ZERPAs

Financing the transition to net zero under future zero-emissions resource supply constraints

UK FIRES

ZERPAs

UK FIRES is a 5-year research programme funded by £5m of UKRI support and the subscriptions of an active and growing industrial consortium. With academics from six universities spanning from materials engineering through data science to economics, corporate strategy and policy and an industry consortium spanning from mining through construction and manufacturing to final goods.

UK FIRES stands for placing Resource Efficiency at the heart of the UK's Future Industrial Strategy. When we proposed UK FIRES, it was to focus on Resource Efficiency as the key means to reduce industrial emissions. However, in 2019, both houses of Parliament unanimously approved a change to the UK's climate change act to target zero emissions in 2050. This has been reinforced by recent Government targets for 2030 and 2035.

So, although we haven't changed our name to UK FIZES, our focus is now on placing Zero Emissions at the heart of the UK's Future Industrial Strategy.

UK FIRES takes a pragmatic approach: we focus only on technologies that are available to us today and exclude those that have yet to be proven at meaningful scale, since they simply may not be ready in time. In 2050 we aim to meet the energy demand of UK society by non-emitting electricity generation.

In December 2019, UK FIRES released the "Absolute Zero" report, a ground-breaking description of the operation of the UK with zero emissions by 2050, without relying on as as-yet un-scaled energy sector or negative emissions technologies. This pragmatic but striking view of the journey to zero emissions has attracted widespread interest including a full debate in the House of Lords in February 2020.

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Summary

In the rapid transition to net zero, demand is likely to exceed supply for three zero-emissions resources: non-emitting electricity, biomass and negative emissions. ZERPAs are a new financial instrument that allow capital markets to anticipate this shortage, evaluate risks and redirect capital in response.

Like-for-like substitution of emitting activities depends on three fundamental zero emissions resources: non-emitting electricity, biomass and negative emissions. For example, an airline targeting net zero can: switch to electric planes or synthetic fuels, requiring non-emitting electricity; use bio-kerosene requiring biomass; continue to use fossil-fuels but cancel their effect through negative emissions technologies. Other forms of service substitution are possible, for example through remote connections, but direct replacement always depends on the three zero emissions resources.

As governments and corporates announce plans for their transition to net zero there is currently no mechanism to confirm sufficient supply of these crucial resources. At present 17% of the world's primary energy comes from non-emitting electricity and biomass, humans already appropriate a high proportion of around 30% of global biomass harvest and global capacity for negative emissions is less than 0.1% of annual emissions caused by humans.[1] It is therefore likely that demand will soon exceed supply. This creates a significant risk to plans for climate safety, which translates into a risk for providers of finance: if corporates fail to deliver on net zero promises, they will in time be restricted by changing demand and by regulation. Credible plans to secure the resources necessary for the net zero transitions reduces risks of missing climate targets.

This paper proposes the development of Zero Emissions Resource Procurement Agreements (ZERPAs), a new financial instrument to address these risk. They provide a mechanism to distinguish rhetoric from commitment in corporate net zero planning. They will operate in a market which will anticipate resource constraints and stimulate responses by investment, substitution or restraint. Finance providers – banks, investors, insurers and asset managers – can improve their climate resilience by demanding ZERPA-backed net zero transition plans.

ZERPAs are 15 to 30 year purchasing contracts that guarantee future resource prices. Resource users agree to pay a set price for future resource supply in exchange for market priority during shortages and proof of carbon-free procurement. Contracts will be tradeable on an exchange, with separate contracts for each resource.

ZERPAs would provide certainty and influence both the supply and demand sides of resource markets. On the supply side, they will stimulate investment in capacity, building on the UK government's Contracts for Differences for non-emitting electricity. On the demand side, ZERPAs will credibly signal companies' climate commitments and support financial risk management. ZERPAs will:

- Reveal the likelihood of future aggregate resource constraints.
- Generate a market mechanism to allocate future resources to users that value them most.
- Support growth of zero emissions resource production by offering price security.

Now is the time to develop mechanisms to protect future resource markets and increase the climate resilience of our finance providers. Government should work with the finance sector and regulators to consider using ZERPAs to support the key pillars of its net zero transition.

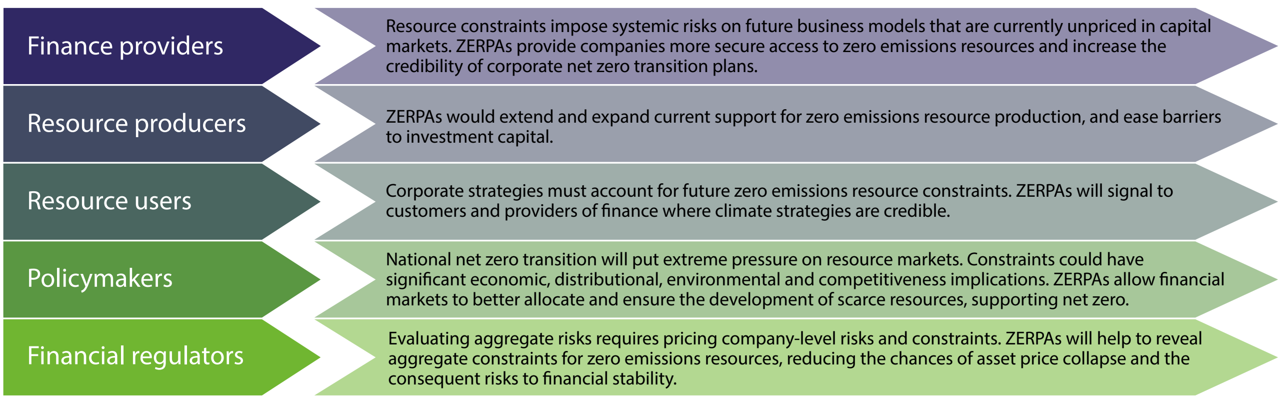

Figure 1: Key takeaways for each stakeholder group

Contents

1.Context: Future resource constraints

The financial sector is rapidly adopting practices to limit climate financial risks. Efforts are largely focused on the disclosure of climate-related financial risks based on individual companies' vulnerability to climate impacts or stress testing banks and institutions for their portfolio exposure.[2] However, these practices do not generally account for aggregate risks of market-wide resource shortages.

The fundamental problem that this report addresses is that there is currently no mechanism for evaluating the aggregate implications of individual decisions or plans in the context of future resource constraints.

1.1. Aggregate resource constraints

Today, many of the goods we consume, services we procure and activities we enjoy generate emissions. Three broad abatement strategies can deliver the transition to net zero:

1. Exercising restraint, for example by reducing consumption to avoid energy use.

2. Attaining the same outcomes differently, for example replacing business travel with virtual communication.

3. Delivering goods, services and activities with alternative technologies that draw on three zero emissions resources: non-emitting electricity, biomass and negative emissions.

UK and international climate strategies currently rely largely on the third of these strategies. Non-emitting electricity refers to variable renewables, such as solar and wind generation, along with firm nuclear power. Biomass is any organic matter, which can be used in energy generation (bioenergy), transport (biofuels), or as a material (fibre or timber).[3] Negative emissions refers to the removal of greenhouse gases from the atmosphere. It may be direct removals, for example if fossil fuel electricity generation, conventional cement production or existing blast furnace technologies are coupled with the negative emissions technology of carbon capture and storage (CCS).[4] It can also be indirect, for example if natural or man-mad carbon sinks such as forests and peatlands are enhanced, or via novel technological processes that directly capture carbon from the air and store it[4]. Non-emitting electricity and negative emissions technologies can also be used to produce zero emissions hydrogen. Hydrogen, often proposed as a key pillar of future net zero economies, is a derived resource which relies on robust markets for the three critical zero emissions resources.

The next three decades will see demand for these three zero emissions resources increase significantly, putting growing pressure on supply. Figure 2 shows the share of projected 2050 resource demand which could be met by today's resource markets and the mid-term supply projections for 2035.

