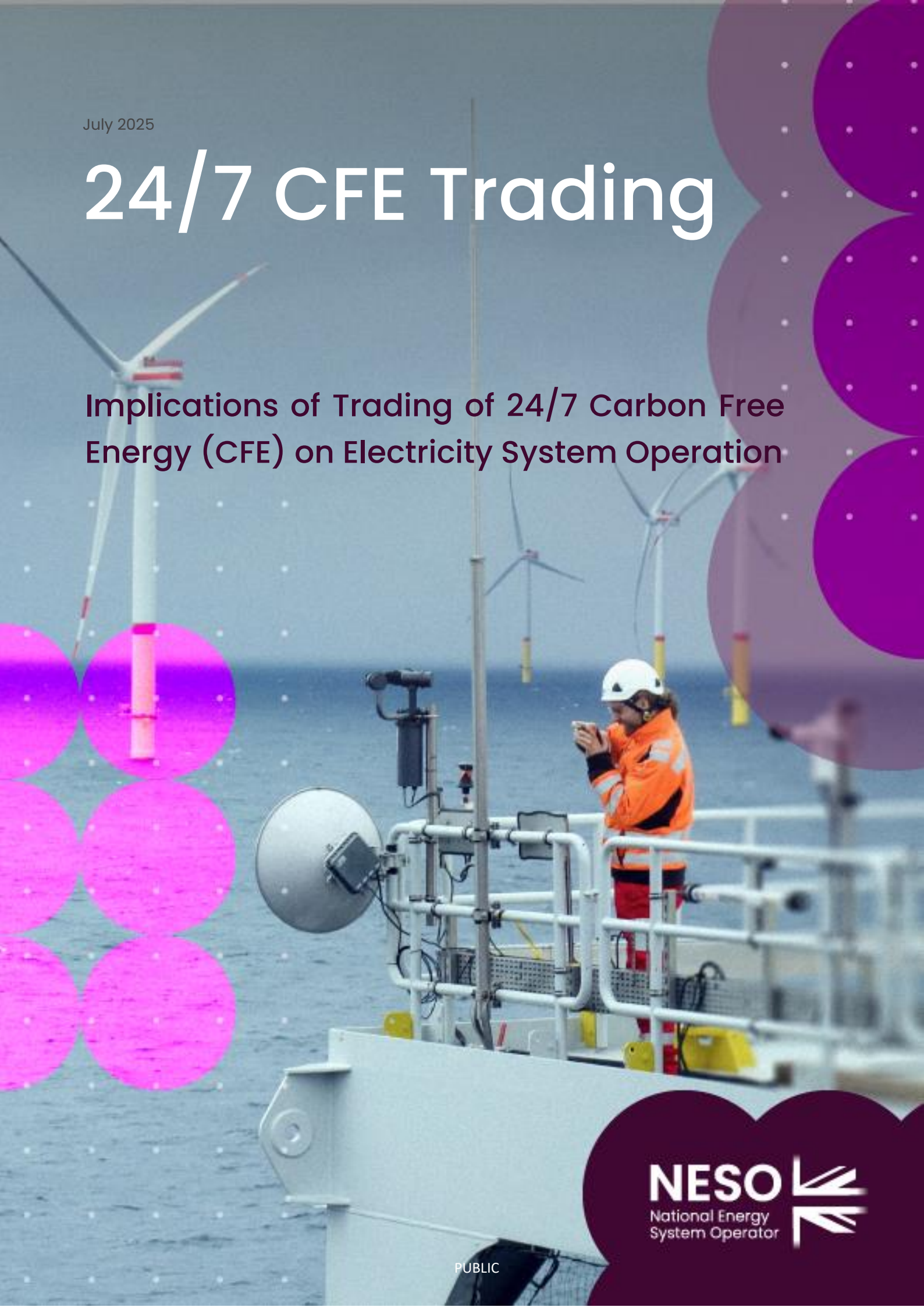
July 2025

24/7 CFE Trading

Implications of Trading of 24/7 Carbon Free Energy (CFE) on Electricity System Operation



NESO
National Energy System Operator

PUBLIC

24/7 CFE Trading Contributing Partners

NESO National Energy System Operator	National Energy System Operator (Lead)
AFRY	AFRY
granular energy	Granular Energy
NORD POOL A EURONEXT COMPANY	Nord Pool

Executive Summary

Moving to 24/7 CFE EACs (time matched carbon free energy attribute certificates) could support the goal of a net zero power system by 2030 by directing voluntary funds into creating a more flexible clean power system.

Energy attribute certificates (EACs) or Renewable Guarantees of Origin (REGOs) are used to support carbon reporting and renewable energy sourcing claims. EACs are used to offer optional 'green tariffs' to consumers when they purchase electricity. This directs consumer money into electricity system decarbonisation, by allowing consumers to choose Carbon Free Energy (CFE) or renewable electricity supplies.

In most markets, including Great Britain (GB), certificates match on an annual basis. This means that currently '100% renewable offers' may not align with the physical realities of the electricity system, with intermittent CFE sources not meeting consumption patterns in real time.

Changing to 24/7 (hourly or sub hourly) matching of CFE, via EACs, would address concerns of the credibility of certificates, by providing consumers with more transparency in carbon free energy procurement. Currently 24/7 CFE tariffs, generally offer 100% CFE matching on an annual matching basis, and report a high degree of matching (70% - 95%) on a granular basis. While some consumers, like Google and Microsoft, have committed to 100% granular matching by 2030, it is expected that for most consumers the target will be to have a granular percentage of matching that starts high and improves over time.

24/7 CFE EACs could also accelerate grid decarbonisation, by providing time-based signals for the use of CFE and demand side response (DSR) encouraging investment and innovation. This could be particularly powerful in incentivising growth in storage solutions, like batteries, and automation of DSR, particularly if longer term trades or contracts emerge. Currently storage and DSR are unable to participate in EAC markets, as the annual granularity does not create an ability to trade these certificates in a useful timeframe.

Consumer demand and reporting standards changes mean that 24/7 matching may scale quickly within the next 5 years. Carbon reporting standards are likely to move away from purely annual reporting, with best practices under The Greenhouse Gas Protocol (GHGP) already being reporting that is as granular as possible.

