: this relates to the value of avoided carbon emissions, which is typically manifested through carbon pricing or taxation and low carbon support mechanisms.

The five categories highlight the diversity of value sources that exist within the electricity sector and the multiple dimensions that need to be reflected or considered in efforts to create appropriate market signals. It also hints at the complexity of market design in seeking to ensure that price signals reflect the different sources of system value and to enable resource providers to capture that value.

2.2 Dimensions influencing system value

Three key dimensions influence the ability of resources connected to the system to deliver system value. These dimensions are as follows and are illustrated in Figure 6:

- **Temporal**: is the ability of resource to deliver sources of value driven by temporal factors (e.g. is value linked to responsiveness in operational timescales or is it linked to longer-term dynamics)?

  Increased variability of generation sources and responsiveness of demand is expected to increase volatility of prices in real-time depending on the prevailing situation.

- **Spatial**: does the location of a resource influence its ability to provide different value sources?

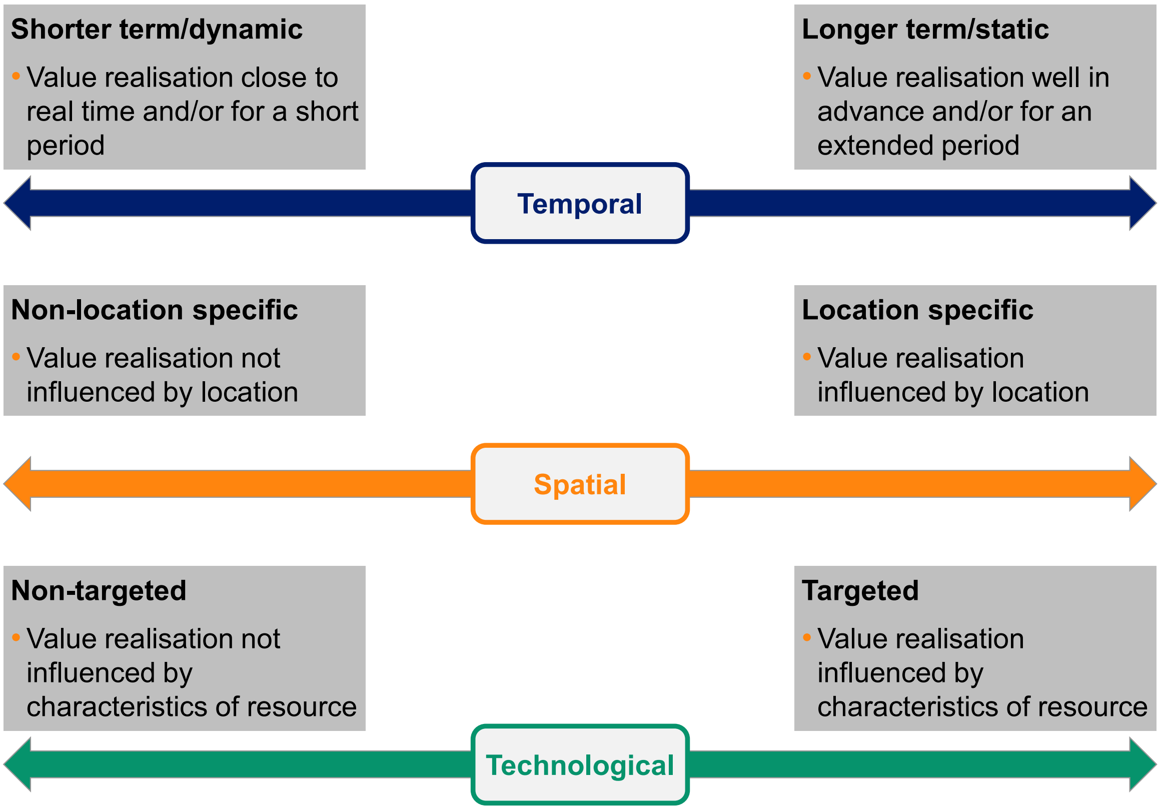
  Increased decentralisation of resource and greater electrification of heat and transport in demand are each expected to make location more important going forward.

- **Technological**: relevance of resource characteristics for ability to deliver against sources of value – is value targeted to particular characteristics or not?

  Different technologies will continue to target different bundles of value depending on their characteristics.

The reason for considering these dimensions is to allow for more in-depth characterisation and appraisal of the factors that drive value creation and influence value realisation by different providers.

Figure 6 – Dimensions influencing value



2.3 Current situation in GB[3]

In GB, the revenue streams that a connected resource can capture stem from a range of sources reflecting different market arrangements/instruments, for example, imbalance pricing, the Balancing Mechanism, the capacity market, balancing services, network charging and low carbon support schemes. Price signals vary in terms of temporal and spatial dimensions. For example, wholesale electricity prices are dynamic, reflecting short-term supply/demand fundamentals, while capacity market signals are more static. The majority of signals are uniform nationally, with location specificity only featuring in aspects of network charging and for some balancing services (e.g. black start contracts are needed in a spread of locations across the system and voltage support is location specific).

Additionally, access to some value streams is dependent on the underlying technological characteristics of potential providers. Most obviously, carbon-related value is focused on low carbon technologies, but there are also elements of technology specificity to some balancing services and the capacity market. Figure 7 provides a summary overview of the nature of signals provided by current GB market arrangements against the '5C' sources of system value.

3 Further information relating to the GB mapping is provided in Annex A, which reproduces the roundtable discussion paper prepared in relation to this topic.

Figure 7 – Value sources and nature of signals in GB

1 – Near term prices drive forward prices
2 – Locational loss factors at tx and dx
3 – De-ratings do differentiate, eligibility exemptions
4 – May need specific characteristics

		Temporal	Spatial	Technology
Commodity	• Wholesale electricity market price (forward, day-ahead, within-day, Balancing Mechanism, imbalance)	Dynamic*1	Non-location specific*2	Non-technology specific
Capacity	• Capacity market clearing price	Static	Non-location specific	Technology specific*3
Capability	• Balancing services contracts, Balancing Mechanism	Varying	Varying	Technology specific
Congestion	• Balancing Mechanism, network charges (e.g. Triad avoidance, super red charges)	Varying	Location specific	Varying*4
Carbon	• Carbon element of wholesale price, ROC value, CfD FIT difference payments	CO_2 pricing -> dynamic Support -> static	Non-location specific	Technology specific

Taking the summary overview from Figure 7, the messages for the different value components are as follows:

- **Commodity:** Prices are variable depending on prevailing or anticipated conditions creating dynamic signals. Adoption of marginal imbalance pricing (including reserve scarcity pricing and cost of disconnections) helps to reflect system tightness in near-term prices, which should then filter along the forward curve.

  While locationally varying loss factors do create some locational dimension to energy pricing, the effect is relatively minor and commodity pricing can largely be considered to be national and non-geographic specific.

  All technologies are exposed to the same wholesale price. But there are variations by technology in terms of value capture potential[4] and balancing risk exposure.

- **Capacity:** Signals from the capacity market are relatively static in nature. Capacity auction clearing prices vary from auction to auction. But, once set, the clearing price holds for the duration of all capacity agreements entered into following the associated capacity auction. In the majority of cases, this means that the capacity price holds for one year but for new capacity the capacity price can hold for up to 15 years. In addition, prices are known up to 4 years ahead for the main auction and one year

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4 For example, resources typically operating in and around periods of tighter system margin higher demand periods will have a higher capture price than resources that are less able to operate in these types of period. Renewables typically have a capture price that is lower than the baseload price.

ahead for the T-1 auction. Therefore, price signals are considered relatively static and long-term in nature.

The GB capacity auction does not differentiate by location of resource, with the clearing process conducted on a market-wide basis. Bidding behaviour into the auction may, however, be influenced by locational factors that exist elsewhere in the wider market arrangements, such as locationally varying network charges.

The capacity market is billed as being technology neutral across generation, storage, demand side providers and interconnectors. However, technology differentiation is introduced through eligibility restrictions, capacity agreement duration availability and capacity de-ratings.

- **Capability:** Temporally, signals linked to the balancing services are mixed. Tenders range from month-ahead provision to multi-month arrangements, with a provider's prices fixed for whatever the contracting period. However, the direction of travel is towards closer to real-time procurement with shorter commitment periods, so this picture is changing.

  The importance of location depends upon the nature of the service. Response and reserve services are non-location specific and so no locational signal is provided. However, location is important for reactive power services and, hence, this feeds into the signals relating to this particular service.

  Given requirements for particular operating characteristics, there is technology specificity inherent within the signals for the capability component.

- **Carbon:** In terms of the temporal dimension, the picture is slightly mixed. Driven by variations on the EU ETS allowance prices, carbon pricing is dynamic and varies in response to the fundamentals of the allowance market. The support schemes are intended to support revenue certainty for investors and so are purposefully relatively static in nature. The difference payment under a CfD FiT will vary, but this is just topping up to a defined strike price and so overall revenue is relatively stable. Similarly ROC prices do vary, but the nature of the buy-out price provides reasonable certainty as to likely value. Nevertheless, once accreditation was received under the RO or a CfD FiT has been entered into, support is known to be available to 20 years and 15 years (in case of intermittent technologies) respectively. These signals are longer-term as they are intended to support investment decisions.

  The signals relating to carbon value are all non-location specific, placing no importance on the geography of the resource for realising value.

  As is to be expected, carbon value is available to zero and lower carbon emitting resource types.

- **Congestion:** With multiple mechanisms in play, the situation regarding congestion related signals is complex. Temporally, a number of the mechanisms are dynamic, with super red, red, amber and green credits[5] having a time of use dimension and

5 The distribution charging methodologies include credits for generators, paid for units of electricity exported onto the distribution system. These credits are tiered, set based on expectations of demand on the network at different times.

bids/offers for constraint resolution capable of regular update.