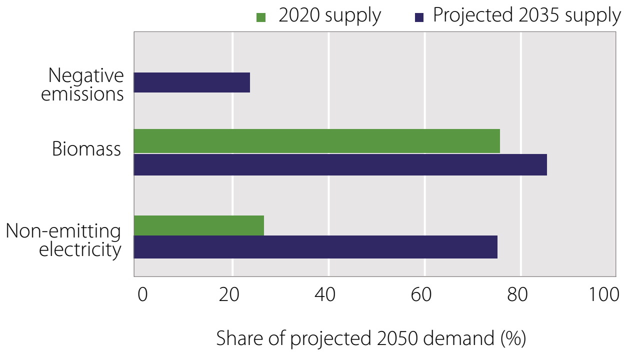

Figure 2: Zero emissions resource supply as a share of projected 2050 demand. Data sourced from CCC[4] and BEIS[5], based on the CCC's Balanced Net Zero Pathway. Biomass includes biogas, biofuels, biowaste and imports.

The UK government has set targets to increase the supply of zero emissions resources over the next three decades.[3,6]. Whether these targets are achievable depends on the rate of deployment of non-emitting electricity and negative emissions technologies, and the sustainable production of biomass. Each resource faces its own barriers. Non-emitting electricity and negative emissions have vast technological and infrastructure needs. Biomass requires careful sourcing to avoid infringing on the use of crops for food and the protection of other species' natural environments.[7]

Developing and deploying new technologies requires investment, clear policy guidance, and—crucially—time. Large-scale energy transitions in the past have generally taken several decades[8,9], constrained by political and social factors and the immense construction requirements[10]. Figure 3 shows the annual build rates required between now and 2050 for five non-emitting technologies, compared to what is being built today.

Required build rates are significantly higher than recent and current activity. Government support mechanisms can accelerate the delivery of new technologies: in 2017, 2.6GW of onshore wind was installed as developers rushed to make use of government funding for renewables.[12] Progress has since slowed and existing incentives are currently insufficient to achieve the UK's generation targets. The ambition-achievement gap is particularly stark for solar power, carbon capture and hydrogen.

Policy approach for aggregate constraints

The UK government has not yet addressed the risk of future aggregate resource constraints. Despite growing evidence that the limited supply of zero emissions resources may constrain the UK economy in the coming decades, the government has proposed only two meaningful strategies to deal with them: investment in battery storage technology and demand side response to accommodate intermittent renewable generation. While both options are essential for supporting the transition to a low-carbon electricity grid, neither account for the potential for long-term constraints across all zero emissions resources.

1.2. Allocating capital for net zero

The financial sector facilitates net zero through project financing and capital allocation. Project financing provides the up-front capital required for large-scale energy investments such as developing low-carbon generation. Capital allocation provides funds to companies in the form of equity investments via share purchases and debt finance from banks. A climate finance transition has begun. For example, project financing is adjusting to the carbon-constrained future, with investors demanding higher returns for carbon-intensive energy projects.[13] Most finance providers in the UK will be required to disclose climate portfolio risks from 2023.[14]

The financial sector signals perceived constraints, opportunities and risks in markets through the allocation of capital. Climate risks are generally evaluated based on companies' net zero transition plans. However, at present these are not easily comparable nor are they usually supported with practicable strategies.[15] The movement towards climate financial disclosure will therefore evolve to require demonstratable mechanisms to 'prove' the veracity of climate plans. Finance providers, including investors, asset managers, banks and insurers, could then more easily evaluate and ameliorate the climate exposure of their investment portfolios.

Credible signals of intent must incorporate aggregate market forces. For example, airlines propose reaching net zero using significant quantities of biomass.[16] However, the total supply of biomass in the UK and globally is limited by sustainability and biodiversity concerns. In the face of competition with other users, it is unlikely that all airlines

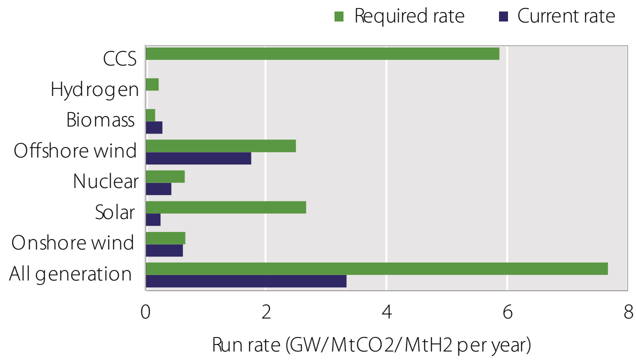

Figure 3: Construction requirements of net zero. Run rate refers to annual capacity additions. Requirements based on CCC forecast and analysis from Atkins.[11]

will be able to secure sufficient biomass to achieve their proclaimed net zero pathways.

A mechanism that enables companies to secure future access to zero emissions resource requirements would enable long-run forecasts of aggregate market demand and supply. This would reveal systemic risks to the financial system and wider macroeconomy.

Timescale of risk

Climate change operates on a scale of decades and centuries. This is beyond the business cycle, political cycle, and the regulatory oversight of most authorities. For example, one stakeholder highlighted the limited timescale of electricity regulators, who consider scarcity only on four year timeframe, because that is the period necessary to build a new natural gas generator. Mark Carney, the UN special envoy for climate action and finance, refers to this as the 'tragedy of the horizon'[17]:

The catastrophic impacts of climate change will be felt beyond the traditional horizons of most actors – imposing a cost on future generations that the current generation has no direct incentive to fix.

- Mark Carney, 2015

Addressing resource constraints, achieving efficient capital allocation and utilising tomorrow's commercial opportunities requires looking past a two to five year investment horizon to consider the next three decades of economic transformation. Financing decisions today will affect long-run markets, particularly for sectors which change slowly. Farsighted investments are essential in addressing the long-term systemic risks of climate change: shareholders and investors will face precipitous losses in a >2°C future. Finance providers therefore have significant influence in mitigating long-term climate financial risk and with the right mechanisms in place will find commercial rewards from improved foresight.

2. Proposal: ZERPA markets

This report proposes a new market-based mechanism to allocate future resources efficiently, using Zero Emissions Resource Procurement Agreements (ZERPAs). ZERPAs will price future zero emissions resource supply, reveal scarcity prices and highlight aggregate constraints on future resource use.

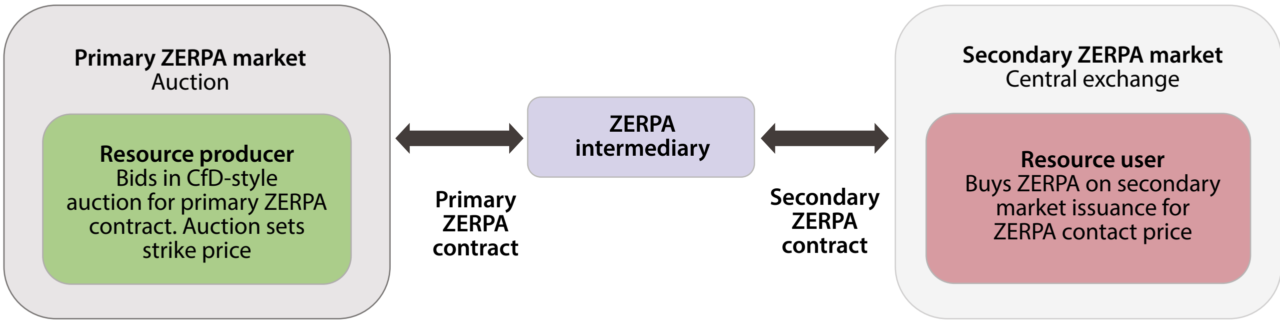

Figure 4: Primary and secondary ZERPA contracts

ZERPAs use prices to generate credible market signals. Resources prices reflect the balance of supply and demand and the expectation of future market conditions. Primary ZERPAs set long-run prices and are similar to Contracts for Difference (CfDs), the UK government's existing mechanism to support renewable energy projects. When a company purchases a secondary ZERPA, they receive the contract's delivery promise and take on the contractual obligation to pay the agreed strike price. Secondary ZERPAs allow private companies to secure their supply of zero emissions resources, hedge prices, and signal their net zero strategy to increasingly climate-aware finance providers.