It is critical for NESO to understand implications for system operation, market design and dispatch patterns of this potential change. This project considers the NESO roles and interactions with system objectives, along with the potential impact on other market participants, and was funded through the Network Innovation Allowance (NIA).

The study involved significant stakeholder engagement through a combination of webinars (which can be seen at the following link[1]), meetings, a survey, and a trading pilot. Interactions were with a wide range of types of market participants including government and its agencies (OFGEM/DESNZ), industry (Energy UK and leading utilities), storage operators and energy traders.

AFRY modelled the electricity market and the underlying 24/7 EAC market, to understand how pricing and dispatch, and investment decisions, could be impacted in the event of widespread adoption of 24/7 CFE EACs. Granular Energy and Nord Pool carried out a trading pilot involving recruited market participants, covering some of the largest energy utilities in the British Electricity market.

Study Key Findings

- **24/7 CFE matching could come at scale soon:** In Britain several energy suppliers are already offering time-matched 'green' supply tariffs to commercial and industrial customers which report the extent of 24/7 matching. Several companies, including AstraZeneca, Google, Microsoft and Vodafone are committed to buying 24/7 CFE. GHGP reporting standards for scope 2 are under review and may become more granular. 24/7 CFE could be accelerated transparently and efficiently through a 24/7 CFE EAC trading scheme, which could be implemented within a few years.

- **Trading of 24/7 CFE EACs is viable:** Leading players in the energy market participated in the trading pilot, run by Nord Pool and Granular Energy. An ex-post system was modelled, which is consistent with current allocation of REGOs. The contract was defined with stakeholder input. The pilot successfully demonstrated price formation would be possible, with results that were in-line with expectations from modelled outcomes. The price duration curves showed a green premium, which depended on the required matching percentage, with prices rising sharply after 75% CFE matching levels. These increasing prices are likely to influence investment and consumption behaviours in support of decarbonisation.

- **Incentivises investment in storage and supports DSR:** Through 24/7 CFE trading, consumers can express their preference for CFE and direct funds towards solutions that meet their consumption patterns. The additional revenue would benefit assets which support CFE but that cannot currently access REGOs, notably DSR and storage. Time matched certificates would allow storage operators to access a new revenue stream, by purchasing granular EACs and storing energy when certificate prices are low and selling EACs and discharging energy when prices are high. This could trigger additional investment in storage, especially if longer term trades or contracts emerge. Purchasers of 24/7 CFE EACs would have stronger incentives for aligning consumption to periods of high CFE supply availability (and thus low EAC prices) than from electricity prices alone, creating shorter payback periods for innovations automating DSR.

- **24/7 CFE EACs enhance the value of flexibility in times of scarcity:** Shortage of CFE supply tends to occur at the same time as increased system tightness. In the GB system. Shortages of CFE occur in Britain at times of low wind supply[2], and this is when 24/7 CFE

[1] Implications of trading of 24/7 Carbon Free Energy (CFE) on system operation | AFRY

[2] See Annex

EAC prices would be highest. Conversely at times of renewable curtailment, generally there is an excess of CFE supply and 24/7 CFE EAC prices will typically be very low or zero. During periods of scarcity, 24/7 CFE EACs provide a stronger price signal for carbon free power production and consumption than energy prices alone. This was shown in both the modelling and trading pilot.

- **A 24/7 CFE EAC market could support the transition to a net zero power system:** If accelerated, a move to 24/7 CFE EACs could support the goal of a net zero power system by 2030 by encouraging the matching of demand, storage and dispatchable CFE supply to the availability of weather-dependent renewables, through incentives for both investment and to change behaviour.

- **Trading of 24/7 CFEs is mostly beneficial for system operation:** The emergence of 24/7 CFE is not foreseen to introduce any major risks and would provide behavioural benefits in the operational timeframe and additional benefits in the investment timeframe.

    - **Beneficial for scheduling:** The stronger price signal in times of scarcity should lead to helpful behaviours particularly for storage and DSR.

    - **Congestion would not be materially impacted:** A 24/7 CFE market is not expected to lead to material changes to the level of constrained boundaries within a national GB system. Congestion is generally associated with windy periods which tend to have very low CFE prices, but when the CFE market is tight, there is usually low wind output and little congestion.

    - **Should not create significant additional costs for redispatch:** While in theory an additional revenue stream for renewable production could add to redispatch costs, in practice, when CFE supply is being curtailed, there would be an abundance of CFE supply and certificate prices tend to zero.

    - **Rules for storage need consideration:** A 24/7 CFE market would create a new revenue stream for storage, but could influence their role and incentives in system balancing. It is worth noting that the rules for batteries and other forms of storage do not yet exist. Simply, storage should purchase certificates when charging and transfer to the buyer when generating, less any round trip efficiency. However, careful rule design and monitoring should be put into place to ensure benefits are maximised.

    - **Accelerated introduction is likely to optimise benefits and minimise risks:** GHG reporting changes, could create high demand for granular certificates. Early introduction of 24/7 CFE EACs, ahead of updates to GHG reporting standards, would allow NESO to gain experience in monitoring of participant behaviour and dispatch decisions. As this is a new product, understanding how trading and operational decisions will change is important for NESO.

    - **Further work on implementation would be required**: Lack of liquidity, imperfect co-optimisation, and uncertain behaviours are risks that should be considered. It would make sense for NESO to be actively involved in forecasting and monitoring how granular certificates will impact market participant behaviour, alongside Ofgem and DESNZ. Mandatory reporting and establishment of price forecasts for the 24/7 CFE EACs could support liquidity. While this was not an implementation study,

implementation would need careful consideration and monitoring to reduce risk of unexpected or intended consequences.