Location is an important feature of signals and value potential. For example, transmission charges vary by zone, red, amber and green credits vary between distribution regions and super red credits are site specific.

Ability to extract value from the various mechanisms tends to be greater for dispatchable resource, with smaller scale embedded or behind-the-meter resource particularly able to target a number of the available value sources.

From the above, it is clear that the current framework for providing signals is highly complex, shaped by a plethora of policy and regulatory mechanisms. The nature of signals provided by the mechanisms is varied and they operate in a meshed framework given many and varied interactions between the value components, both in terms of impact on one another and their collective influence on the business case for different resources.

In combination, the signals can create incentives for actions by individual actors which are entirely rational for the party in question, but potentially counterproductive from a system wide perspective. For example:

- embedded benefits created by features of network charging arrangements have supported business cases for an upsurge in engine arrays, which have carbon emission implications;
- socialisation of constraint costs reduces incentives for siting decisions to fully reflect costs of network congestion, which may exacerbate congestion and increase associated system balancing costs;
- output based renewables support schemes create incentives for negative bidding to compensate for lost support revenue in the event of potential turndown, with potential for distortionary effects on wholesale price formation; and
- interconnectors are not currently exposed to certain network charges and are not allocated a share of system losses beyond losses on the cable from transfer between electricity markets. Discrepancies between costs faced by generators may give a signal on which market to locate despite the potential increase in total system costs.

The current situation raises the question of whether the framework can be modified to improve the set of market signals provided by the arrangements in the context of expectations regarding future system evolution.

2.4 Approaches taken elsewhere[6]

Given this question, it is instructive to see if lessons can be learned from elsewhere. Looking to other jurisdictions, different market design frameworks have been adopted and there are resultant variations in the nature of signals created under these arrangements. The examples considered here are the arrangements in Germany, Nord Pool, New York and New Zealand. These markets were selected as they present, in particular, a range of approaches when it comes to the locational granularity of pricing and the extent to which

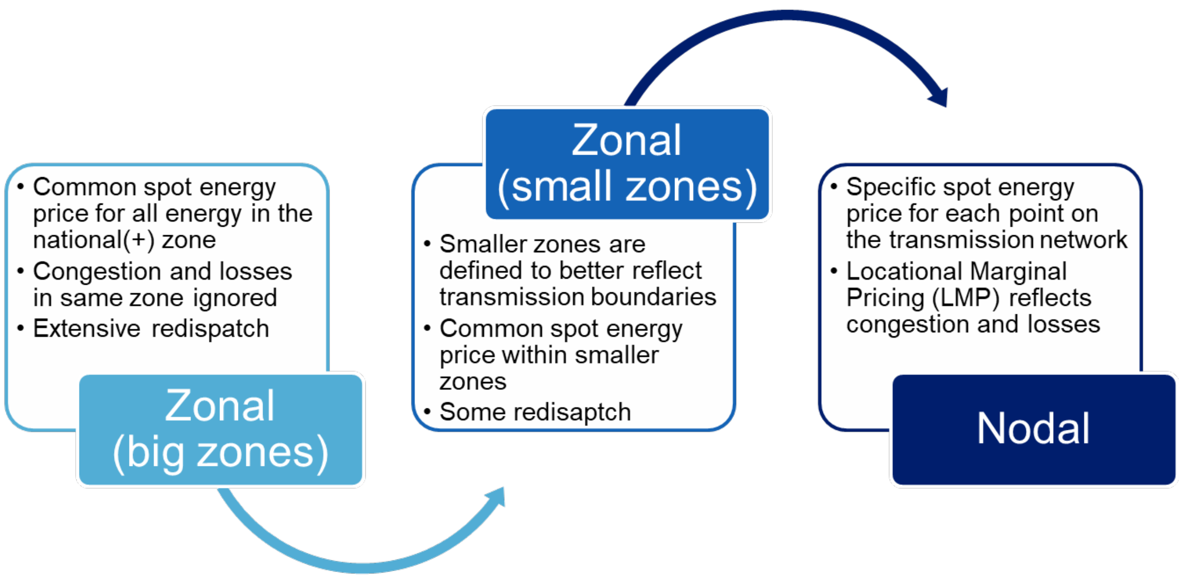
[6] Further information relating to the case study markets is provided in Annex B, which reproduces the roundtable discussion paper prepared in relation to this topic.

congestion is reflected within pricing. Summary market design building blocks for these case studies are provided in Table 1. Additionally, Figure 8 summarises the key differences between variations in wholesale pricing structure concepts with different approaches to locational granularity of pricing.

Table 1 – High level market design building blocks for case study markets

Feature	Germany	Nord Pool	New York	New Zealand
Energy pricing	National	Zonal	Nodal for generators, zonal for consumption	Nodal
Basis for trade	Bilateral	Bilateral	Centralised (predominantly)	Centralised
Basis for dispatch	Self-dispatch	Self-dispatch	Central dispatch	Central dispatch
Congestion management	TSO re-dispatch	TSO re-dispatch	Central dispatch	Central dispatch
Security of supply	Energy-only (albeit multiple reserve mechanisms)	Mixture	Capacity obligation	Energy-only market

Figure 8 – Key differences between locational granularity of pricing structures



2.4.1 Germany has national energy pricing

Like GB, Germany is example of a market with uniform national wholesale pricing arrangements. However, transmission bottlenecks are a significant issue in Germany that need to be managed by TSOs through re-dispatch, with an annual cost of around €350m in 2018. There is no locational element in either energy pricing or network charging, which is a likely contributor to the congestion problem. Multiple mechanisms (Grid

Reserve, Capacity Reserve) sit around the energy-only arrangements to support the market and their existence has some linkage to the challenges of managing transmission constraints with national energy pricing[7].

2.4.2 Nord Pool has zonal pricing with locational hedging tools

The Nord Pool arrangements provide an example of zonal pricing arrangements. Norway, Sweden and Denmark[8] are composed of multiple price zones that reflect structural bottlenecks on the system, with these sub-national bidding zones defined to reflect grid bottlenecks. If the transmission capacity between bidding areas is not sufficient to reach full price convergence across the areas, congestion will lead to bidding areas having different prices with the difference based on the cost of congestion. Hedging tools[9], in the form of a contract for difference between a specific area price and the unconstrained, system price[10], are available to allow parties to manage price risk caused by constraints in the transmission grid.

2.4.3 Forms of nodal pricing within centralised market arrangements operate in New York and New Zealand

New York and New Zealand, both of which operate around a centralised physical wholesale energy market, have nodal wholesale pricing arrangements with the spot energy price reflecting the cost of energy, congestion and losses at each node.

The wholesale trading arrangements in New York are based around centralised physical trading at the day-ahead stage and in real-time, which co-optimises for energy and operating reserve requirements, with financial trading options existing around these marketplaces. For generators, prices are determined at a nodal granularity, with a Locational Based Marginal Price (LBMP) determined at each relevant connection point. For consumption, prices are set zonally for 11 zones, based on a load weighted average of the nodal LBMPs in the zone. Persistent and significant grid bottlenecks make location important in New York, creating a strong driver for nodal pricing in the energy market in order to seek to appropriately reflect congestion costs in the wholesale prices. But bottlenecks remain an issue. Transmission congestion contracts (TCCs) are financial instruments that can be used to hedge against day-ahead transmission congestion costs.

In New Zealand, the system operator, Transpower, operates the spot market as a mandatory energy-pool and dispatch is determined via co-optimisation of energy and reserve requirements based on complex bids/offers from generators, customers and reserve providers. It has wholesale prices at half-hourly and nodal granularity (currently

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7 The Grid Reserve is an aggregation of system relevant power plant that would otherwise not be available (planned decommissioning or plant that has already been temporarily decommissioned) to ensure the stability of the electricity system, especially for the management of transmission system bottlenecks, for voltage stability and the systems black-start capability. The Capacity Reserve is an additional mechanism intended to support the system in the event that a shortage of supply.

8 An individual bidding zone exists for each of Finland, Estonia, Lithuania and Latvia (i.e. zones for these jurisdictions are mapped to political borders).

9 Electricity Price Area Differentials (EPADs).

10 The system price is calculated as a (hypothetical) reference price in which physical bottlenecks between the bidding areas are not taken into account. The system price is very often quoted in contracts and has the highest liquidity in forward trading on Nasdaq OMX Commodities.

for 244 nodes comprised of 196 grid exit points and 52 grid injection points). Due to the long shape of the country with north and south islands connected via an HVDC link, the New Zealand transmission grid structure provides limited alternate paths to flow from generation to demand which results in higher losses on transmission lines. However, there is a significant level of nodal price convergence in some areas. Financial Transmission Rights (FTRs) are available to hedge locational price risk caused by transmission losses and constraints.

2.4.4 Insights emerging from other markets

Observations from consideration of these other markets are as follows:

- **Market designs are diverse and there is no single answer:**

  There is significant diversity in electricity market design options across different jurisdictions. There is no single answer and different approaches have emerged given different backdrops to and philosophies for market development.

- **Within-market, locational price differentiation approaches exist:**

  There are alternatives to national pricing and reliance on system operator re-dispatch to manage congestion. Within-market congestion can be reflected in wholesale pricing arrangements through zonal or nodal pricing approaches. To differing extents, these approaches allow for locational differentiation in pricing and creation of location specific signals.

- **Hedging tools tend to accompany locational pricing:**

  Financial products, such as long-term future products or FTRs, are likely to be needed to enable the market participants to hedge price and congestion risk.