ZERPAs will replace existing mechanisms for long-run resource allocation, which focus on supply in the non-emitting electricity market. This misses two points: first, they do not incorporate demand for zero emissions resources. Second, industries which cannot be electrified will require alternative resources: biomass or negative emissions. ZERPAs address these gaps. Unlike CfDs, they utilise both demand and supply signals to reveal future market conditions. They are available for all zero emissions resources, and over the entire period to the net zero 2050 target. Finally, they will be standardised and facilitated by an intermediary, so available to many different market participants – not just large users, like the complex Power Purchasing Agreements (PPAs) used to set long-run electricity prices in the private sector. Section 4.3 compares specific features of ZERPAs to existing mechanisms.

The remainder of this section provides more detail on the primary and secondary ZERPA markets. It then discusses potential structures of ZERPAs for each type of resource; the role of the intermediary; market implications. Additionally, a case study in the steel sector is presented, developed in collaboration with ArcelorMittal. The following sections use several key price terms:

- **ZERPA strike price:** Constant price for long-run delivery of resources under ZERPA contract, determined in primary ZERPA auction, for per unit delivery of resources.
- **ZERPA contract price:** Variable cost of purchasing a secondary ZERPA contract from the central exchange. The ZERPA contract batch price refers to the price of the entire project; the ZERPA contract unit price refers to the (expected) average p/kWh for that project.
- **Wholesale spot price:** Variable spot price for resources on the wholesale market.
- **ZERPA top up:** Variable difference between the wholesale spot price and the strike price.

2.1. Primary ZERPAs: Allocating contracts in resource auctions

The primary market will facilitate long-run contracting with zero emissions resource producers by building on current CfD auction mechanisms. These auctions will be facilitated by an intermediary: either a government agency or a commercial exchange (the role of the intermediary is discussed in Section 4.4). ZERPA contracts will then be accredited based on the likelihood of contract realisation.

ZERPA auctions will have three key differences to CfD auctions:

1. **Expanded scope:** ZERPAs can be allocated for any type of zero-emissions resource.

Primary ZERPA market

Participants	Resource producers, ZERPA contract intermediary, accreditation intermediary
Mechanism	Sealed bid pay-as-clear auction, resource certification
Timing	Regular, scheduled auctions with frequency set to meet demand
Contrcts	Primary ZERPA between resource producer and intermediary
Price	ZERPA strike price
Price determinants	Wholesale spot price expectations. Estimated levelised cost of resource.
Risk Management	Accreditation of producers/bids by accreditor Contract design includes physical and financial pre-qualifications

Table 1: Features of the primary ZERPA market

2. **Distant commissioning dates**: For example, a producer might place a bid for delivery beginning in 10 years. Such contracts would support innovation and infrastructure planning.
3. **Stricter financial pre-qualifications:** A charge will be collected at time of bidding, which is forfeited if the producer fails to deliver a contract. Such charges have been shown to increase the realisation of contracted projects.[18]
4. **Technologically neutral**: CfDs are generally allocated only to technologies for which the government wishes to catalyse a market—more mature technologies, including solar and onshore wind, have been excluded from past CfD auctions. ZERPAs will be technologically neutral.

For producers, primary ZERPAs offer a way to derisk revenue streams by setting a guaranteed price far into the future. This will reduce barriers to project investment, which can be challenging without price security. As one energy investment expert put it, the dearth of long-run contracts means "there is a large amount of low cost capital that is essentially sitting on the sidelines". For renewable generators, particularly those utilising mature technologies, one of the core business challenges is finding cheap capital for investment. Long-run ZERPAs will address this problem.

Derisking revenue is very appealing, and would allow us to access lower cost of capital.

– Stakeholder, Ørsted

Accreditation

After contracting, an independent accreditation intermediary will verify and rate contracts based on the probability that the project will be realised. Accreditation can build on existing methods for project finance evaluation[19] and pre-generation checks under CfD, such as the requirement for a 10% capital investment within a year of contracting.[20] Pre-generation checks will be more complex for the ZERPA mechanism due to long commissioning dates. The same principles can nonetheless be applied.

Once resource production begins, the accreditation agency will allocate ZERPA certificates for each unit sold. Similar certification is undertaken today by Ofgem, for the Renewable Energy Guarantees of Origin (REGO) scheme. ZERPA certificates will be crucial for the secondary ZERPA market.

Secondary ZERPA market

Participants	Auction agency, ZERPA contract intermediary, resource users, investors
Mechanism	Central exchange for secondary ZERPAs, ZERPA certificates.
Contract	Secondary ZERPAs between resource user and intermediary
Price	ZERPA contract price
Price determinants	Demand and supply in secondary ZERPA exchange. Wholesale prices and expectations.
Risk management	Accreditation means riskier contracts will be cheaper. Technology risk potentially underwritten by government agency. Market provides aggregation of potential energy futures.

Table 2: Features of the primary ZERPA market

2.2. Secondary ZERPAs: Reselling contracts to private users

After each auction round, the intermediary will issue secondary ZERPAs to a central exchange. Secondary contracts will be linked to primary ZERPA allocation, but may be sold in smaller batches, for example separating the generation of one wind farm into many secondary contracts. The contracts can be purchased by users or investors at the ZERPA contract batch price. ZERPA holders are then obliged to pay the strike price for delivery of resource under the contract specifications.

When a company purchases a secondary ZERPA they agree to pay the ZERPA top up, effectively hedging resource prices over the contract duration. ZERPAs also offers buyers:

1. **Priority market access:** When resource constraints bind, contracted buyers will have priority access to a quantity equivalent to the contracted amount.
2. **ZERPA certificates:** Trade will be verified using certificates as the virtual procurement vehicle. Trading electronic certificates requires no additional delivery infrastructure.

Once issued into the secondary market, ZERPAs can be continually traded in a central exchange, much like stocks. Trading reduces risks. Companies can resell their obligations if they no longer need the resources, instead of defaulting on the contract. While trading reduces the power of ZERPAs as a climate commitment signal (if companies can 'trade out' of ZERPA procurement), its risk-reduction effect vastly increases the appeal for companies who may otherwise be hesitant to commit to long-run prices.

Secondary ZERPAs may be purchased by large resource users, such as industrial producers, for direct procurement. They may be purchased by demand-side intermediaries, who could subcontract to smaller companies or consumers for smaller quantities or shorter durations. Like electricity retailers or hedge funds, these risk-diversifying intermediaries will likely arise as a natural consequence of establishing a secondary ZERPA market. Trading offers a role for investors in the ZERPA market, who could provide liquidity to enable trading and price realisation.[21]

The secondary market price of ZERPAs as a unit of account

Shareholders can use ZERPAs to evaluate whether a company will be able to deliver on their climate strategies. This will support the allocation of capital towards genuinely climate-aligned firms and reduce the climate exposure of asset owners. Large funds and regulators can also use prices as aggregate signals of supply and demand for zero emissions resources. The contract price of ZERPAs on the secondary market will depend on the supply and demand for contracts. At a market level, these prices will also proxy future supply and demand for the resources themselves. When future resource demand is high, either due to economic forecasts or a desire to signal net zero compatibility, more companies will want to secure their supply arrangements using ZERPAs, pushing secondary contract prices up. Prices will act as a unit of account to signal future demand and supply. High ZERPA contract prices will indicate a risk of resource constraints and incentivise allocation of resources toward addressing the supply constraint or reducing demand.

Primary and secondary ZERPA transactions

The market operations of both ZERPA markets are illustrated in Figure 5. A producer contracts with the intermediary in the primary ZERPA auction at time t=0. The contract is certified, and the intermediary then immediately issues the contract to the secondary market, where it is purchased by resource user A. The ZERPA contract binds at t=t0, the commissioning date at which the project begins delivering zero emissions resources. Delivery is certified by the intermediary, and the producer delivers resources and certificates to the user while the user transfers the strike price to the producer. (The effect of virtual procurement on this operation is explored below) A third market operation may occur if user A decides to trade out of their ZERPA. At this point, t=T, they issue the remainder of the contract back to the secondary market and receive the secondary market contract price from the purchaser, user B, who then trades with the producer.

Open questions: Volatility

How will ZERPAs be accounted for on companies' balance sheets?

Should ZERPAs include a reopener clause?