- **Benefits are amplified in the case of a move to a zonal market:** In a zonal energy market , the ease with which CFE demand could be met varies significantly between zones.
    - **EAC prices would vary by zone:** In a zonal market the dominant factor for the ability to meet CFE demand is the wind generation output. Areas with a high penetration of wind have lower EAC prices. Based on AFRY's assumptions of zonal splits within GB, Scotland and the East of England have lower prices over the year. Equally, areas within system constraints, such as the south of England and South Wales, are likely to face higher EAC prices.
    - **Rules for cross zonal EAC transfers have not been agreed:** interactions with transmission capacity and intra-zonal congestion management have not been considered in this study, but remain an issue for future consideration dependent on the arrangements which buyers and sellers agree for the delivery of 24/7 CFE between price zones.
    - **Encourages regional investment:** A zonal market would see regional CFE prices which can encourage the locational siting of CFE and storage. Margins for storage would improve most in zones with CFE supply and capacity constraints.
- **Better reporting could improve transparency:** Providing consumers with transparency and understanding their CFE matching percentages in real-time empowers consumers take actions to gradually improve it should they so wish.
- **Analysis and monitoring is required:** The introduction of a new trading scheme can impact supply demand dynamics, so preparation by NESO and other market stakeholders would be important. This preparation ccould include, further trading pilots, stakeholder engagement and modelling of potential outcomes.

Contents

Executive Summary 3

1. Project introduction 8

Introduction 8

Study objectives and scope 9

2. 24/7 CFE EACs 10

What are EACs? 10

The case for 24/7 CFE EACs 12

Implementation of 24/7 CFE EACs 18

3. Trading pilot 20

Objectives and approach 20

Auction Results 26

4. Modelling of Electricity system impacts 28

Objectives and approach 28

Pricing of 24/7 CFE EACs 32

Impact on investments 39

Implications for NESO 44

24/7 CFE EACs in a zonal market 48

Annex 51

Glossary 51

Weather year characteristics 53

1. Project introduction

Introduction

This study is about understanding how the introduction of 24/7 Carbon Free Energy Attribute Certificates (24/7 CFE EACs) would impact the National Energy System Operator (NESO) and other stakeholders in the market.

Energy attribute certificates (EACs) or Renewable Guarantees of Origin (REGOs) are used to support carbon reporting and renewable energy sourcing claims. However, the EACs are currently annually matched, which does not reflect the physical reality of electricity supply. This has created concerns of greenwashing and created demand for more granular reporting. 24/7 (hourly or sub-hourly) or granular time matching of EACs would be an evolution to the current British REGO market.

Visibility on time matched CFE (carbon free energy) matching percentages would enable consumers to gradually improve it by encouraging demand side response (DSR), at times of renewable scarcity. 24/7 CFE EAC trading would reward suppliers who can provide carbon free flexibility. However, to date there has been little practical insight into how the trading of 24/7 CFE EACs would impact stakeholders in the energy sector.

In April 2024, NESO asked AFRY to help it better understand the implications for system operation which arise from the development of 24/7 CFE EAC trading. AFRY engaged with stakeholders and modelled the GB electricity system to understand how 24/7 CFE trading could impact market participants and system operation. AFRY is working with Granular Energy and Nord Pool on this import study.

- AFRY Management Consulting provides engineering, design, digital and advisory services to accelerate the transition towards a sustainable society. The analysis is underpinned by the AFRY BID3 power market modelling software.
- Granular Energy provides an all-in-one software tool for green energy and energy certificate management for energy companies.
- Nord Pool offers day-ahead and intraday trading, clearing and settlement services and data services with around 400 customers from 20 countries trade on Nord Pool's markets.

Nord Pool and Granular Energy ran a trading pilot. This was groundbreaking analysis, by firstly demonstrating the viability of trading and secondly creating a fundamentals-based model created by AFRY for the valuation of granular energy attribute certificates.

Study objectives and scope

The study objectives were to understand:

- Speed and potential scale of uptake
- Implications for electricity system operation
- How 24/7 CFE EACs will impact other stakeholders in the GB market
- Market design interactions, particularly with a potential move to zonal pricing being considered as part of the ongoing Review of Electricity Market Arrangements (REMA)

2. 24/7 CFE EACs

What are EACs?

Interest is growing in moving from today's annual matching EACs towards more granular certificates.

In most energy markets, electricity suppliers use EACs to offer optional 'green electricity tariffs' to their customers when they purchase electricity. In Great Britian, EACs are traded as REGOs. Purchase of REGOs is voluntary, but REGOs are required to support green energy procurement claims. Furthermore, companies use REGOs to enable emissions reporting.

Changing to 24/7 (hourly or sub hourly) matching of CFE, via EACs, would address concerns of the credibility of certificates, by providing consumers with transparency in carbon free energy procurement. Current 24/7 CFE tariffs generally offer consumers CFE supply covering 100% of consumption on an annual basis. Some suppliers also report on a more granular basis and reporting a high degree of matching (70% - 95%). It is expected that most customers will not demand 100% granular matching as this could be cost prohibitive.

It is worth noting that 24/7 CFE generally refers to granular matching of a one-hour duration or less. In this study, the trading pilot and modelling was based on 60-minute granularity, however these EACs could also be introduced at other granularities such as 15-minute or 30-minute, depending on metering data within the system.

In Great Britain the current REGO system was introduced in 2003.

Renewable Energy Guarantee of Origin (REGOs) certificates were implemented in 2003 by OFGEM. The aim was to provide transparency that electricity generated was from renewable energy. The certificates match on an annual basis. Once issued, REGOs can be traded with or without the electricity to which it was issued.

When REGOs were introduced in 2003, renewable energy only accounted for around 3% of supply, in 2024 it was around half[3]. The challenges of time matching and additionality have become significantly more important, compared to when these were first implemented.

A 2023 DESNZ consultation found that REGOs do not provide consumers with sufficient transparency.

As shown in Figure 1, the energy market and the EAC market, or the REGO market in GB, market operate independently of each other. EACs only match annual supply to annual

[3] Source: Digest of UK Energy Statistics (DUKES)

demand. The use of REGOs does not involve putting incremental renewable energy into the grid, nor does it reward innovation in new technologies such as vehicle to grid.

The use of REGOs for making 'green' energy claims has faced criticism. In July 2023, the Department of Energy Security and Net Zero (DESNZ) published a summary of responses on "Designing a framework for transparency of carbon content in energy products"[4].