- **Nodal pricing tends to be accompanied by centralised dispatch and trading:**

  Co-optimisation of energy, reserve and congestion under nodal pricing tends to require centralised algorithms and coordination, as well as being accompanied by centralised dispatch and trading. These features are at odds with the philosophy of bilateral trading (including continuous trading intraday) and self-dispatch in GB.

- **There are inevitably trade-offs between nodal, zonal and national approaches:**

  The decision between models is not simple and a range of trade-offs exist. Table 2 lists a selection of opinions commonly raised in relation to different pricing approaches.

Table 2 – Commonly cited arguments relating to pricing approach

	National	Zonal	Nodal
Efficient use of existing grid	Moderate if re-dispatch process is effective	Moderate if re-dispatch process is effective and zone definition is sensible	Good if well implemented
Incentives for efficient resource dispatch	No incentives linked to location within zone	Mixed, depending on number of zones	Strong locational incentives but could constrain innovation in context of complex bidding
Re-dispatch volume (i.e. extent of TSO revision to market positions)	High if network expansion delayed	Lower than national	No re-dispatch
Risk of market power abuse on pricing	Lower risk because of broad price setting geography	In between	High because of local scarcity potential
Market power abuse on re-dispatch[11]	Potentially high in absence of regulation	In between	Low due to central dispatch
Incentives for locationally efficient resource investment	None from energy prices	Moderate, effectiveness depends on credibility and stability of zonal price signals	Stronger, effectiveness depends on credibility and stability of local price signals
Credibility of prices as incentives for investment	High, linked to price stability across broad geography	In between	Reduced if local prices are difficult to predict/unstable

11 This relates to potential for the requirements for re-dispatch actions to be influenced by market participants and/or the available range of bids/offers for re-dispatch purposes to be limited in instances of market power.

3. WHAT ARE THE STRATEGIC CHOICES FOR ELECTRICITY MARKET DESIGN?

3.1 Strategic choices

The previous Sections have introduced conceptual sources of value, the different mechanisms for providing value in GB and alternative arrangements from a selection of other markets. Against this backdrop, the following Sections set out strategic choices that can be combined to create a potential framework for electricity market design with the aim of supporting delivery of and operating under a transformed energy system.

3.1.1 Focus on enhancing near-term price signals

Temporal dimension	
Long-term	Short-term

Over recent years, the wholesale energy market has been supplemented by additional instruments, such as renewables support schemes and the capacity market, to support investment in different types of technology in response to insufficient signals for investment (in the case of renewables support) or concerns regarding risk levels linked to market-led investment (in the case of the capacity market). This de-emphasises the role of the wholesale electricity market in providing signals for investment in a secure and decarbonised resource mix. Additional instruments can also impact on short-term price formation, potentially dampening price signals and creating a cycle of continued reliance on ongoing or additional interventions.

However, with greater variability in generation and potential for demand flexibility, the need for accurate short-term signals to allow for efficient short-term operation is expected to increase. Improving near-term price signals linked to actual market operation, could improve their ability to reflect value and in turn drive investment in an optimised mix of technologies, reducing the need for additional measures.

In support of this goal, the following initiatives can be progressed:

- make market operation more temporally granular and as close to real-time as possible; and
- ensure prices better reflect the value of scarcity.

A number of positive initiatives have already been progressed or are in motion, which are supportive of the above, including:

- **Sharpening imbalance incentives**: implementation in 2018 of single, marginal imbalance pricing now means that imbalance volumes are priced at the most expensive energy balancing action, thereby strengthening the financial incentives for market participants to balance their own positions.
- **Reflecting scarcity in pricing**: the reserve scarcity price function included within the imbalance pricing arrangements now means that reserve actions are priced to reflect prevailing system conditions, with the price rising as the system gets tighter.

- **Shorter-term reserve procurement and commitment**: National Grid is trialling weekly auctions for frequency response procurement and at the European level[12] there are initiatives for, in time, daily procurement of response and reserve products.
- **Shortening settlement periods**: linked to European initiatives, the adoption of 15 minute settlement periods, as opposed to the current 30 minute duration, must be assessed[13]. Reducing the duration of trading periods allows for better alignment between variable generation profiles and market operation.

These developments are all positive, allowing the markets to operate closer to real-time and to reflect short-term value.

These types of development will create volatility in the near-term markets, which necessitates complementary innovation in the development of trading and risk management tools that suit this environment. Market-led development of trading and risk management approaches may be stimulated by this increase in volatility. The market has shown previously that it is capable developing new products in response to signals[14]. Development of market-led hedging products that are suitable for the revised energy mix will allow for risks to be mitigated and so for investment to be progressed.

Focus: enhance value reflection through dynamic short-term pricing, along with market led innovation and risk management.

3.1.2 Locational dimension becoming more relevant

Spatial dimension	
National	Local

Currently, the key market segments in GB operate at the national level. This applies for the wholesale market, the capacity market, low carbon support and a good number of the balancing services. Locational variations are evident to some extent in a subset of balancing services (e.g. voltage support which varies by location and black start which needs coverage across different parts of the system) and in aspects of the network charging arrangements. However, the mainstays of the market are non-location specific.

This national, non-locational nature means that the market does not take account of network congestion. Consequently, transmission congestion issues need to be resolved

12 The Guideline on Electricity Balancing creates requirements for common platforms for procurement of different response/reserve products.

13 The Guideline on Electricity Balancing requires TSOs to implement a 15-minute settlement period by the end of 2020, unless exemption is secured. This requirement is further endorsed in the Clean Energy Package.

14 For example, EEX has introduced Wind Power Futures as a standardized exchange traded wind power derivative to enable the dedicated hedging of risk of wind power generation (https://www.eex.com/en/products/weather). This development was a direct response to the need for a hedging instrument to manage both volume and price risk in markets with greater quantities of variable generation and, as a result, more uncertainty in terms of running patterns and prices.

by the System Operator via re-dispatch actions to manage flows across the constrained parts of the network. The cost of these constraint management actions has increased over time from around £100m/year in 2006/07 to approaching £700m/year in 2018/19. This highlights the growing cost of congestion resolution and potentially indicates growing need for consideration of location specific dynamics in the market.

There are additional indications that the locational element is becoming more relevant for market operation, across the voltage levels. Firstly, there is greater decentralisation of resource mix in the electricity sector and its location has significance for market and system operation. Looking cross-vector, location is clearly also an important dimension for heat and transport related demand in the context of increased electrification. Secondly, alongside growing decentralisation in the resource mix, large scale and often geographically remote projects, such as offshore wind, continue to form an important part of the mix.

In combination, we are looking at a system with greater activity at the local level and on lower voltage parts of the system, combined with a transmission network with a larger geographic footprint, albeit with potentially lower overall utilisation than has historically been the case. These drivers interact to contribute to the potential for greater variability in size and direction of network flows, which may mean that the capabilities of the networks to accommodate flows will become more binding than has been the case historically.

The changing dynamics on the system suggest that location is set to become much more significant, strengthening the case for considering options for locational differentiation in the markets. As discussed above, various models of locationally differentiated market pricing are in operation in other markets, with variants of nodal pricing in place in New Zealand and New York and zonal pricing in operation in Nord Pool. The merits of nodal versus zonal pricing solutions for GB will need specific consideration. Similarly, a potential move away from national pricing to multiple price areas that reflect significant congestion boundaries could be considered (and including features such as the number and size of pricing zones and the coverage of zones across different voltage levels).

A more zonal approach presents different risks for market participants. Examples of these risks are presented below, alongside potential mitigating steps:

- **congestion cost exposure**: various forms of contract for difference can be employed to manage spatial risk linked to congestion across zones and price area risk. Electricity Price Area Differentials (EPADs) are a form of hedging employed in the Nordics, settled as the difference between price in a specific area and the unconstrained system-wide price; and
- **zone re-definition**: over time congestion boundaries may change as the system is reinforced, patterns of resource utilisation changes and resource retirals/additions occur. This should lead to updates to zone definition to reflect evolution in system congestion. As a consequence, resources may shift between zones over time. To help manage risk arising from this, there is a need for:
  - a clear, transparent methodology and process for reviewing and revising pricing zones (an established bidding area review process already exists for this purpose under the European Network Codes); and
  - hedging instruments to cater for pricing zone migration over time.

As part of this, consideration could be given to reduced reliance on network charging to provide locational signals. This is for a number of reasons. First, as things stand, there is no option to hedge exposure to future evolution of network charges and there is scope for increased variability in charges in future as the blend of resources on the system and their characteristics change. Second, charging statements are reasonably static, set generally on an annual basis, and so may not be best able to deal with more dynamic system conditions. Third, allowed revenue recovery is the primary objective for network charging and ability to offer incremental signals is influenced by this primary function.

Focus: options for locational differentiation within market operation and pricing, along with complementary hedging mechanisms.

3.1.3 Market co-ordination remains key

Market co-ordination	
Centralised	De-centralised

For approaching 20 years, the GB wholesale electricity market has been underpinned by a philosophy of bilateral trading between market participants and self-dispatch, with a residual balancing role for National Grid as the System Operator. More recently, centralised mechanisms such as the capacity market and low carbon support arrangements have been added as overlays.

The preceding Sections have suggested consideration of more locationally differentiated and dynamic short-term market operation and pricing. A number of other markets with greater locational and temporal granularity, such as New Zealand and New York, operate with greater centralisation in terms of trading and dispatch, involving a more algorithmic focused approach for operating the market. Greater reliance on central algorithms may, however, be restrictive for innovation and evolution of service offerings at a time when the system dynamics are changing, which could be counter-productive.