Contract volatility for resource users

The ZERPA mechanism can and should be designed to limit buyers' exposure to secondary market volatility to increase participation. Accounting for contract volatility on balance sheets depends on whether the contract is held to maturity or available for trade. For corporate PPAs, generally held to maturity, accounting practices depend on contract features such as how much influence the buyer has over the generator's operation.[22] ZERPAs are tradeable so will probably be accounted as available for trade. This can create significant balance sheet volatility. However, a large and liquid market for ZERPAs would likely stimulate a healthy market for ZERPA derivatives (similar to the market for derivatives of the EU Emissions Trading Scheme) which companies can use to hedge secondary market volatility. Another potential way to mitigate price-related volatility is to include 'reopener' clauses into ZERPAs, whereby certain parameters of the contracts could be negotiated at pre-agreed intervals, such as every five years. This would likely limit any major, long-term divergences between the ZERPA strike price and resource spot prices.

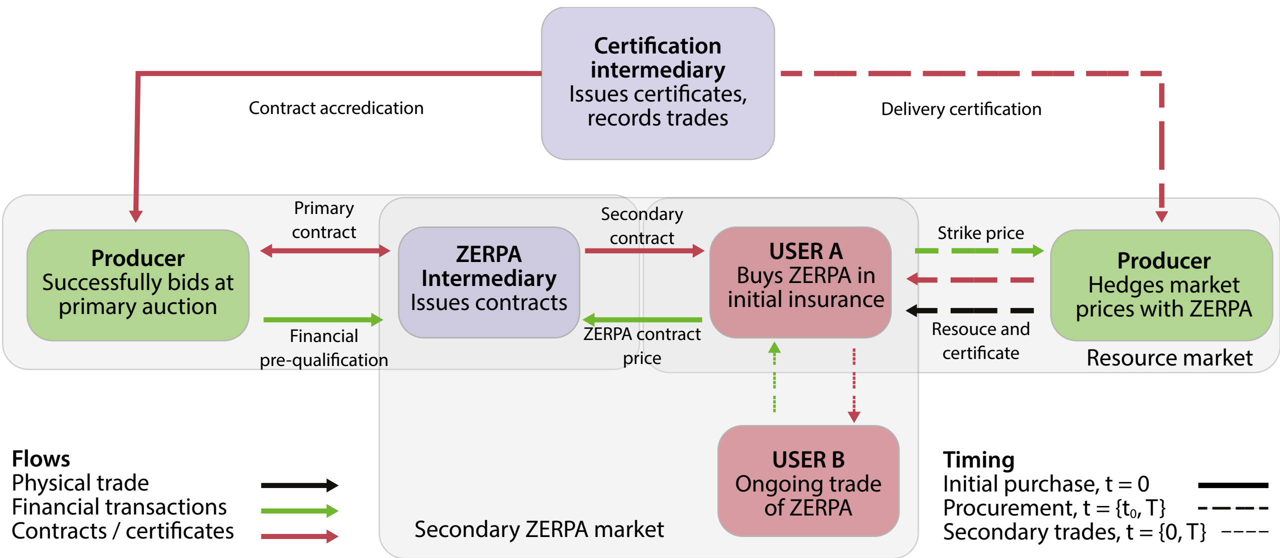

Figure 5: The operations of the primary and secondary ZERPA market.

2.3. ZERPAs for each type of resource

This proposal spans three resources. In the first instance, it will cover non-emitting generation, biomass and negative emissions. In future the scheme might be expanded to hydrogen (which must be created using these three initial ZERPA resources), storage and other resources as demand grows. Each resource market has different features; ZERPAs contracts will reflect these differences. Two questions stand out: will contracts be for virtual or physical procurement? How should network costs be allocated across counterparties?

Non-emitting electricity

The government's *Ten Point Plan for a Green Industrial Revolution* set a target to quadruple the supply of non-emitting generation from offshore wind over the next decade, and deliver more nuclear power.[6] Non-emitting electricity will therefore play a substantial role in the UK's low carbon future. However, it is the most complex market and has several peculiarities which must be accounted for in the design of ZERPA contracts.

First, electricity is delivered through the transmission and distribution networks. The infrastructure required to connect generators and users of electricity precludes direct contracts for physical delivery between ZERPA counterparties as they would be prohibitively expensive. To avoid this problem, ZERPAs for non-emitting electricity would probably be virtual contracts: physical procurement will remain on the wholesale market, and prices will be secured by an additional financial settlement between counterparties. The physical and financial flows of financially settled ZERPAs are illustrated in Figure 6, for the example of the electricity market. They are contrasted against a physically settled market, such as biomass. The payment of ZERPA top ups and strike prices would probably be facilitated through a central clearing house. Virtual contracts mean that ZERPA holders consume whatever is in the generation mix at a given time but pay for clean electricity supply. Priority market access compensates them for this positive externality.

Second, renewable generation is inherently intermittent, producing electricity when the sun is shining or the wind is blowing. Other forms of non-emitting electricity are dispatchable on demand—known as 'firm power'—including nuclear and hydropower. There may be a case for separating electricity ZERPAs into intermittent and firm contracts. Intermittent contracts could specify the delivery of a fixed amount of electricity over a period; firm contracts would offer supply at specific times and would be more expensive. On the supply side, the price differential between intermittent ZERPAs and firm ZERPAs would stimulate investment by renewable operators into storage options such as batteries. On the demand side, the price differential would incentivise the flexibility measures that allow users to capitalise on cheap renewable electricity when it is available.

Open questions: Intermittency

Should there be separate ZERPAs for variable non-emitting generation (renewables) and firm non-emitting generation (nuclear)?

How will ZERPAs for non-emitting electricity account for intermittent generation?

ZERPAs' approach to intermittency can draw on the structure of renewable CfDs and PPAs. Intermittent generation creates two contract risks: 'volume' risk, which considers the likely output over a period of time, such as a year, and 'shape' risk, which considers the hour-to-hour variability

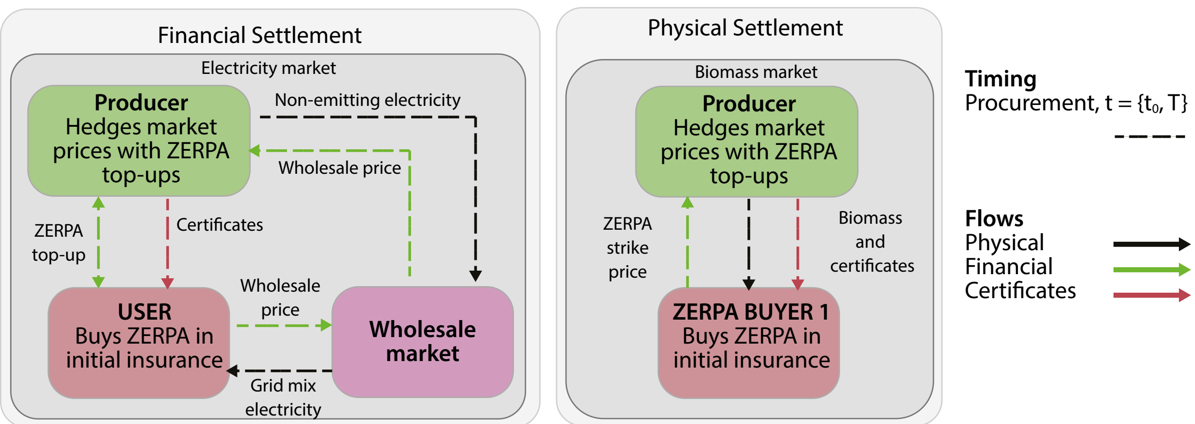

Figure 6: The market flows for financially settled 'virtual' ZERPAs versus physically settled ZERPAs

of demand.[23] CfDs do not have any particular volume or shape requirements; the government guarantees the price of any electricity produced. Under PPAs, corporate users often have volume and shape requirements. PPAs may therefore specify a minimum output requirement over defined periods, or specify arrangements with utilities to cover intermittent shortfalls.[23] Non-emitting electricity ZERPAs can draw on this precedent.

Finally, the intermittency of renewable generations means that the electricity grid will require more flexibility infrastructure to balance demand and supply. The cost of these measures must be allocated between market participants. They are currently funded through levies on electricity suppliers. Cost allocation under ZERPAs remains an open question; one possibility is that the funds generated in initial secondary market sales are earmarked for grid flexibility investment.