Most respondents to the DESNZ consultation stated that the current REGO scheme does not provide sufficient transparency to consumers. This is because different energy companies take different approaches to marketing 'green' tariffs.

Research by the organisation Which?, in response to the consultation, found that there is often a mismatch between consumers' expectations of 'renewable' and 'green' tariffs, and the approach taken by energy companies[5]. Which? recommended that the definition of 'green' and 'renewables' should be clarified in regulations, so usage is standardised, and consumers have greater clarity over what they are buying.

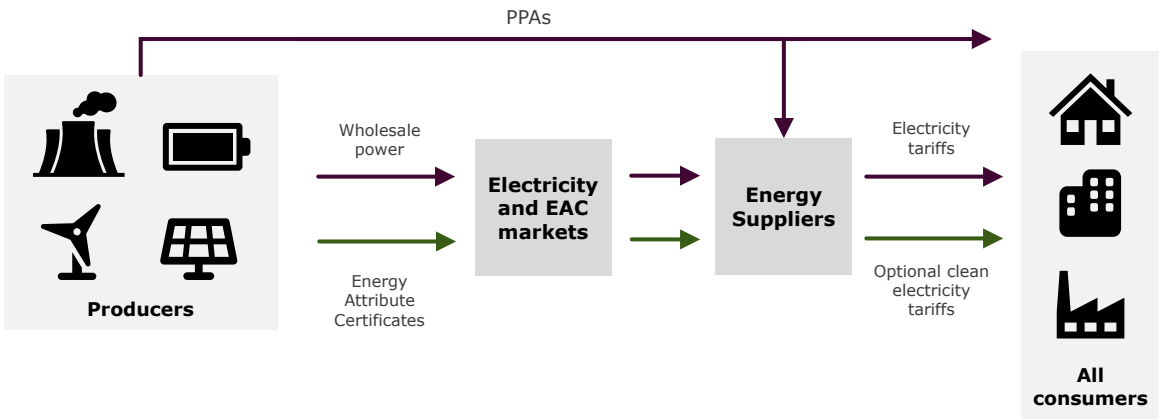


Figure 1: EACs like REGOS match annual renewable supply to annual demand

[4] Designing a framework for transparency of carbon content in energy products: call for evidence - GOV.UK

[5] BEIS designing a Framework for Transparency of Carbon Content in Energy Products - Which? response - Which?

The case for 24/7 CFE EACs

Time based matching of EACs aligns power and EAC market.

The previous section showed that there is currently a mismatch between the annual or monthly REGO certificates purchased to underpin green energy claims and hourly, or sub-hourly electricity pricing. Moving to more granular certificates would better align the EAC market with the power market, as shown in Figure 2.

As almost all electricity consumers buy their electricity through a supplier, either via Power Purchase Agreements (PPAs) or a retail tariff, consumers are reliant on their suppliers to support their CFE procurement and represent the consumer in the power market.

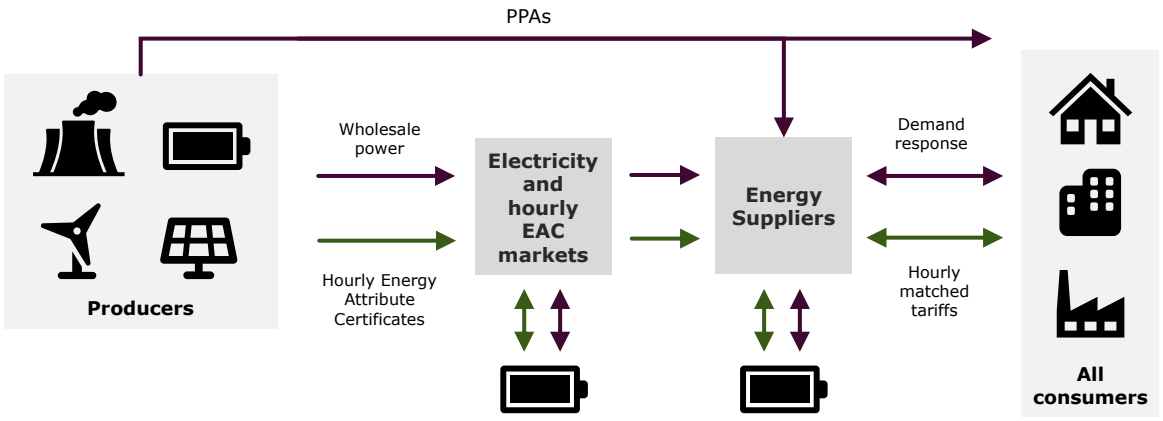


Figure 2: Granular EACs can be used to provide consumers with better transparency on temporal matching

Requiring energy companies to provide reports to their customers on where their renewable (or CFE) supply comes from, including their approach to managing intermittency would improve transparency. Providing customers with visibility about their supply mix, and their granular matching percentage on each electricity bill, would help customers make more informed choices about energy purchases and consumption patterns.

The use of 24/7 CFE EACs could support this transparency for customers, while providing energy companies the flexibility to secure CFE supply certificates at times of shortage within their own portfolio.

24/7 CFE EACs create a price signal for whichever generation unit can deliver clean energy when it most needed.

Consumers who are relying only on annual certificate matching do not have transparency on the physical reality of electricity supply, which means that they might think that solar power can be consumed when it is dark, and wind energy can be consumed when there is

no breeze. While theoretically storage can address some of these imbalances, a customer does not know if their supplier is using storage to address CFE supply shortfalls or fossil fuels.

Batteries and other forms of storage are a key tool for addressing the intermittency of renewable energy. Storage is unable to benefit from annually matched EACs because with annual pricing, and storage losing some energy through each charge, discharge cycle the economics do not incentivise participation. If a 24/7 EAC market was available, storage could charge at times of abundant CFE supply and discharge in times of shortage.

Sellers and buyers of 24/7 CFE have already emerged.

Energy Retailers in the British market, including Good Energy and Octopus, are already offering 24/7 CFE tariffs to commercial and industrial customers with smart meters[6]. These tariffs do not guarantee a specific matching percentage but rather report the level of CFE matching a customer has based on their metered supply and Good Energy has stated that its customers typically achieve a matching percentage above 90%[7].