Alternatively, fostering de-centralised and market-led solutions as much as possible, rather than increasing roles for central bodies, could be preferable. The underlying hypothesis is that increasing the role for market players in delivering consumer requirements across the 5C sources of value will encourage innovation in service offerings and market-based trading opportunities. This should support reduction in the role of central coordination in delivering consumer requirements.

Focus: retain emphasis on market-led coordination as the underpinning philosophy.

3.1.4 Decentralisation of security of supply delivery

Security of supply	
Centralised	De-centralised

Building on the above theme of decentralised solutions, there is scope for this philosophy to increasingly be applied to security of supply considerations. As the resource mix shifts, with demand side flexibility becoming more accessible and cross vector consumer-centric business models developing, the need for centrally procured capacity will change.

The engaged service provider-led style model referred to previously is founded on the basis that the providers will be able to build detailed knowledge of consumer requirements including reliability, in the same way that Amazon or Google have built detailed knowledge of their customers. This knowledge and the ability to offer differentiated services to different customers will enable a service provider to form an accurate assessment of the level of resource needed to deliver required reliability in a way that a central body cannot. It will also allow the service provider to manage the resources within its portfolio in a range of ways to deliver required reliability across its customers.

This approach could be given a more formal footing by placing an obligation upon the service providers to secure the resource that it determines necessary to meet its customers' service requirements. Within this structure, the service provider has flexibility to choose the level and type of resource to secure to meet the reliability requirements of its consumers and with whom to contract to secure it (including the ability to internalise flexibility across its customer portfolio in the assessment of its requirements).

While service providers will take the prime role in delivering reliability, there may be a requirement for backstop measures to support the system in certain cases (e.g. if there are considered to be circumstances that it is not efficient for a service provider to plan and procure for). A residual system operation function, providing ability to access and, within appropriately tightly defined and transparent criteria, call on resource to maintain system operability in extreme conditions, could provide a safety measure. This provides some comfort that there is some back-up to normal market operations for extreme contingencies. The quantity of back-up required can be re-evaluated as information concerning the contingency emergency risks and wider mitigation measures evolve.

Of great importance in all of this is the provision of acceptable levels of service to consumers. Service providers will have the ability to offer differentiated service levels based on consumer preferences and also to use customers' resources as part of its approach to delivering overall reliability requirements. The latter can include measures that do not materially impact consumers, such as control of smart appliances, and measures that potentially do have a material impact, such as interruption or reduction of supply for particular periods. Given the latter, this type of decentralised approach is likely to need to be accompanied by minimum standards for service offerings in order to provide protection to consumers.

Focus: options for de-centralising responsibility for delivering reliability.[15]

3.1.5 Rationalise low carbon policies within an intensity target

Carbon policies	
Carbon pricing	Carbon intensity

Carbon remains an externality that needs to be addressed. The current suite of low carbon related policies is many and varied. Carbon prices emerging from the EU ETS

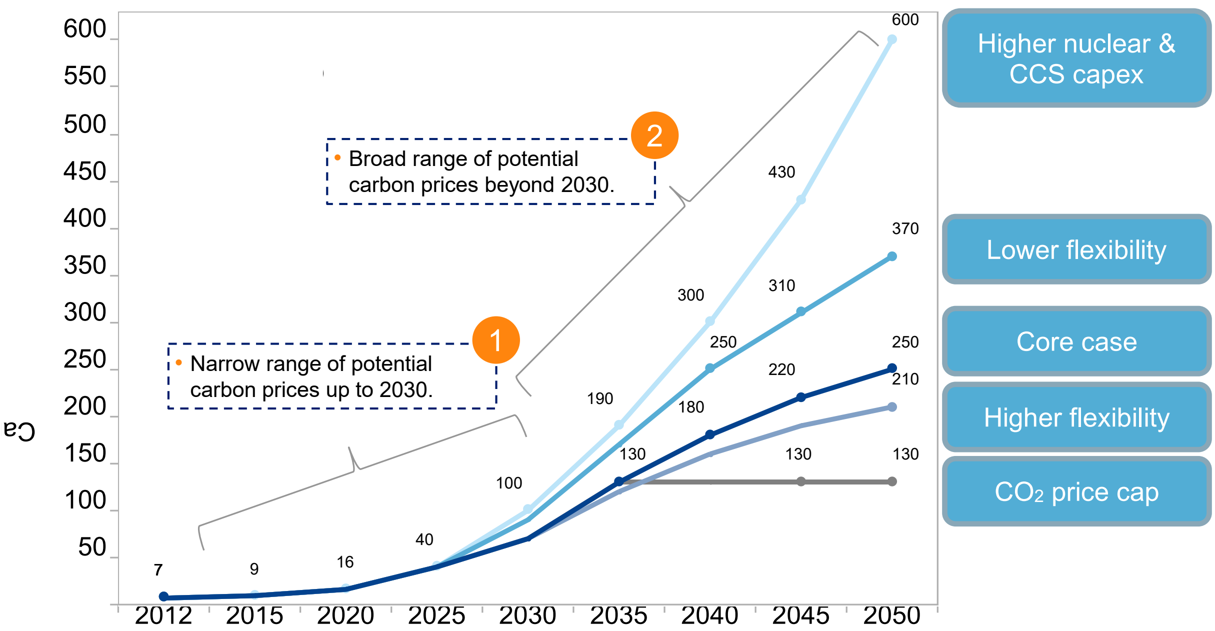
15 A potential model for decentralised delivery of security of supply is considered further in a separate piece of work prepared by Pöyry for ESC, which is summarised in a report entitled 'Broad Model for Capacity Remuneration in an ESP-Led Market' that is available on the ESC website

have been modest, albeit increasing in significance over the last year or so. The UK Carbon Price Support policy has supplemented the EU ETS price since its introduction. But in the light of (and potentially contributing to) modest carbon prices, the majority of low carbon investment has been delivered through renewables support schemes of one form or another.

Looking to the future, the situation is changing. The prospect of subsidy-free renewables investment is increasing and, as alluded to above, carbon prices are expected to continue their upward trajectory to some extent.

Delivering low carbon investment without direct support requires a carbon price (and associated wholesale electricity prices) that can incentivise delivery of the marginal low carbon technology. However, as the generation mix becomes less carbon intensive, the influence of the carbon price upon wholesale electricity price formation starts to reduce. There are, therefore, diminishing returns from increases in carbon prices, as carbon falls out of the generation mix and exerts less impact on the wholesale price. Combined with the lumpiness of the supply curve and uncertainty regarding future costs, this means that the future carbon price required to drive further decarbonisation ultimately becomes high, uncertain and sensitive to marginal technology costs. Figure 9 is drawn from previous Pöyry analysis and provides some insight into the potential range of carbon prices that may be needed to deliver incentives for market-led investment under a number of different scenarios.

Figure 9 – Potential carbon price trajectory



Source: Pöyry 'From ambition to reality? Decarbonisation of the European electricity sector'[16]

As we stand today, a widening range of potential carbon prices from 2035 onwards presents credibility issues for reliance on carbon pricing to drive investment in the longer-

16 https://www.poyry.com/sites/default/files/media/related_material/0013_pov_from_ambition_to_reality_-_decarbonisation_final1111_web2.pdf

term. It is likely that if we were to step forward 10 years, the picture for 2035 would be clearer and the range of uncertainty reduced due, for example, to technology development. But, it remains the case that investors today face growing uncertainty as the required future carbon price rises and becomes more sensitive.

This suggests that there may be a ‘divergence point’ for the role of carbon pricing as the primary driver for decarbonisation. In the short to medium-term, non-dramatic carbon price increases can help to support reduced carbon emissions. But at some point, diminishing returns from further increases may kick in and the ability for carbon pricing alone to drive further decarbonisation becomes increasingly challenging.

In this context, there may be merits in the longer-term of a form of carbon intensity standard with an obligation on service providers to reduce the carbon content of the energy they sell. The service providers can operate within the standard either by reducing the emissions intensity of the energy they sell, or by buying credits from parties who are supplying energy with a carbon intensity below the standard. This type of approach may be supportive of cross-vector response, supporting innovation in offering development by service providers.

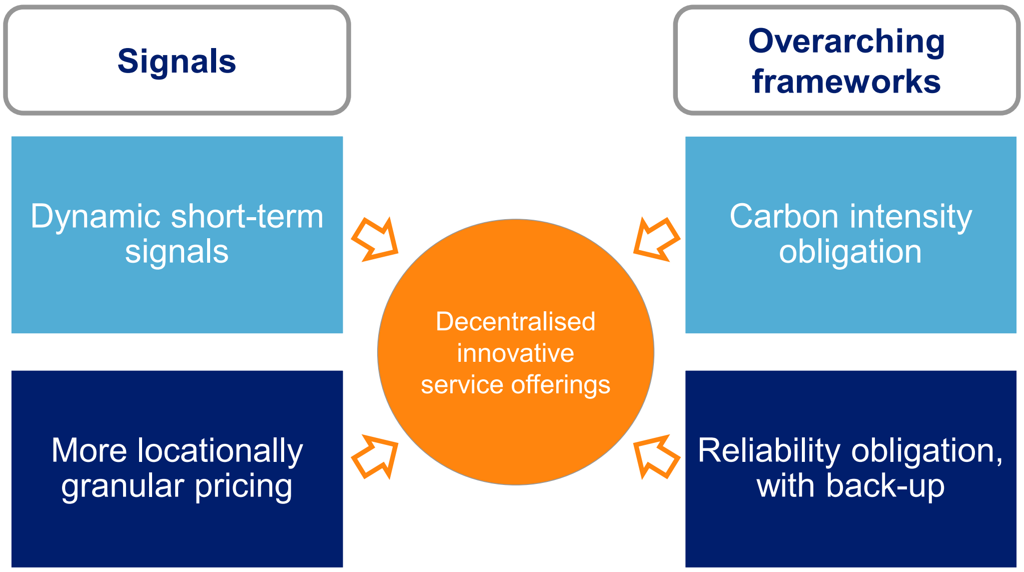
Focus: options for carbon intensity obligation to support carbon pricing.