Biomass

Biomass also plays a key role in the government's net zero transition plans. Delivery is less complicated than for non-emitting electricity, but the sector as a whole requires more oversight to avoid unsustainable practices. Physical biomass products can be delivered using existing transport networks, making trade between counterparties much more straightforward. As a result, ZERPAs for biomass could be physical contracts, meaning they would be settled by physical delivery and direct payment between producer and user, rather than with a financial transfer of the ZERPA top-up. Physical contracts remove the need for intermediary trade on the wholesale market. Physical settlement is illustrated in Figure 6.

Open questions: Flexibility infrastructure

How much should ZERPA counterparties pay for flexibility infrastructure?

Open questions: Physical or financial settlement

Can some ZERPA contracts specify physical delivery rather than financial settlement?

Case study: ZERPA-backed green steel

Developed in collaboration with ArcelorMittal

Steel is a key component in the modern world, used in construction, manufacturing, household appliances and infrastructure. It is also a carbon intensive industry. The way forward lies in 'green steel', produced in innovative processes using zero emissions energy sources such as non-emitting electricity and green hydrogen. ZERPAs offer a way for steel manufacturers to secure long-run procurement of these essential resources in the net zero transition.

ArcelorMittal is Europe's biggest steelmaker and a leader in decarbonising the industry. However, like any business, they are wary of the costs of net zero steelmaking, which they estimate to be between EU15bn and EU40bn. Executive chairman Lakshmi Mittal says net zero technologies "will increase the cost of our steel. It is not cheap, and our customers should be ready to pay."[26]

ArcelorMittal could use ZERPAs to secure the resources necessary for non-emitting steel production. ZERPA-backed steel would be certifiably 'green': the verification process for resources in the primary market would allow ArcelorMittal to prove the current and future carbon neutrality of their steel. Investors can price the strategy in to future profit forecasts and customers can distinguish ArcelorMittal's steel as genuinely non-emitting.

Any derived instrument should make it clear to consumers that the product is clean steel, to justify higher prices.

– Stakeholder, ArcelorMittal

Since production is backed by long-run ZERPAs, ArcelorMittal would be able to offer customers long-run procurement contracts for zero-emissions steel. These contracts would fund in-house innovation. Establishing the ZERPA mechanism would stimulate a tertiary market for derived contracts for ZERPA-backed procurement.

Biomass resources face a particular challenge not present in other markets: it must be sourced sustainably, to avoid negative effects on food crops, land use and biodiversity. Biomass ZERPAs must be developed with this in mind, and there may a role for the accreditation agency to oversee and enforce sustainable practices amongst suppliers.

Negative emissions

Negative emissions can also be facilitated by physical contracts. In some cases, negative emissions technologies must be co-located with the emitting process, such as for gas or biomass energy with CCS. Other forms of negative emissions, such as natural sinks, do not have to be physically co-located for meaningful trade. Either way, trade can operate with physical 'delivery' where delivery refers to the process of transporting and storing carbon. This will require significant infrastructure. Developing this infrastructure is a key goal of the government's *Ten Point Plan*, and negative emissions ZERPAs will need to consider how this infrastructure is funded. Like electricity, the revenues from the initial sale of secondary ZERPAs may be allocated into a CCS infrastructure fund.

Negative emissions technologies are relatively new and have not yet been commercialised at scale. However they are essential components in the current plans of some industries. Given the challenges of developing scalable CCS2[4,25], there may be significant unmet demand for negative emissions in the 2030s and 2040s. ZERPAs will provide investors, energy and climate regulators a sense of the scale of reliance on unproven technologies. This can be used to evaluate risks if these technologies are unsuccessful or slow to mature and stimulate the development of alternatives to existing industrial operations.

2.4. The role of the intermediary

The success of the ZERPA mechanism depends on three features:

1. **Coordination**: Balancing signals of demand and supply to facilitate trade and price revelation.
2. **Risk sharing**: Mitigating the risk and volatility involved in long-run procurement contracts.
3. **Verification**: Accrediting primary contracts to ensure high likelihood of project realisation, and verifying the delivery of genuinely zero emissions resources once delivery begins.

Where these requirements cannot easily be met by market forces, there is a role for a market intermediary. Today's future allocation mechanisms operate both with and without an intermediary. Under CfDs, the government acts as a counterparty—but the contract is supply-side only. PPAs do not usually operate with an intermediary, and this contributes to their expense and inconvenience for users. The futures market, which trades financial contracts for commodities and financial assets, operates via a commercial futures exchange that coordinates trade and manages risk.

The intermediary faces three major types of risk. First, the risks of contract default by either counterparty. In primary ZERPAs, this may occur due to technological barriers to deployment, particularly for contracts with long commissioning dates and more speculative technologies. In secondary ZERPAs, a user might default if they are no longer able to use the resource—for example due to bankruptcy. Trading mitigates default risk. Second, the risk that projects are able to deliver but do not meet the contract's specifications, for example delivering too little resource, or a delayed start date. Depending on the market structure, it may be the intermediary's responsibility to ensure contract delivery via the wholesale market for these project-level risks. Finally, idiosyncratic or policy risks which affect both the supply and demand side of the market. These include macroeconomic downturns which dampen demand, natural disasters which affect market supply, or changing legislation. Given the uncertainties of long-run contracting, we anticipate that a ZERPA market will require an intermediary to provide some form of contract insurance.

Open questions: Insurance

How much insurance is necessary to secure participation?

Will insurance create moral hazards that would undermine efficient signalling?

Commercial or public intermediaries

The intermediary can be a private company, like the futures exchange, or a government body, like the Low Carbon Contracts Company which is the CfD counterparty. Companies may take on the role of the intermediary where there is an opportunity to make a profit on the risk spread between primary and secondary contracts. However, government may be a more appropriate intermediary if market failures are inhibiting the delivery of its overarching net zero strategy. In particular, the level of government involvement might vary depending on the risk profile of particular resources. For example, CCS is key to the *Ten Point Plan*, but a highly risky technology. The government may be willing to take on some contract risk for negative emissions to facilitate market operations by reducing market participants' exposure to technology risks. This has precedent in large-scale infrastructure projects: the UK government took on the sizeable and highly uncertain financial responsibility for the long-run storage of nuclear power waste to enable safe and efficient operation of the commercial nuclear generation market.[27] More recently, it also provided contingent financial support for several types of risk in the construction of the Thames Tideway Tunnel Project.[28] The government may have a similar role in ZERPAs where technology risks are high. Private companies may be willing to take on the role of intermediary for more established markets where technologies are less risky and infrastructure is better developed.

Open questions: Government's role

Will the government act as a contract intermediary, or just facilitate auctions and trade?

Can and should the government mitigate technology risks to encourage participation?

What are the delivery bodies for ZERPA?

2.5. Market implications

Primary ZERPAs will support the growing role of zero emissions resources in the UK economy by stimulating supply. Secondary ZERPAs will support efficiency by generating long-run demand signals. This section considers the effect of various market scenarios under ZERPAs.

Temporary shocks to resource supply and demand

Under both demand and supply shocks, resource constraints bind temporarily. Market supply can no longer meet market demand; the priority market access clause of ZERPAs is enacted, allowing ZERPA-contracted users to secure their supply ahead of non-contracted market participants. This then tightens the shortage in the residual market for non-ZERPA supply, and increases the wholesale market price. These effects are illustrated in Figures 7 and 8. Figure 7 shows a short-run increase in resource demand, such as for electricity during periods of high heating or cooling requirements. The increase in demand is coupled with a ZERPA-induced supply contraction as ZERPA-contracted users secure their supply via priority market access. Figure 8 illustrates the contrasting effect of a short-run supply shock, for example if intermittent renewable electricity sources are not generating or biomass stocks are damaged by a poor harvest. The external shock is then exacerbated by the ZERPA-induced supply contraction.

In an unconstrained economy, the balance between demand and supply gives rise to a market equilibrium at quantity Q1 and price P1. When the market equilibrium increases beyond the resource constraint at Q2, prices increase to the constrained price on the wholesale market P2. Once resource constraints bind, ZERPA-contracted resource claim their allocated supply. Resource users who do not hold ZERPA are forced to pay the residual scarcity price P3 to secure resources, over and above the constrained wholesale price P2.