For the biggest customers, 24/7 CFE matching can be achieved through PPAs. However, it would be beneficial for these customers, and could encourage DSR, if there was a liquid granular certificate market. For example, a data centre could sell certificates, purchased via a PPA, during periods of low CFE supply, by reducing consumption, creating a financial incentive to act.

In late 2024, The Climate Group launched the 24/7 Carbon-Free Coalition (an evolution of RE100), where corporate consumers, including AstraZeneca and Vodafone (UK), have committed to 24/7 CFE and to report matching percentages. These arrangements are being supported via the use of existing annual REGOs, along with metered data.

The UN launched the 24/7 CFE Compact (Figure 3) in 2021 which currently has 171 signatories collaborating for the implementation of an hourly matching solution.

The 24/7 Carbon-Free Energy movement is coordinated by Sustainable Energy for All, a UN organisation, with a growing list of signatories from companies, organisations, and governments around the world. This is adding to the number of suppliers and buyers of electricity who are interested in 24/7 CFE procurement.

The list of signatories includes, but is not limited to:

- Major energy buyers: Including Google and Microsoft, who have committed to 100% 24/7 CFE procurement by 2030
- Energy suppliers: Centrica, Statkraft, Orsted, SSE, Engie, Jera, Mitsubishi Electric, Osaka Gas

[6] See Electric Match: Traceable energy that's made for your business | Octopus Energy and Introducing Hourly Matching: the future of renewable energy supply | Good Energy for Business

[7] Good Energy reports as of June 2025, that 'Good Energy's percentages are **100% true green** power direct from renewable sources, **40% new green** from generators connecting to the grid for the first time and **90% time-matched green** power produced when our customers use it'

Figure 3: UN 24/7 CFE Compact

GHG Protocol is reforming Scope 2 GHG reporting with new standards, which could create demand for a more granular product.

The GHG Protocol Corporate Accounting and Reporting Standard provides guidance for companies and other organisations, such as NGOs, preparing a corporate-level GHG emissions inventory. As it relates to electricity usage, in additional to reporting the emissions of the grid to which they are connected (location-based emissions), it also allows market-based reporting, based on purchasing EACs.

The Greenhouse Gas Protocol (GHGP) is in the process of reviewing its standards. Ahead of the GHG Protocol revisions, several workshops were held in 2022-24 to discuss moving to hourly matching for Scope 2 emissions, with many in favour of the revision which closed some loopholes seen with annual matching.

A key part of this review is the update of the Scope 2 guidance — the rules that define how companies account for emissions from purchased electricity. The current guidance allows unbundled EACs, such as REGOs, to be used to support claims. This means that customers in the UK can purchase international EACs to support their emissions reporting.

Granular accounting, where Scope 2 claims align with the time and location of actual use, is already the best practice for reporting Scope 2 emissions.

If tighter standards are put in place, then corporates may have to report higher Scope 2 market-based emissions. The review process is underway, and draft proposals are due for consultation by the end of 2025, with a view to updating the standard by 2028. This could lead to significant demand for more granular EACs from companies.

Other standards are emerging.

- **Green Hydrogen and Sustainable Aviation Fuel Projects** require procurement of 'green electricity'. While standards are evolving, currently there is a requirement for 30-minute matching of CFE supply, with some restrictions on biomass.
- **24/7 CFE products are emerging in other countries:** markets in Europe including Denmark and Ireland, as well as countries like Australia, New Zealand, Taiwan (sub hourly) and parts of the USA (currently monthly) are all considering more granular EACs.
- **EU's Carbon Border Adjustment Mechanism (CBAM):** CBAM extends carbon pricing to imported goods including electricity. CBAM is in the transitional phase and could evolve to include granular matching of clean electricity production.

A survey of market stakeholders showed strong belief in the importance of 24/7 CFE.

In June and July 2024, AFRY, Granular Energy and Nord Pool conducted a survey across three types of 24/7 stakeholders. Of the respondents, 11 were suppliers, 9 consumers and 3 generators. The main findings of the survey were:

- All consumers and suppliers said buying clean energy and reporting/reducing Scope 2 emissions is either **business critical or important.**
- All stakeholders believe 24/7 CFE will happen in the next decade, nearly half believe it will happen in the next **2-5 years.**
- The survey showed **some willingness to pay for 24/7 CFE**, albeit in a low number of respondents. This is further evidenced by a portion of customers agreeing to the premium 24/7 tariffs already on the market. **Avoiding greenwashing**, aligning with company goals and reporting requirements would be the biggest drivers for adoption.

- Different consumers have different definitions of carbon free energy. All survey respondents defined wind, solar and hydro as CFE. Only around half of the respondents included biofuels and nuclear in their definition of CFE.
- Storage was the most popular solution to address the intermittency challenge, ahead of non-intermittent generation, improved transmission and DSR respectively.
- Most suppliers believe the certificate time granularity should match the imbalance period, implying that 30-minute certificates may be more popular than 1-hour certificates, in the GB electricity system.

We note that as 24/7 CFE EACs are a new product, with no existing stakeholder preferences the results of the survey should be considered as indicative only. The complexity and novelty of the topic means that many participants may have found it difficult to provide a considered view.

Consumers are unlikely to achieve 100% 24/7 matching initially.

Providing consumers with transparency and understanding their CFE matching percentages in real-time empowers green tariff consumers to take actions to gradually improve it. For example, in 2023 the average Google facility matched 64% of its energy consumption with renewable power generated either on-site or on the local grid[8]. Google aims to increase this to 100% by 2030.

Tracking and reporting percentage matching involves giving customers information on both their consumption patterns and how their electricity profile is being supplied. This allows action to address these imbalances and take actions that result in higher matching percentages.

If consumers are aware that a certain time is regularly difficult to time match CFE, there is an incentive to improve matching scores by:

- Shifting demand from that period to a time when CFE supply is more abundant.
- Using energy storage to improve matching percentages.
- Procurement of flexible CFE energy sources that address the gaps.