3.2 Potential framework

Drawing the suggestions of the previous Sections together, the strategic choices can be combined to create the framework presented in Figure 10, which is built around short-term price dynamism and market driven solutions. It operates under a set of overarching obligations on energy service providers relating to carbon intensity and reliability. This framework places decentralised decision making based on market driven responses to these dynamic market signals and obligations at the centre of market operation.

This framework seeks to re-focus on the role of markets and market prices as the drivers for creating investment and operational signals within the electricity sector. It is presented as a hypothesis for further examination. Section 4 considers how this topic can be evaluated and progressed further.

Figure 10 – Potential future framework



4. HOW TO PROCEED?

Section 3.2 proposes a high level market design framework which is markedly different from current arrangements. If we accept the case for reform to improve market signals, then we need (a) to identify realistic next steps along a coherent direction of travel, and (b) to consider options for developing the evidence base to inform strategic choices in electricity market design. To tie this to preceding Sections of this document, this draws upon the frameworks introduced in Section 2, namely:

- the different dimensions (temporal, spatial and technological); and
- the 5C framework of value sources (commodity, capacity, capability, congestion and carbon).

The underlying challenge is to consider what can potentially be done to improve the quality of signals, for both operational and investment purposes, across the different dimensions in support of the model suggested in Section 3.2. The following Sections focus on each of the dimensions in turn.

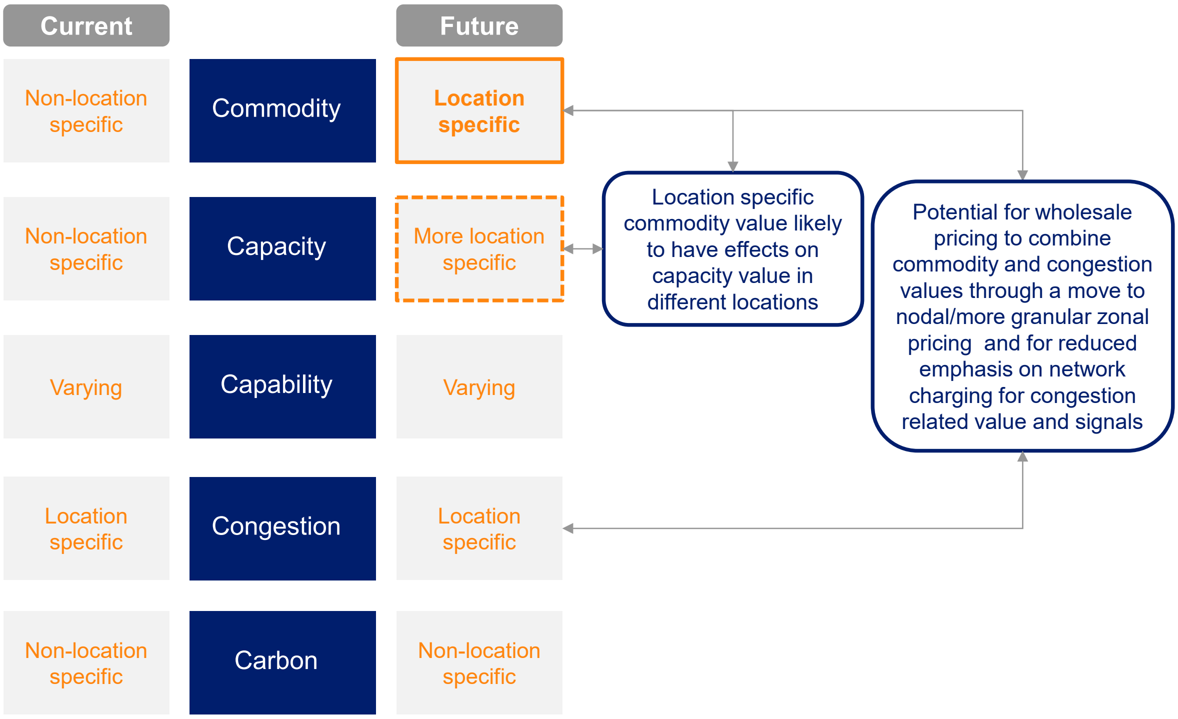
4.1 Spatial dimension

The spatial dimension has relatively limited prominence in the current GB arrangements. In the wholesale market and the capacity market, which are the primary origins of commodity and capacity value streams respectively, the location of resource is not particularly important, with pricing and associated signals national in nature. Some balancing services, such as constraint resolution and voltage support, do attach importance to location, but this is not generally the case, meaning that there is only limited reflection of location specific value in the capability component. At present, the main source of locational differentiation comes via network charging arrangements which seek to provide signals of the value of congestion alleviation/avoidance.

However, as discussed in Section 3.1.2, the importance of location is expected to increase in future with more decentralisation of resource and greater heat and transport related load, with consequences for the variability of network flows and the capabilities of the networks to handle this. This expectation led to the suggestion for focus on the potential for locational differentiation within market operation and pricing. In particular, this includes the possibility of locational differentiation in the wholesale market, such that the wholesale price has an increased role as the vehicle for signalling and providing congestion related value.

Figure 11 shows the main areas of impact of this potential development across the 5Cs. This highlights the potential for an increased role for locational wholesale pricing arrangements that combines commodity and congestion values to a greater extent than today. Greater locational differentiation in wholesale pricing may also lead to more location specificity in capacity value. For example, capacity value may be greater in a demand heavy pricing area.

Figure 11 – Potential evolution of 5Cs for spatial dimension



The potential adoption of more locationally granular wholesale pricing would be a fundamental shift for the operation of the wholesale market design. However, it is not conceptually radical and there are existing requirements for regular reviews of bidding zones which could, in principle, already trigger deviations from a national pricing area in GB[17].

To inform the debate further, however, questions, such as the following, can be considered to seek to enrich the evidence base for future discussions on this topic:

- Locational conflicts:
  – Given expected developments on the system, when and where do locational conflicts become more significant?
- Future role for network charging in providing locational signals:
  – Given the changing dynamics of the resource mix and nature of system operation, to what extent can network charging arrangements be expected to provide locational signals that inform operational and investment decisions?
  – Noting that network charging reforms are ongoing, how far into the energy transition are these arrangements expected to take us?
- Scope for locational differentiation in wholesale pricing:
  – How effective could different levels of locational differentiation be in providing signals and that inform operational and investment decisions?
  – How could locational differentiation work across different voltage levels?

17 Article 34 of Guideline on Capacity Allocation and Congestion Management.

- Interactions with local flexibility initiatives:
  - How could local flexibility solutions interact with or be affected by greater locational differentiation in wholesale pricing?

4.2 Temporal dimension

The current GB arrangements present a mixed picture in terms of the temporal dimension. The wholesale market is dynamic at a half-hourly resolution, with prices varying based on the supply/demand position for that timeframe. The spot carbon price is also dynamic driven by the demand for and supply of allowances under the EU ETS. Certain balancing services and aspects of the charging arrangements also provide elements of dynamism for capability and congestion values.

The value of capacity stemming from the capacity market, however, is static, set annually and so not varying to reflect shorter-term variations in value based on system dynamics. Additionally, the forward timing of capacity auctions, and the associated lock-in of capacity agreements and prices, can affect value and prices for energy and balancing services. As market participants stack revenues across multiple sources to support project economics, securing capacity value up front can reduce revenue requirements from the later occurring energy and balancing services markets, potentially dampening prices and signals of value in them. To elaborate on this, observations are that capacity contracts can be secured further ahead of time and for longer durations than flexible services. This reduces the value associated with flexible services, which risks compromising business models which place a strong emphasis on capturing value from their provision.

As suggested in Section 3.1.1, there is scope for greater emphasis on enhanced shorter-term price signals to help drive efficient operation of a system with greater variability in generation and potential for demand flexibility. In turn, enhanced near-term pricing signals with improved ability to reflect value may help to drive market-led investment in the future resource mix. To achieve this for capacity related value component, given its static nature at present, there may be scope for greater alignment between timeframes for commodity and capability elements, such that capacity value is reflected at a more granular temporal resolution. This would potentially allow capacity value to be better aligned with shorter term supply/demand conditions in the energy market and to be more closely linked to capability requirements for system operability.

Noting that several initiatives have recently been completed or are underway, Figure 12 outlines the types of changes that could be progressed to increase the temporal dynamism of signals across each of the 5Cs.

Figure 12 – Potential evolution of 5Cs for temporal dimension

Current		Future	
Dynamic	Commodity	**More dynamic**	Potential for increased dynamism though closer to real-time market operation and shorter settlement periods
Static	Capacity	**Dynamic**	Ensure that scarcity value is reflected in wholesale pricing avoiding dampening effect of capacity market. Potential for enhanced dynamism in capacity value.
Varying	Capability	**Dynamic**	Potential for increased dynamism though closer to real-time contracting and shorter commitment periods
Varying	Congestion	Dynamic	Potential for locational differentiation in wholesale pricing to increase dynamism of congestion value
Dynamic (CO_2 pricing)	Carbon	Dynamic (CO_2 pricing)	

In the main, the types of changes envisaged are incremental to and developments of the existing arrangements. For example, potential initiatives to reduce settlement period duration and gate closure timings are adjustments to the existing arrangements, rather than radical reforms. Similarly, efforts to procure balancing services for shorter durations and commitment periods are in line with ongoing initiatives regarding reserve procurement. However, there is scope for these types of initiative to be pursued with greater urgency to facilitate delivery of improved market signals.