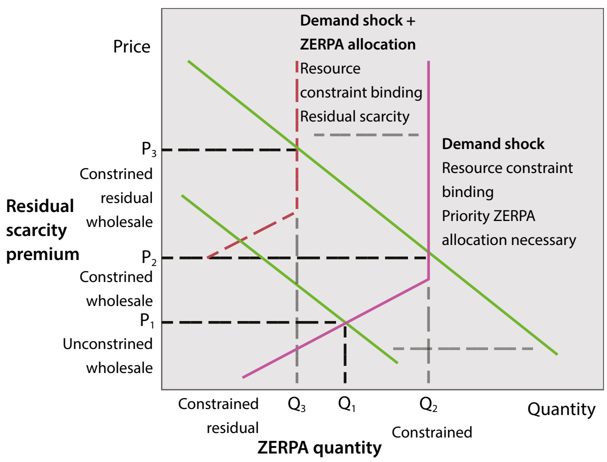

Figure 7: The effect of a demand shock on a resource market under ZERPAs

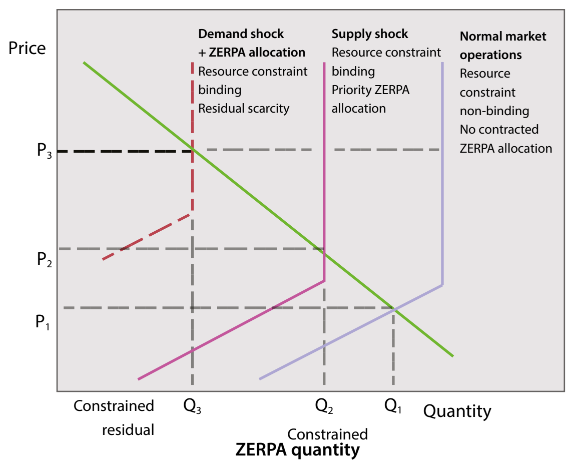

Figure 8: The effect of a supply shock on a resource market under ZERPAs

ZERPA price outcomes in constrained resource markets

There are two potential scenarios for future zero emissions resource markets. Resource constraints could bind: supply will be unable to meet demand and market shortages will lead to resource price hikes. Alternatively, supply expansion could enable a looser resource market where constraints do not bind. As discussed in Section 1, it is probable that resource constraints will bind in the transition to net zero.

ZERPA prices will reflect expectations of future resource constraints. In an efficient market with a sizeable share of ZERPA-contracted supply, the unconstrained wholesale price will converge to the in-year ZERPA strike price (or the average strike price), due to the possibility of ongoing contract trade on the secondary ZERPA market. This means that the price payoff of holding ZERPAs during a supply or demand shock is the difference between the constrained residual price, P3, and the unconstrained wholesale price (or strike price), P1. Non-contracted users pay a residual scarcity price premium and may be unable to secure resources at all.

Along with wholesale prices, aggregate resource constraints affect contract prices in the ZERPA-secondary market. When constraints are binding, the value of holding a ZERPA is high and in-year contracts will have a high resale value. The opposite is true when resource constraints are non-binding. There are therefore two potential scenarios for resource markets under a ZERPA mechanism:

Table 3 summarises the outcomes for each market party under binding and non-binding aggregate resource constraints.

Party	ZERPA position	Outcome
Binding resource constraints: High wholesale resource prices, high ZERPA contract price		
Intermediary	Counterparty	Contractually bound to buy and sell resources at ZERPA strike price. Position perfectly hedged.
Resource producers	Primary ZERPA contracted	Contractually bound to sell resource below wholesale spot price to ZERPA counterparty.
	Not contracted	Can sell at high wholesale spot price
Resource users	Secondary ZERPA contracted	Contractual right to buy energy below market value, or option to sell ZERPA
	Not contracted	Can only buy at high wholesale spot price
Non-binding resource constraints: Low wholesale resource prices, low ZERPA contract price		
Intermediary	Counterparty	Contractually bound to buy and sell resources at ZERPA strike price. Position perfectly hedged.
Resource producers	Primary ZERPA contracted	Contractual right to sell resources above wholesale spot price to ZERPA counterparty
	Not contracted	Can only sell at low wholesale spot price
Resource users	Secondary ZERPA contracted	Contractually bound to buy resources above wholesale price. In-year ZERPA resale worthless
	Not contracted	Can buy at the wholesale spot price

Table 3: Impact of binding and non-binding resource constraints on market participants under ZERPA

Stress testing

Any resource market mechanism must be resilient to adverse shocks. Table 4 shows the in-built reactions of market participants to adverse shocks which mitigate risk under ZERPAs.

Adverse shock		Concern	Reaction
Project level supply-side risks	Construction delays	Energy not available when contract comes to term	Supplier compensates user if resources unavailable or expensive on wholesale market
	Output less than predicted	Energy not available when contract comes to term	Supplier compensates user if resources unavailable or expensive on wholesale market
	Output more than predicted	Oversupply under ZERPA	Additional supply sold to wholesale market at wholesale price
	Output intermittent	Short-run supply and demand imbalance	Wholesale market pricing and capacity mechanisms
	Supplier bankruptcy	No supplier	Bankruptcy procedures. Potential role for intermediary risk management.
	Supplier reneges on agreement	No supplier	Credit rating, law enforcement. Potential role for intermediary risk management.
Project level demand-side risks	Buyer bankruptcy	No buyer	Buyer can sell ZERPA on secondary market. Potential role for intermediary risk management.
	Buyer renegues on agreement	No buyer	Credit rating, law enforcement. Buyer can sell ZERPA on secondary market. Potential role for intermediary risk management.
Market risks	Energy shortages in 2050 and all supply committed	Strong incentives to revert to fossil fuels	Government regulation for net zero resource use (not ZERPA mechanism).
	Mass speculation in inflates price	Distributional impact	Limit access to ZERPA market to those who can prove resource needs
	Inflation	ZERPA value eroded	Strike prices set to real value
	New legislation bans contracted use of resources	ZERPA delivery banned	Government buys back contracts which have been invalidated by new legislation

Table 4: Stress testing the ZERPA mechanism

3. Establishing ZERPAs as part of the UK's climate strategy

Rolling out the ZERPA mechanism in the UK can be undertaken as an extension of today's CfD auctions. The first round will indicate secondary demand for ZERPA contracts.

Some aspects of implementation depend on specifics of the mechanism which are not prescribed in this proposal, such as the role of the intermediary. They can be evaluated and ameliorated as the price, demand and sectoral uptake of ZERPAs is realised. Implementing the mechanism can be undertaken in four steps, illustrated in Figure 9. Government procurement could support and accelerate the implementation of ZERPAs. The UK public sector consumed 18TWh of electricity, 40ktoe of biomass and emitted 7.9MtCO2 in 2019[29,30]. Government could purchase secondary ZERPA contracts to secure their own supply of zero emissions resources. This would establish a ZERPA contract price and increase liquidity in the secondary market.

Protecting vulnerable resource users

Mitigating the distributional impacts of resource scarcity will also require government intervention. Current policy protects essential services such as hospitals from demand disconnection during blackouts[31]. A similar scheme may be used in a resource market under ZERPAs, whereby the government secures resource allocation for essential sites. Another way to mitigate the impact of high scarcity prices on non-ZERPA-contracted users may be to earmark a certain portion of production for non-ZERPA sale. Ensuring affordable energy for consumers is a key priority for government. As resource constraints tighten, additional support will be required for vulnerable citizens who may face higher prices for energy and consumer goods. Power price increases are regressive, placing a heavy burden on poor households who spend a higher share of their income on these products[32]. This effect was seen after the implementation of carbon pricing[33]. The government has a role to reduce harm, building on existing policies that limit electricity prices and lump-sum charges for vulnerable customers. Policies to counteract potential negative distributional effects of resource constraints should tackle them directly, either by supporting vulnerable resource users or adjusting social benefit payments to reflect higher living costs. This avoids distorting the aggregate market signals of scarcity and demand which will incentivise the transition to zero emissions resources.