[8] 2024 Environmental Report - Google Sustainability

Figure 4 shows an example of a customer profile over a one-week period, for a baseload buyer. It shows that on average there is enough CFE and storage to meet demand, so over the week, a 100% matching score could be achieved. However, during times of low wind supply there would be shortages of CFE on an hourly basis. The area where CFE supply is less than demand represent non-matched hours. In 56 hours out of the week, there is insufficient CFE supply to meet demand, giving the customer a granular matching score of 67%.

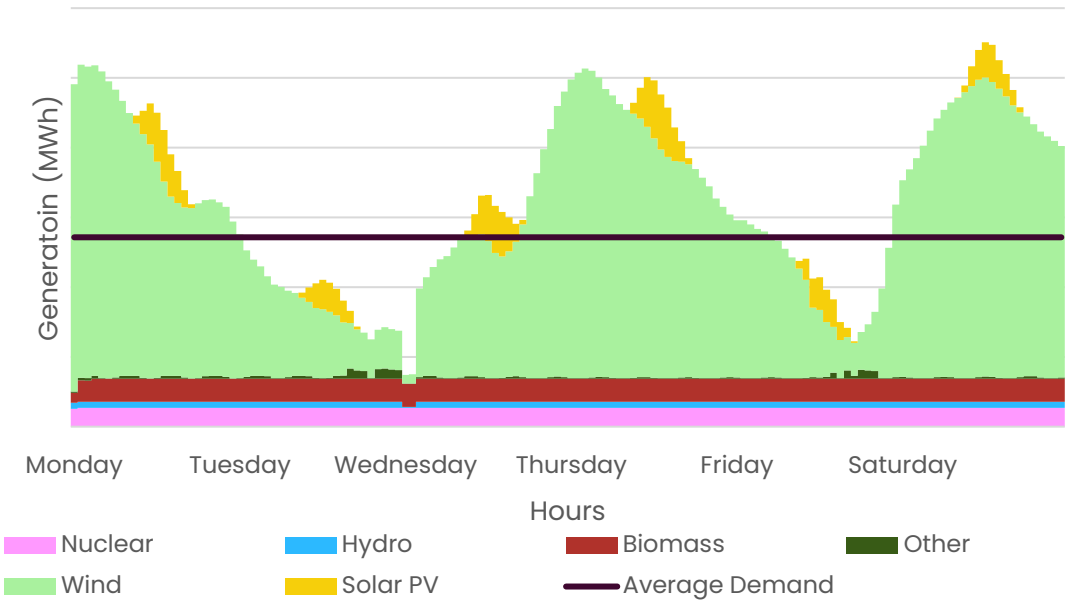


Figure 4: Week 6 Feb 2030 – 24/7 CFE Supply vs Demand

This could involve simple changes in times when buildings are heated or cooled, or electric vehicles are charged. It would also allow storage operators and carbon free energy suppliers to work with consumers, to address any gaps.

Implementation of 24/7 CFE EACs

While this was not an implementation study, thoughts have been provided in this section on the key steps required to introduce 24/7 CFE EACs.

Early implementation can maximise benefits and support a 2030 decarbonisation goal.

Britain has a 'Clean Power' by 2030 goal[9]. This means that by 2030, Great Britain is targeting that it will generate enough clean power to meet its total annual electricity demand, backed up by unabated gas supply to be used only when essential.

'Clean Power 2030 Action Plan' requires consumer led flexibility, as well as investment in both long and short duration storage. As shown in this report, 24/7 CFE EACs, if implemented quickly could encourage both the investments and DSR that supports this decarbonisation goal.

Early implementation appears to be possible. Based on the successful trading pilot, Nord Pool believes that an exchange for trading of 24/7 CFE EACs could be put into place. Data for the supply and allocation of 24/7 CFE EACs is already available via ELEXON. Energy suppliers were able to price and trade certificates.

REGOs are a voluntary scheme, but necessary for anyone wanting to sell or buy a 'renewable energy' tariff. It would make sense if 24/7 CFE EACs were also voluntary but again necessary for any supplier offering time matching green or CFE tariffs. It would reduce implementation risk if demand was allowed to grow organically.

Early adopters of granular certificates would gain insight into their consumption profile and have time to adapt and improve their matching percentage ahead of changes to GHG Scope 2 reporting guidelines. This would be particularly important for corporates who are currently using REGO backed supply to report zero scope 2 emissions.

24/7 CFE EACs information could act as additional information in parallel with the current annually issued REGOs.

Energy consumers use REGOs to support carbon reporting claims, particularly Scope 2 reporting requirements. Currently all 'green tariffs' offered in GB are supported by REGOs which are aggregated annually. Not all consumers on green tariffs have smart metering, and excluding these customers from green tariffs would not be ideal. So, considering the transition is important.

The existing system of annual REGOs may need to be maintained, for a transition period of several years, until regulations and Scope 2 reporting requirements make annually matched REGOs redundant. This is unlikely to happen prior to 2030, as even if the GHGP

[9] Clean Power 2030 Action Plan: A new era of clean electricity – main report - GOV.UK

updates Scope 2 reporting requirements in 2028, this is unlikely to be implemented immediately and only applies to corporate GHG reporting.

24/7 CFE EACs could be treated as a 'premium product', in the GB market, with every consumer of a 24/7 CFE EAC being guaranteed annual matching, with a time-matched percentage (e.g. simple reporting, 70%, 80%, 90%, 95%, 98%, 100%) agreed on a case-by-case basis with their energy supplier.

One concern is to ensure that there is not double counting between supplier annual reporting systems and more granular reporting systems. It would also be important that suppliers cannot 'cherry-pick' cheaply priced hours from granular certificates and sell these to consumers with annual reporting. This could be achieved by all suppliers offering a green tariff providing their customers a matching percentage.

Supply of 24/7 CFE EACs would likely be managed in a similar way to current REGOs, where energy companies manage REGOs on behalf of most customers. Larger buyers, such as industrials or data centres may choose to manage granular certificate purchases and trading.

Framework and Ofgem systems are solvable barriers to implementation.