In these regards, the basic mechanics of the arrangements appear to be in place, albeit with scope for incremental enhancement to allow the arrangements to better suit the future system context. Progression of these types of potential development requires appropriate evaluation to assess the potential costs and benefits. Additionally, there may be a requirement for development of hedging and contracting tools to allow for management of price and volume risks in the changing market dynamics, but such initiatives can be market-led.

In terms of congestion, the potential for more locationally differentiated wholesale pricing discussed above would also help to increase the temporal dynamism of congestion values and signals.

Measures to increase the dynamism of the capacity component, however, have the potential to entail more significant changes to the arrangements. At the less substantive end of the scale, the effectiveness of recently introduced scarcity pricing arrangements has not been tested in practice and this can be reviewed on an ongoing basis. If review suggests that the scarcity pricing arrangements could benefit from sharpening, then this can be progressed through industry processes. In contrast, the type of decentralised, more dynamic and less explicit arrangements for security of supply suggested in Section

3.1.4 will require a substantial revision to the capacity market arrangements. This type of potential development requires specific assessment.

As for the spatial dimension, there is a series of potential questions to consider to inform the discussion and to develop the evidence base in respect of possible enhancements to the temporal dynamism of the GB arrangements. Potential questions to consider include the following:

- Cost benefit analysis for wholesale market enhancements:
  - What are the relative pros and cons of options such as shorter settlement periods and closer to real-time gate closure given expectations of the future system dynamics?
- Future visibility of challenges for reliability and system operability:
  - What is the anticipated nature of future challenges and requirements?
  - What are market participants expected to cover / not cover? How do responsibilities potentially interact?
- Scope for bilateral solutions for security of supply:
  - What is the feasibility of more decentralised, bilateral solutions for security of supply and how could such approaches influence capacity value over different timescales?
  - What is needed to allow for risk management given market participant responsibilities and to support market-led investment?

4.3 Technological dimension

If the market arrangements are able to provide signals across the 5Cs that appropriately reflect the value of each component to the system, then the resultant resource mix should be well aligned with the needs of the system. In this sense, the technology mix of the system should be allowed to materialise without additional measures. On this basis, focusing on getting the signals right across the 5Cs and ensuring that resources capable of providing a particular service to the system are able to capture value for it is preferable to attempting to use specific instruments to drive the mix. With this ambition in mind, there may, however, still be a case for some forms of innovation mechanisms to support new technologies in the proof of concept phase or some method for supporting technology developments considered to have strategic value for the system. However, support of this nature should, wherever possible, be provided in a way that does not dampen signals across the 5Cs.

4.4 Considering issues in the round

The Sections above have separately considered a range of possible developments to aspects of the 5Cs across different dimensions. The reality, however, is that the different elements interact with one another and changes to one aspect of the arrangements could potentially affect signals and value potential elsewhere. This is evident in the arrangements in place today. For example, the capacity market can have a dampening effect on price formation in the wholesale market and revenue stacking between different activities or services creates linkage between price or value creation in the individual areas.

These types of interactions will continue to exist in future and, in this context, it is important for assessment of options for reform to consider consequential implications and interactions wherever possible. This should help to deliver a cohesive set of arrangements in their totality.

With cross-vector interactions expected to increase, the relevance of whole system modelling assumes greater importance in this context. There is a general need for assessment to consider how potential changes to arrangements could impact decisions in the linked sectors and so influence overall whole system decarbonisation. Understanding cross-vector consumer choices within this whole system context will be increasingly important for assessment going forward.

ANNEX A – ROUNDTABLE 1 DISCUSSION PAPER

A.1 Introduction

The resource mix in the electricity market is evolving as decarbonisation, decentralisation and digitalisation drivers are having an increasing impact.

This evolution in the resource mix is changing the dynamics of the system in real time, with, for example, a growing need for flexibility to complement increasing intermittent renewables. Getting an appropriate response to short-term conditions relies on appropriate and visible near-term price signals. In turn, having the right resources available to respond to the short-term conditions relies on provision of signals to support investment decisions to deliver an appropriate resource mix.

The goal of efficient real time operation and investment relies on the market and supporting arrangements being capable of providing signals to drive operational and investment decisions in a manner that supports overall system efficiency. There is, therefore, a need for 'good' market signals that reflect the true value to the system of different resource types, with different characteristics.

Against this backdrop, Energy Systems Catapult (ESC) has launched initiatives to explore the nature of market signals within the current GB electricity market set-up and their appropriateness for both support delivery of and operation within a decarbonised electricity sector. At the heart of this, ESC's focus is upon:

- the ability of the current arrangements to create appropriate signals to support the transition;
- identification of potential issues within the arrangements and, where issues exist, what remedies or alternatives may be available; and
- establishing information and evidence-base requirements needed to inform the debate further.

To support ESC with the focus set out above, Pöyry is conducting work to, as an initial step, identify and characterise key sources of value within electricity markets, including mapping to the existing GB arrangements. This will be followed by consideration of a selection of case studies to identify approaches taken elsewhere and to identify possible insights for consideration in GB. Stemming from these steps, the aim is to have a clearer perspective on areas for further investigation in the GB context in respect of the electricity market signals and to identify proposals for a structured approach for improving the evidence-base in respect of market signal issues.

A.2 GB market signal insights

The market arrangements include a broad range of mechanisms that remunerate provision of the different components that are of value to the system and, in so doing, contribute to provision of signals of their value. A selection of the prominent parts of the overall arrangements that contribute to signalling of value is shown in Figure 13. While presented as discrete items under specific value components, in reality there are extensive interactions between the different mechanisms, creating a meshed framework.

Figure 13 – Mechanisms influencing value across the components

Commodity

- Imbalance settlement
- Balancing Mechanism
- Spot markets
- Forward markets
- Losses arrangements

Capacity

- Capacity market

Capability

- Firm frequency response
- Short-term operating reserve
- Fast reserve
- Enhanced reactive power service

Carbon

- EU ETS
- Carbon Price Support
- Renewables Obligation Certificates
- Contract for Difference Feed-in Tariffs
- Small-scale Feed-in-Tariffs

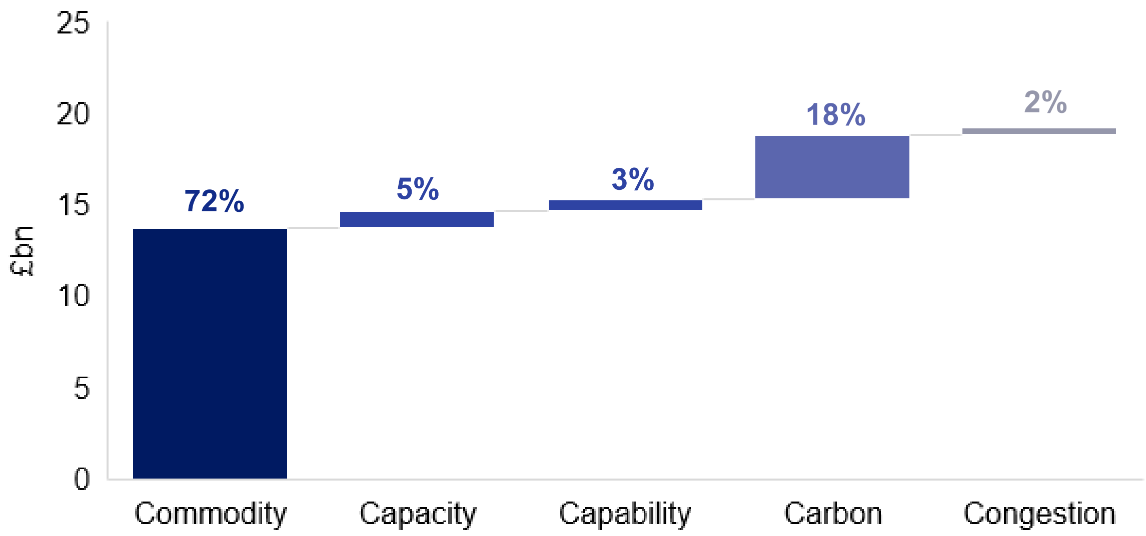
Congestion

- Generator TNUoS charges
- Demand TNUoS charges
- Red/Amber/Green credits
- Super Red Credits
- Local flexibility markets
- Constraint payments

The value available under each of these five components is varied, with Figure 14 providing ballpark estimate values. Added to this, different resources offer different characteristics which are capable of targeting and providing to the system different combinations of the overall market value components. This means that that different resource types will be focused on and responding to different signals depending on their ability to realise value based on underlying characteristics.

In addition to technological variations, the nature of signals provided is varied across temporal and spatial dimensions, as illustrated in Figure 15. In terms of the temporal dimension, some signals are dynamic in nature changing in response to system conditions and others reasonably static over time. Across the spatial dimension, some signals have little or no location specific focus while for others location is significant to the signal.