The potential for international ZERPA market

As global climate ambition—and climate financial risk management—grows, the ZERPA scheme can be expanded. ZERPAs could be implemented in individual countries, at a level of ambition commensurate with that country's climate targets. Linking international ZERPA markets could increase participation and market liquidity. Because they capitalise on commercial incentives for price security and climate commitments, ZERPAs will sidestep some of the problems faced by the alternative policy of carbon taxation, which generates incentives to shift production—and emissions—offshore to avoid the tax. Some carbon pricing schemes operate across multiple markets, such as the EU and UK Emissions Trading Schemes, and may provide guidance for interoperable ZERPA markets.

2023

Government announces ZERPA: One year ahead of the first ZERPA primary market auction and two years before first secondary market issuance, to allow producers, users and investors to plan and prepare.

2025

First ZERPA primary market auction: Run similarly to current CfD auctions, with some auction design adjustments to support distant contracting. Capacity and budget caps should be consistent with current CfD auctions. This will be the first auction available for biomass and negative emissions bidders. Successful bidders will be reviewed by the accreditation agency.

2026

ZERPAs issued to the secondary market: Contracts made available on a central exchange. Profits from the initial issuance accrue to the auction agency to cover costs. Secondary market trade is ongoing.

2026+

Ongoing primary auctions and secondary trade: After the first secondary market issuance, demand and prices will be used to guide the capacity and budget caps for future primary auctions. As more contracts are issued to the market and financial pressure for ZERPA-backed climate plans increases, secondary market interest will grow, potentially attracting speculators and other investors.

Figure 9: Proposed timeline to implementation of ZERPAs.

4. ZERPAs, climate policy and other mechanisms

Various alternative mechanisms might support the transition to a net zero economy and facilitate the efficient allocation of resources and capital. They can be classed into policy-supported market mechanisms and direct interventions, shown in Table 5.

Market mechanisms	Direct interventions
• ZERPAs: Long-term price agreements between resource users and producers. • Futures market: Buyers, sellers and speculators trade contracts for products traded in the future. • Electricity market reform (EMR): Redesign electricity markets so prices cover capital costs rather than based on short-run marginal costs. • Project financing model: Risk sharing across investors	• CfDs: Guaranteed future price support for renewable generation, allocated and funded by government. • Carbon pricing: Increase price of emitting products compared to non-emitting substitutes. • Regulations: Set requirements for companies to procure a set share of zero emissions resources. • Innovation funds: Government funds for low-carbon research and development.

Table 5: Potential market mechanisms to allocate future resources

Zero emissions resource allocation comes under market mechanisms, and would be a form of climate policy. ZERPAs build on the policies to stimulate innovation and deployment of low carbon technologies to meet the government's *Ten Point Plan*. For companies and shareholders, they offer tradeable contracts for long-run supply and price certainty, as well as verification of corporate net zero plans. Unlike common direct climate interventions such as carbon pricing or regulations, ZERPAs are aligned with commercial incentives for the climate transition.

4.1. ZERPAs through the lens of climate policy

The UK government has four guiding principles for transforming the power sector, summarised by Business Secretary Greg Clark in 2018:34

1. **Market:** wherever possible use market mechanisms that take full advantage of innovation and competition
2. **Insurance:** given intrinsic uncertainty about the future, government must be prepared to intervene to provide insurance and preserve optionality
3. **Agility:** energy regulation must be agile and responsive if it is to reap the great opportunities of the smart, digital economy, and finally
4. **No free-riding:** consumers of all types should pay a fair share of system costs

These four principles can be extended easily to include all zero emissions resources. They aim to deliver a low-cost, low-carbon, and secure energy system for the net zero transition, and can be used to evaluate policy proposals. Table 6 compares five possible allocation mechanisms under the four principles.

CfDs, carbon pricing and EMR have all been proposed or implemented as valuable energy market strategies in the pathway to net zero; indeed they all satisfy the four principles to some extent. ZERPAs also satisfy the four principles while offering three additional benefits: accounting for future aggregate resource constraints; establishing a tool to verify companies' climate strategies; and covering all three zero emissions resources. These benefits will be crucial in the path to net zero.

	ZERPAs	CfDs	Futures	Carbon pricing	EMR
Market principle	Auctions stimulate price competition. Secondary prices reflect demand.	Auctions stimulate price competition. Capacity caps reflect policy targets.	Full free market mechanism.	Taxes set based on climate targets. Permit prices set by supply and demand.	Prices determined based on long-run cost factors and demand.
Insurance principle	Government counterparty minimises default risk.	Government counterparty minimises default risk.	No government involvement.	Government sets prices, enforces compliance.	Incorporate other policies (eg, CfDs) to support optionality.
Agility principle	Quantity, type of primary resource; secondary ZERPA requirements adjustable.	Quantity, type of primary generation adjustable.	No direct energy regulation.	Taxes and permit quantity adjustable.	Pricing plan adjustable; can incorporate other policies.
No free riding principle	Cost of decarbonising resources borne by users via ZERPA contract price.	Cost of decarbonising electricity borne by customers via supplier levy.	No direct system cost sharing. Prices reflect future expectations.	Supplier costs and consumer prices theoretically reflect carbon-intensity.	Reduces externalities of low short-run marginal cost generators.

Table 6: Comparing mechanisms under the four principles

4.2. Review of alternative resource pricing mechanisms

Three alternative mechanisms for long-run pricing and allocation of resources exist and have been mentioned throughout this report. They could operate over distant time horizons, and address several different types of price risk. This section provides more detail on each alternative; Section 4.3 compares them to the proposed ZERPA mechanism.

Any future allocation mechanism will specify a long-run delivery price for resources, thereby eliminating the risks associated with fluctuating prices. For example, falling electricity prices will reduce generators' revenue, known as 'merchant risk', while benefitting users as their energy costs decline. The opposite is true as prices rise. Mechanisms which specify long-run prices eliminate merchant risk, which is usually a requirement for securing the loans necessary to finance new resource projects. Energy users also hedge their prices. The downside of price security is that neither party can benefit from any upside price fluctuations. If prices fall, users face an opportunity cost of price hedging as their non-contracted competitors benefit from lower prices. However, this opportunity cost is generally seen as an acceptable tradeoff for price security—particularly given the uncertainty in electricity markets over the coming decades.

Contracts for Difference

Public sector stimulus for zero emissions resources focuses on renewable electricity generation through CfDs, which guarantee a fixed price for electricity over a 15-year period. They are allocated in auctions run by National Grid. Separate auctions for different technologies ensure that nascent technologies stand a chance of getting contracts. National Grid sets a budget cap, maximum capacity and a maximum price for each auction, and bidders are required to fulfil a number of pre-qualification criteria, including grid connection agreements and spatial planning permits. CfD auctions are pay-as-clear, or uniform price, which means winners all receive the strike price of the highest winning bid. Under a CfD, generators continue to sell electricity on the wholesale market at the wholesale spot price. Price hedging is facilitated by the transfer of a variable 'top up' between buyers and producers, illustrated in Figure 10.

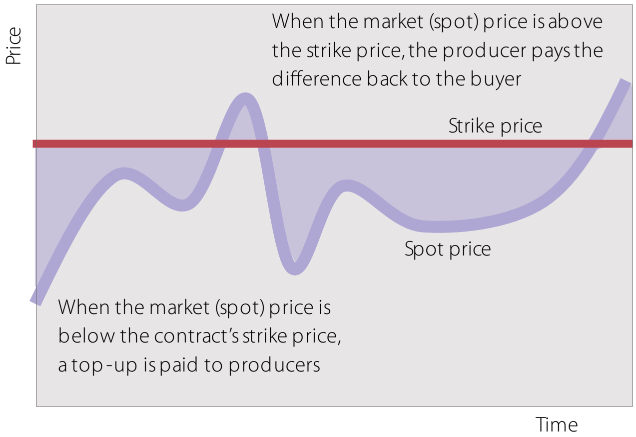

Figure 10: Financial transactions in Contracts for Difference

CfDs achieve swift increases in capacity compared to other renewables policies, but are expensive for governments.[35.] The capacity of awarded contracts has grown in successive allocation rounds, indicating strong market interest in price support mechanisms for resource suppliers.[36]

Corporate power purchasing agreements

Corporate PPAs are private-sector electricity supply agreements, usually brokered between electricity generators and users for delivery at an agreed price over several years. PPAs can be 'virtual', where each party still operates via the electricity grid and the contract specifies a financial transfer to mimic direct payment at the agreed price, or 'physical', where the generator directly supplies electricity to the user.