DESNZ and Ofgem would need to be actively involved in implementation and design of a framework for issuing and reporting granular EACs. Ofgem is the current issuer of REGOs in GB and uses a custom software solution ("the Renewables and CHP Register") developed by third party consultants.

To implement 24/7 CFE EACs, Ofgem could develop a solution in house or issue a tender for a replacement 'off-the-shelf' EAC registry solution that meets international standards. There are two main providers of such solutions in Europe (Gretel and Unicorn/Certify) which provide registries on behalf of nearly all European countries. Both have the capability to issue hourly or more granular EACs.

Ireland is considering requiring Large Energy Users to match their consumption with clean energy on an hourly basis[10]. The Danish transmission operator, Energinet, is the issuing body for guarantees of origin in Denmark. As of June 2025, they were accredited by Energy-Tag to issue granular EACs[11]. Hydrogen standards in Europe[12] and the UK[13] require granular energy matching.

---

[10] 2023 Climate Action Plan Page 134: "Pg 134" More granular certification processes will be required, including 'time stamped' guarantees of origin, so that energy intensive users can demonstrate that they are using zero emissions electricity during the same hour and geographical location to match all of their consumption on a 24-hours a day, seven days a week basis. "

[11] EnergyTag-Press-Release-June-25-2025_Publication.pdf

[12] EU 24/7 Hydrogen Standard adopted in 2023: Article 4.2.(c) "The renewable liquid and gaseous transport fuel of non-biological origin is produced: (i) during the same one hour period as the renewable electricity produced under the renewables power purchase agreement "

[13] Low-carbon hydrogen standard adopted in 2023 in the UK states in Sec 8.1.2 "Real time tracking of generation and consumption (temporal correlation) is required across all 30-minute consignments."

3. Trading pilot

Objectives and approach

The trading pilot objective was to show that trading of 24/7 CFE EACs was viable.

Nord Pool and Granular Energy ran a trial ex-post auction, complementing the current framework on the European integrated electricity market, with ambitions to:

- Establish a price reference for hourly clean energy
- Increase liquidity and improve access to granular certificates for large and small players
- Provide needed market signals for buyers, sellers, and risk managers
- Add stack to the existing value stack - yield additional revenues for flexibility (e.g. storage, demand-response)
- The ulimate goal: accelerate the transition to clean energy by closing the gap between traditional power markets and certificate markets

The work was carried out in two phases resulting in market rules (Figure 5) and a pilot.

The first phase ran from May to July and was about seeking stakeholder feedback. A survey was carried out to test preferences from potential participants. The feedback was used to produce the draft market rules for running a trading pilot in Phase 2. Leading players in the energy market, including EDF, npower Business Solutions, Field Energy, and Good Energy, participated in the trading pilot, run by Nord Pool and Granular Energy. The trading pilot was started in September. Results were available in draft form in December 2024 and were presented to the trading pilot participants in February 2025.

Figure 5: Market Regulations and Product Specifications

Market framework for the Pilot

An ex-post auction was held in November 2024 for the delivery months of February and May 2024. An ex-post auction, which means the Auction would be held after the 24/7 CFE EAC issuance. The rules are described below, and the market framework is shown in Figure 6.

The auction was:

- A double-sided blind auction, fully anonymous market with Nord Pool acting as a central counterpart
- Auctions for February 2024 (696 hours) and May 2024 (744 hours) auctions were run during the pilot
- 3 market parties participated in the February auction, including 2 retailers and one producer.
- 5 market parties participated in the May auction, including 2 retailers, a battery and 2 producers.
- The trading pilot was started in September 2024. Results were available in draft form in December and were presented to trading pilot participants in Febuary 2025.

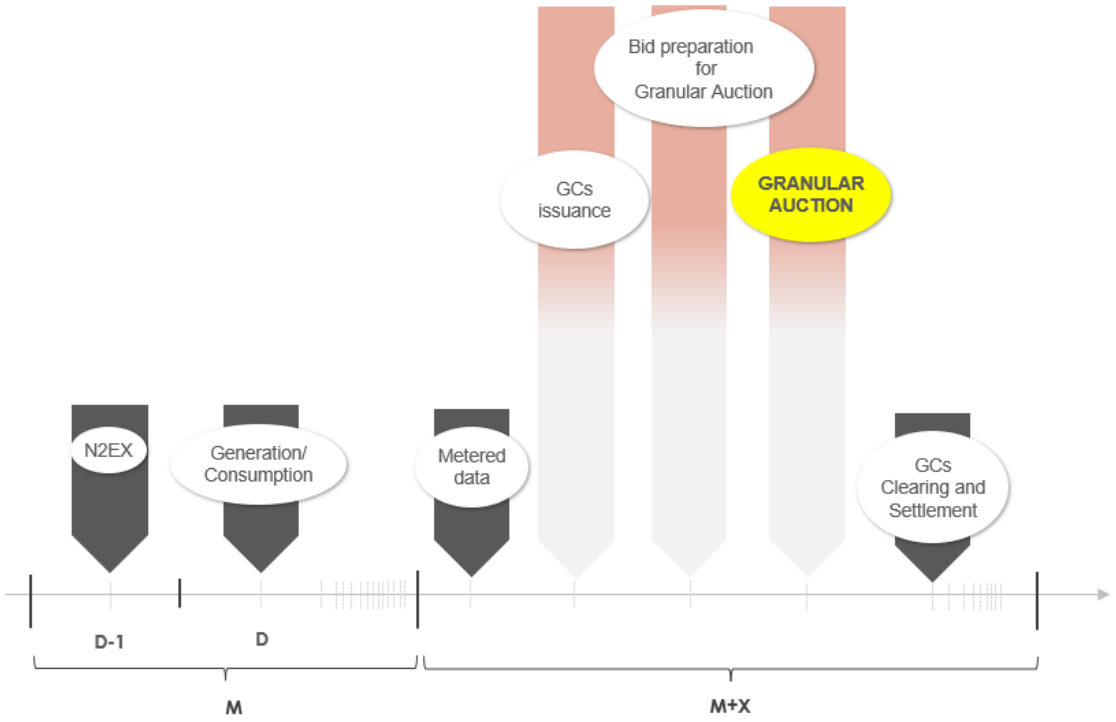


Figure 6: Market Framework for the Pilot

Currently REGOs are allocated ex-post. In the trading pilot it was assumed that the 24/7 CFEs EACs would also be allocated ex-post. However, as shown in Figure 7, market participants would forecast the expected certificate prices, and this would drive behaviour in operational timeframes.