Figure 14 – Annual monetary value attached to each source of value



Commodity: Wholesale market revenue for FYE 2018 is calculated by monthly demand and day-ahead baseload prices
Capacity: Total capacity payments made to generators in FYE 2018
Capability: Annual cost of ancillary services between June 2017 – May 2018
Carbon: Total Climate Change Levy received and the government spending for RO, ssFiT and FiT CfD in FYE 2018
Congestion: Annual cost of constraints (as a component of BSUoS) between June 2017 – May 2018

Figure 15 – Nature of signals across value sources

		Temporal	Spatial	Technology
Commodity	• Wholesale electricity market price (forward, day-ahead, within-day, Balancing Mechanism, imbalance)	Dynamic*1	Non-location specific*2	Non-technology specific
Capacity	• Capacity market clearing price	Static	Non-location specific	Technology specific*3
Capability	• Balancing services contracts, Balancing Mechanism	Varying	Varying	Technology specific
Carbon	• Carbon element of wholesale price, ROC value, CfD FIT difference payments	CO_2 pricing -> dynamic Support -> static	Non-location specific	Technology specific
Congestion	• Balancing Mechanism, network charges (e.g. Triad avoidance, super red charges)	Varying	Location specific	Varying*4

1 Near term prices drive forward prices.
2 Locational loss factors at transmission and distribution levels.

3 De-ratings do differentiate, eligibility exemptions.
4 May need specific characteristics.

A.3 Current situation

Individual party responses to the various signals can lead to unintended outcomes from a system perspective, even though actions are rational at the individual actor level. For example, behind the meter generation is able to avoid certain components of retail electricity prices, notably certain system, network and carbon (green support scheme costs) signals, providing an incentive for increased deployment. Some charges, such as those linked to network reinforcement costs, can truly be avoided by onsite generation. But other costs, such as those linked to support schemes, are not avoided but rather just pushed onto other users. The actions of behind the meter developers are rational in response to the signals they face, but this may not be contributing to an efficient outcome overall.

Consideration needs to be given to whether observed responses to market signals, such as in this example, are appropriate and whether there is merit in revising arrangements.

In this regard, it is fair to say that a range of initiatives are already underway. These initiatives are positive and have the potential to improve signals. As part of these processes, the opportunity to consider the broader coherence of signals across the different value components should be considered.

A.4 Questions

Multiple questions arise which are relevant for next steps:

Current arrangements:

- **Coverage**:
  - Do signals exist for all important value areas?
  - Is relative value from different sources appropriate?
- **Application**:
  - Are signals targeted and efficient?
  - Are interactions between value sources effective?
- **Issues**:
  - What imperfections exist and what are options for addressing them?
  - Are there other obstacles for efficient investment in response to signals?

Future needs:

- **Coverage**:
  - How might signals need to be revised to deliver in future? E.g. change in emphasis between value components, addition or removal of components.
  - What is the appropriate boundary for markets in future? E.g. growing role for local markets.
- **Roles/responsibilities**:

  - Who should be providing signals for investment? E.g. ESO/DSOs, policy makers.
  - How to manage evolving relationships between stakeholders? E.g. ESO/DSOs.
- **Transition**:
  - How can current arrangements be revised to facilitate delivery of and operation in anticipated future system set-up?

ANNEX B – ROUNDTABLE 2 DISCUSSION PAPER

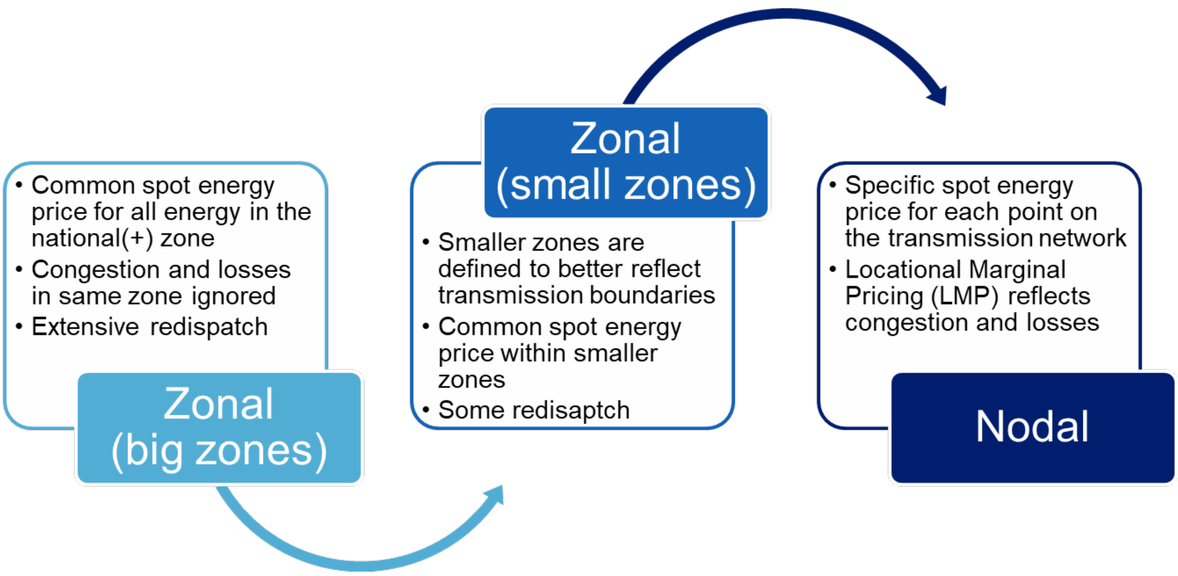
B.1 Introduction

This note presents insights from the case studies on different wholesale market design options, as follows:

- Nodal pricing: New Zealand, New York;
- Zonal pricing: Nord Pool; and
- National pricing: Germany.

For each market, we aim to provide a brief overview of the wholesale electricity market arrangements, the price formation mechanisms and the impact of the pricing structure on market signals. Figure 16 summarises the key differences between different wholesale pricing structures.

Figure 16 – Key differences between pricing structures



Source: Pöyry

B.2 Characteristics of the case study markets

The case study markets vary in terms of underlying market design, with an overview of main design elements provided in Table 3.

Table 3 – Market arrangements overview for case studies

Feature	New Zealand	New York	Nord Pool	Germany
Energy pricing	**Nodal** Nodal pricing which reflects the cost energy, congestion and losses for around 244 nodes with half-hourly settlement.	**Nodal for generators, zonal for consumption** Nodal energy price for each generator, taking into account marginal price for losses and for congestion in relation to a reference node. Zonal energy price for consumption based on volume weighted average of nodal prices in the zone.	**Zonal** System wide and bidding area specific prices are calculated for each hour. If the transmission capacity between bidding areas is not sufficient to reach full price convergence across the areas, congestion will lead to bidding areas having different prices.	**National** Germany wide hourly day-ahead prices are calculated in parallel to other markets included in Day-Ahead market coupling. Intraday market allows for trading half-hourly.
Basis for trade	**Centralised** Physical trade in mandatory spot market, which acts as energy-only pool, without any sequential markets. Trade based on real time spot prices (non-binding), and ex post, next day settlement pricing (after dispatch). Physical trade supplemented by financial trade.	**Centralised (predominantly, with opportunity for bilateral transactions)** Physical trade concentrated in day-ahead market and then the real-time market. As an alternative, opportunities exist to enter into bilateral transactions. Financial (or virtual) trading also possible. Financial contracts allow for hedging of congestion charges in day-ahead market, which entitle holders to payments corresponding to congestion charges between two specific locations.	**Bilateral** Physical trade concentrated in day-ahead power exchange, which acts a voluntary pool, with intraday fine-tuning. Physical trade supplemented by financial trade, which for allows hedging. Financial contracts include hedges for price zone differences relative to the system wide price (TSOs are not counterparties to these).	**Bilateral** Physical trade concentrated in day-ahead power exchange, which acts as a voluntary pool, with intraday fine-tuning. Supplemented by financial trade.

Feature	New Zealand	New York	Nord Pool	Germany
Basis for dispatch	**Central dispatch** Central dispatch by the TSO via central scheduling and commitment.	**Central dispatch** Day-ahead market commitment process determines dispatch schedule for generators for the following day as well as schedule of consumption for load serving entities. Following day-ahead scheduling, the real-time commitment process allows for binding commitment/de-commitment decisions based on prevailing conditions.	**Self-dispatch** Parties self-dispatch based on day-ahead positions which respect inter-zonal transmission constraints (amended by intraday fine-tuning).	**Self-dispatch** Self-dispatch based on day-ahead positions (amended by intraday fine-tuning).
Congestion management	**Central dispatch** No separate congestion management needed due to central scheduling and commitment.	**Central dispatch** Day-ahead scheduling process takes account of transmission limitations and bottlenecks in delivering least-cost schedule. Real-time scheduling process allows for adjustments to reflect prevailing conditions.	**TSO re-dispatch** TSOs conduct residual balancing to manage any within zone issues, as well as real time inter-zonal issues and supply/demand fluctuations.	**TSO re-dispatch** TSOs conduct residual balancing to manage any within zone issues, as well as real time inter-zonal issues and supply/demand fluctuations.
Security of supply	**Energy-only market** Energy and reserve constrained system co-optimised.	**Capacity obligation** Centrally determined state-wide and, to reflect transmission constraints, location specific capacity requirements are translated into obligations for LSEs to procure capacity. This can be via bilateral transactions or centrally coordinated auctions.	**Mixture** Finland and Sweden have strategic reserve mechanisms. Norway and Denmark do not have explicit generation adequacy measures.	**Energy-only (notionally)** Type of strategic reserve to be in place from October 2019 until 2025.

Feature	New Zealand	New York	Nord Pool	Germany
Renewable support	**Carbon pricing** New Zealand ETS requires provision of allowances or payment of buyout price.	**Certificates schemes** Renewable and zero carbon certificate schemes in operation. Proposals to introduce carbon pricing into the wholesale electricity market. Proposal for carbon pricing.	**Mixture** Sweden and Norway operate a joint renewable certificates scheme. Denmark and Finland have forms of premium feed-in tariffs. EU ETS carbon pricing.	**Mixture** Feed-in-tariff and one-way CfD. EU ETS carbon pricing.