There is rising interest in PPAs, particularly for renewable electricity sources.[23] In 2015, PPAs totalling 3.8GW were signed; by 2020, they totalled 24.5GW.[37] Delivery prices have simultaneously fallen. The growth of PPAs signals both the growing interest in corporate sustainability and concerns over access to clean energy.[37] However, PPAs are costly to negotiate and tend to be agreed only by large corporations.

PPAs can be difficult for smaller players to negotiate, which creates barriers to the participation of small to medium-sized enterprises in the corporate PPA market. Getting them involved would be great.

– Energy investment expert, International Energy Agency

Addressing resource constraints across the whole economy will require a more standardised and less complex mechanism. The mechanism proposed here will draw on the growing demand for PPAs, while making them more accessible for small and medium-sized enterprises.

Futures markets

Futures markets are a commercial allocation mechanism where parties trade medium-term contracts for the future delivery of commodities or financial assets. Contracts are traded at a centralised exchange and standardised in size and duration. Futures contracts enable hedging to secure prices, and speculation by professional traders who bet on futures price fluctuations. Most futures contracts are financially settled: a financial transaction avoids the inconvenience and infrastructure of physical delivery between geographically dispersed counterparties.

Futures exchanges manage price risk by requiring a 'margin account', a cash collateral that is settled daily based on changes in the futures price between contract agreement and expiry. Daily maintenance of the margin account can become very expensive when the future price fluctuates heavily. Constant margin payments during periods of high market volatility negates some of the price hedging value of futures. Contracts are rarely offered more than two or three years in advance, meaning they have little value for long-term resource allocation. There are a number of contracts available for the delivery of UK electricity, though not non-emitting electricity specifically, and for some limited forms of biomass.

4.3. Comparison to existing mechanisms

Table 7 compares the ZERPA mechanism to CfDs, PPAs and futures markets across a number of dimensions.

	ZERPAs	CfDs	PPAs	Futures markets
Mechanism				
Counterparties	Producer–Intermediary User – Intermediary	Generator-Government	Generator - User	Buyer - Seller
Sectors covered	Non-emitting electricity; sustainable biomass; negative emissions	Low-carbon electricity	Electricity, usually renewable	Renewable electricity
Trade	Secondary exchange	None	None	Futures exchange
Supply-side incentives	Revenue certainty; access to project financing.	Revenue certainty; access to project financing.	Revenue certainty; access to project financing.	Price hedging.
Demand-side incentives	Price and supply security; credible climate signal.	No demand side participation.	Price and supply security; credible climate signal.	Price hedging; speculation.
Climate pledge verification	Share of pledges covered by ZERPA purchases.	Analytics only	Share of power covered by long-run renewable PPAs.	No long-term mechanism
Contract				
Contract size	Project; share of project	Project	Project; share of project	Standardised contracts
Duration	15-30 years	15 years	>10 years in UK	<5 years
Commissioning	Projects can have near or distant delivery dates	Projects typically start 2-4 years after auction	Delivery or construction usually begins soon after contracting	Typically only viable 2-3 years ahead
Settlement	Physical or financial	Financial	Physical or financial	Largely financial
Price				
Strike price units	Electricity: £/kWh Biomass: £/kg Emissions: £/tCO2	£/kWh	£/kWh	£/kWh
Price determination	Strike: Primary auction Contract: Secondary market	CfD auction	Wholesale spot price expectations	Futures market
Price restrictions	Long term purchase price set	Long term supply price set	Long term price set (can be indexed)	Prices set by market
Price signals of future shortages	ZERPA contract unit price > strike price	Analytics only	No market aggregation	Futures price > current spot price
Risk management				
Trust	Intermediary verifies trade, government may underwrite contracts.	Government counterparty guarantees price.	Contract enforcement	Credit rating, margin payments, law enforcement
Access to market	Wholesale market participants	Pre-generation checks	Large users only, due to high contract costs	Financial margin payments

Table 7: Features of ZERPA markets compared to existing resource allocation mechanisms

5. Open Questions

ZERPAs are a novel market mechanism. They would build on existing capabilities amongst regulators, government delivery bodies and commercial contract exchanges. However, just like the net zero challenge itself, ZERPAs pose unique challenges including market risk management and cost sharing. Table 8 reviews the open questions raised in this document and summarises relevant considerations for each.

Question	Considerations
Volatility	
How will ZERPAs be accounted for on companies' balance sheets?	Accounting practices determine secondary market volatility affects buyers' balance sheets. Volatility accounting should reflect the liability of a company to future downside risks in particular. Accounting for ZERPAs will build on existing methods for measuring liability under PPAs and financial instruments such as future contracts.
Should ZERPAs include a reopener clause?	Including a reopener clause would mean contracts could be adjusted for changing market conditions, and ZERPA strike prices would be unlikely to diverge hugely from the market spot price. This would reduce volatility and potentially increase their appeal to counterparties. However, it would also reduce their forecasting power, the certainty they offer to 'price' future climate commitments, and their standardisation.
Intermittency	
Should there be separate ZERPAs for variable non-emitting generation (renewables) and firm non-emitting generation (nuclear)?	The need for two different types of non-emitting electricity will depend on the development of flexibility and storage infrastructure. Price differential for different types of non-emitting electricity would stimulate innovation and deployment of flexibility mechanisms, but would make ZERPAs less standardised.
How will ZERPAs for non-emitting electricity account for intermittent generation?	Lessons can be taken from corporate PPAs. Common contract clauses include a minimum delivery requirement, which is then facilitated by intraday trading during periods of low generation.
Flexibility infrastructure	
How much should ZERPA counterparties pay for market infrastructure?	Markets require infrastructure to facilitate trade. This is especially true for non-emitting electricity and negative emissions. System costs must be share amongst participants; ZERPAs may be able to facilitate this using the revenue generated from initial issuance of contracts to the secondary market. Alternatives can be explored as infrastructure plans develop.

Settlement	
Can some ZERPA contracts specify physical delivery rather than financial settlement?	Settlement will depend on the type of resource and features of the market. Where physical settlement is easily available, this will probably be preferrable because links between supply and procurement will be easier to verify. Biomass and negative emissions face lower barriers to physical settlement, which may be preferrable in these markets.
Insurance	
How much ZERPA contract risk can be insured by government?	ZERPAs are proposed as a key mechanism to achieving UK targets for net zero, so the government may have a significant role in delivering the scheme. To facilitate market participation and overcome the market failures which currently inhibit trade, they may elect to take on some contract risk.
How much insurance is necessary to secure participation?	The amount of insurance or risk sharing necessary to achieve market participation must be determined as implementation progresses. The market should be designed with these incentives and risks in mind.
Will insurance create moral hazards that would undermine efficient signalling?	Insuring contract risk increases the 'option value' of entering into contracts: with little downside risk, producers and users will be more likely to enter into contracts which they are not certain they can fulfil. The need for insurance to increase liquidity must be balanced against moral hazards which could distort incentives and participation.
Government's role	
Will the government act as a contract counterparty/ intermediary, or just facilitate auctions and trade?	Viability of a commercial counterparty depends on the level of risk that a counterparty must take on. Government may have a role where technology/market is highly risky, or where market failures inhibit trade.
Can and should the government mitigate technology risks to encourage participation?	High technology risk could detract from the value of ZERPAs for companies. The government therefore may have a role to take on some of the liability of contracts in order to increase participation, similar to their role in the large and uncertain liability for decommissioning nuclear power plants.
What are the delivery bodies for ZERPAs?	The delivery bodies for ZERPA will depend on the government's role in the market. The current delivery bodies for Contracts for Difference involve National Grid and three government owned companies who act as contract counterparties and oversight bodies. The same structure could be utilised for ZERPAs. Involvement of a commercial intermediary may make a different structure more desirable.

Table 8: Open questions for implementation of the ZERPA mechanism

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