B.3 Market specific observations

B.3.1 New Zealand

- **Market outcomes stem from centralised optimisation arrangements**:

  The system operator, Transpower, operates the spot market as a mandatory energy-pool and optimal dispatch is determined based on complex bids/offers from generators, customers and reserve providers via Transpower's Scheduling, Pricing and Dispatch (SPD) model in a half-hourly and nodal granularity.

- **Scarcity pricing adjustments supplement price formation in periods of tightness but only after the event, hampering response:**

  In the event of reserve shortfall on an island, interim prices, which are produced the day after real time, are adjusted with a scaling factor to reflect tightness. But parties cannot respond to this signal either at the time of the event or even in the subsequent periods until interim price publication the next day. Proposals have been made to replace the current scarcity pricing adjustment with arrangements to set reserve prices in real-time pricing via a risk-violation curve with increasing reserve price as increasing shortfall based on the economic cost.

- **Significant level of nodal price convergence in some areas:**

  Studies have identified a significant level of nodal price convergence in some areas signalling the potential for the aggregation of the price nodes in these areas to zones which would reduce the computational burden with negligible loss in the accuracy of the price signals divergence.

- **Option for distribution level LMP considered but looks unlikely to be progressed:**

  Work has been undertaken to explore the potential costs and benefits of shifting LMP to distribution level (DLMP). But the latest position is that full DLMP is impractical for the New Zealand market at the moment due to the significant computational complexity it brings and lack of reliable optimisation methods.

- **Concerns regarding appropriateness of transmission pricing methodology:**

  The Electricity Authority (EA) has raised various concerns that the existing transmission pricing methodology does not reflect the true cost of the grid and has unfair allocation of costs, which may lead to inefficient use and expansion of it. The EA has been looking at different options for transmission cost allocation methodologies to create better signals for future network investments and to reduce the transmission costs. Issues include:

  - cost recovery not reflecting the level of benefit different generators and customers receive from grid investments; and
  - transmission cost avoidance by load shifting creating incentives for behind the meter solutions that may be more expensive than alternatives.

Transpower is exploring a benefits-based approach for setting forward looking charges based on an assessment of the future grid entry/exit points to identify the beneficiaries.

- **Distribution pricing may be modified to produce peak/off-peak signals:**

  A review of distribution pricing suggests the implementation of a time-of-use charge in distribution and retail pricing to align it with transmission peak pricing.

B.3.2 New York

- **Strong emphasis on complex centralised arrangements for delivering efficient market outcomes in New York**:

  The New York wholesale market is centralised in nature, with coordinated market operation co-optimising energy and reserve requirements, alongside congestion management. In addition, its capacity mechanism involves central definition of capacity requirements. The coordinated optimisation processes and the outturn prices are, therefore, very important for providing signals to the market in terms of commodity, capability and congestion.

- **Supplemental scarcity pricing measures sit alongside arrangements:**

  Shortage pricing arrangements are in place to increase standard market prices in the case of both operating reserve and regulation shortages and transmission shortages. But there is some concern that these measures do not appropriately reflect scarcity, particularly relative to scarcity pricing measures in place in interconnected, neighbouring markets.

- **Persistent and significant grid bottlenecks make location important in New York**:

  This is a strong driver for nodal pricing in the energy market in order to seek to appropriately reflect congestion costs in the wholesale prices. But the bottlenecks remain an issue. On average, the impact of transmission congestion and losses led real-time prices to vary from an average of $27/MWh in the North Zone to $49/MWh in Long Island in 2018[18]. Whether this spread adequately reflects the costs of congestion and so provides appropriate signals for congestion resolution is unclear.

  The importance of location is also evident in the capacity mechanism and reserve/regulation procurement. The capacity mechanism includes load area specific capacity demand curves and retailers need to meet area specific capacity obligations. Similarly, reserve requirements are specified for particular load areas and are secured via the centralised co-optimisation processes.

- **Transmission congestion contracts are important tools for hedging against day-ahead transmission congestion costs and providing signals relating to congestion:**

  Transmission congestion contracts (TCCs) are financial instruments that can be used to hedge against day-ahead transmission congestion costs. A TCC creates the right to collect, or the obligation to pay, the congestion rent associate with a 1MW unidirectional transfer between two specific points. Revenue from the

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18 2018 State of the Market Report for the New York ISO Markets.

auction of TCCs flows, via NYISO as the auctioneer, to the transmission system owners.

- **Assessment of alternative options for addressing congestion:**

  If 10 year forward looking assessments suggest potential for transmission security issues, NYISO responds by soliciting market-based solutions, which may entail investment in transmission, new supply resources, or demand reduction measures. Effectiveness of this in practice could be investigated further.

- **Profitability issues for many classes of market participant:**

  Analysis prepared by the market monitor (2018 State of the Market report) considers the long run investment incentives for different plant types based on expected revenues versus costs. This indicates that profitability is an issue for many types of resource and suggests that there are challenges in providing incentives to meet low carbon objectives and ensuring reliability.

- **Proposals for carbon pricing and marginal locational capacity pricing:**

  There are live proposals to introduce carbon pricing mechanisms that would mean that a social cost of carbon would be included in carbon emitting generator costs and outturn prices.

  Concurrently, the potential for locational marginal pricing of capacity, which sets locational capacity prices that reflect the value of capacity at each node, has been suggested. It is considered that this would be less administratively burdensome and involve less approximations than the current approach.

B.3.3 Nord Pool

- **Sub-national bidding zones defined to reflect grid bottlenecks**:

  Norway, Sweden and Denmark are composed of multiple price zones that reflect structural bottlenecks on the system. In the case of Norway, zones have been re-defined several times in response to system developments. But zones have been stable over time elsewhere.

  On average, price divergence across zones is generally modest. A convergence across 9 to 10 price areas is the most commonly observed pricing outcome over the last 5 years.

- **Electricity Price Area Differentials are important tools for hedging against day-ahead transmission congestion costs:**

  Electricity Price Area Differentials (EPADs) allow members to hedge against the price risk caused by constraints in the transmission grid. EPADs take the form of a contract for difference between a specific area price and the system price. EPADs are traded between market players, independently from TSOs.

- **Congestion rent forms income to the TSOs:**

  The congestion rent from price difference between zones multiplied by the flow between zones is an income to the TSOs as they are owners of the transmission grid. The Nordic congestion income is shared between the four Nordic TSOs

(Energinet.dk, Statnett, Svenska Kraftnät and Fingrid) based on a common agreement. TSOs are required to either spend congestion rent on grid reinforcement or use it to reduce bills for consumers.

B.3.4 Germany

- **Transmission bottlenecks are a significant issue in Germany that need to be managed by TSOs:**

  A high share of wind generation located in northern Germany that needs to be transferred to demand in the south combined with the delays in the necessary grid infrastructure, necessitates repeatedly short-term intervention from the TSOs to re-dispatch resource. This leads to additional costs, with the figure around €350m for 2018.

- **Multiple mechanisms sit around the energy-only arrangements to support the market:**

  TSOs have multiple supplementary levers around the energy-only market framework to support adequacy and system operation including:
  - postponement of system-relevant power plant decommissioning;
  - Grid Reserve, made up of plant with planned decommissioning or that has already been temporarily decommissioned, to support management of transmission system bottlenecks, for voltage stability and the systems black-start capability; and
  - Capacity Reserve, which is a type of strategic reserve.

The addition of these mechanisms has some linkage to the challenges of managing transmission constraints with national energy pricing.

B.4 Broader insights emerging from case studies

- **Market designs are diverse and there is no single answer**:

  Just on the basis of these four case studies, it is clear that there is significant diversity in electricity market design options across different jurisdictions. There is no single answer and different approaches have emerged given different backdrops to and philosophies for market development. All arrangements are more complex than a high level appraisal of the design may suggest, with multiple examples of adjustments or additional mechanisms in place to support market operation.

- **Nodal pricing tends to be accompanied by centralised dispatch and trading:**

  Co-optimisation of energy, reserve and congestion under nodal pricing requires centralised algorithms and coordination, as well as being accompanied by centralised dispatch and trading. These features are at odds with the philosophy of bilateral trading (including continuous trading intraday) and self-dispatch in GB.

- **There are inevitably trade-offs between nodal, zonal and national approaches:**

  The decision between models is not simple and a range of trade-offs exist. Table

4 lists a selection of opinions commonly raised in relation to different pricing approaches.

Table 4 – Commonly cited arguments relating to pricing approach

	National	Zonal	Nodal
Efficient use of existing grid	Moderate if re-dispatch process is effective	Moderate if re-dispatch process is effective and zone definition is sensible	Good if well implemented
Incentives for efficient resource dispatch	No incentives linked to location within zone	Mixed, depending on number of zones	Strong locational incentives but implications for innovation within complex bidding
Re-dispatch volume	High if network expansion delayed	Lower than national	No re-dispatch
Market power abuse on pricing	Limited because of broad price setting geography	In between	High because of local scarcity potential
Market power abuse on re-dispatch	Potentially high in absence of regulation	In between	Low due to central dispatch
Incentives for locationally efficient resource investment	None from energy prices	Moderate, effectiveness depends on credibility and stability of zonal price signals	Stronger, effectiveness depends on credibility and stability of local price signals
Credibility of prices as incentives for investment	High, linked to price stability across broad geography	In between	Reduced if local prices are difficult to predict/unstable

B.5 Questions

- What insights do the case studies provide in relation to the market design approach adopted in that jurisdiction?
- How may these insights be considered in the GB market context?

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