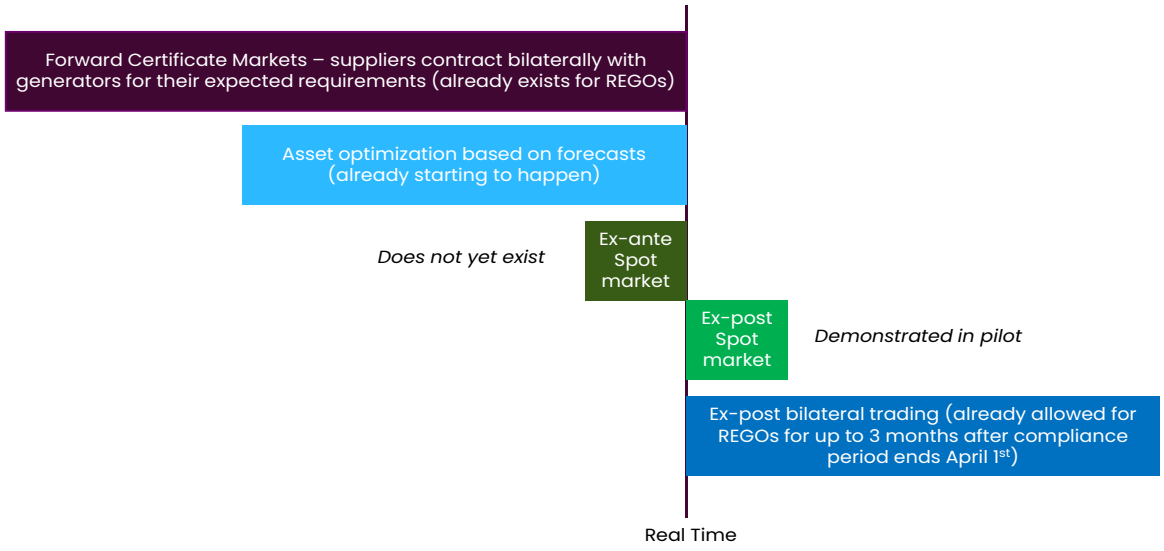


Figure 7: Illustrative Trading Timeline

Contract description

The below product specifications were agreed with stakeholders during Phase 1 of the study and used for the trading pilot.

1 - PRODUCT DESCRIPTION	Unit of Trading	MW
	Contract size	0.01 MW
	Type of products	Granular Certificates as defined by the Energy Tag guidelines and issued by the UK GC registry (any type of generation type)
	Contract period	One hour
	Quotation	Continuous submission of orders until Gate Closure
	Minimum trading size	0.01
	Price unit	£/MWh
2 - TRADING	Volume tick	0.00
	Price tick	0.1
	Trading model	Double-sided anonymous blind auction
	Trading hours	Submission of orders: sent to GB demonstrator and Nord Pool desk Gate Closure: according to a predefined schedule
	Min and Max prices	Min price: 0 Max price: 500 GBP
	Settlement prices	Pay-as-clear
3 - SETTLEMENT	Type of delivery	Physical delivery through Nord Pool CCP GCs account
	Delivery points	Granular Certificate Registry
	Payment	Bank transfers through Nord Pool CCP bank account
	Contract security/risk management	Nord Pool acting as a central counterpart to all trades and ensure default management mitigation
	Position limits	According to collateral at hand

Curve orders have been matched in a blind auction, resulting in a market clearing price.

The primary role of a market operator is to establish a crossover between supply and demand curves based on an economic merit order, as detailed in Figure 8. So, any seller whose price and volume falls to the left of the cross-over has their positions cleared. While any buyer whose price and volume falls to the left of the cross-over has their positions cleared.

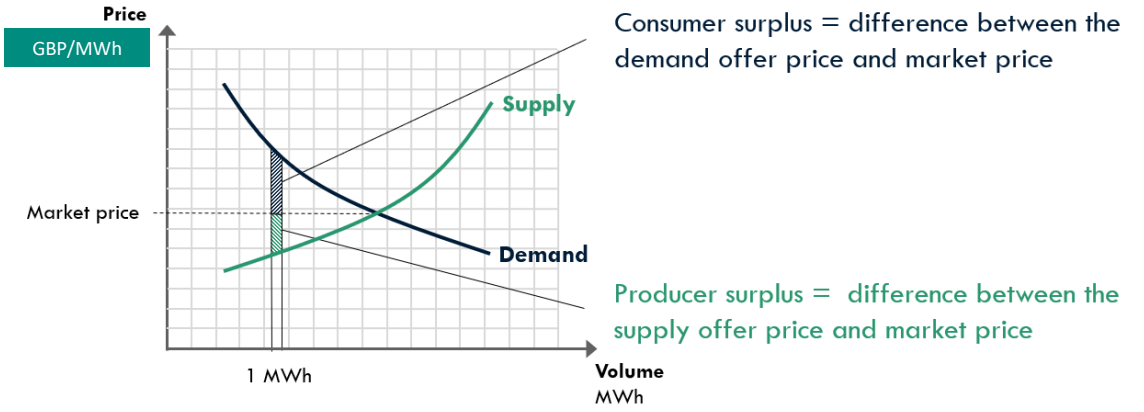


Figure 8: Clearing rules

Orders were submitted via a spreadsheet, with up to five pricing steps per hour for each of the months (February 2024 and May 2024) included in the trading pilot. Orders consist of both prices and volumes.

Auction Results

Green premiums increase significantly after 75% matching.

The green premium means the price of purchasing 24/7 CFE EACs for a given level of demand. In both February and May prices were achieved for around 75% of hours, with zero prices expected in other periods. The resulting 24/7 CFE EAC price for the February test auction is shown below in Figure 9.

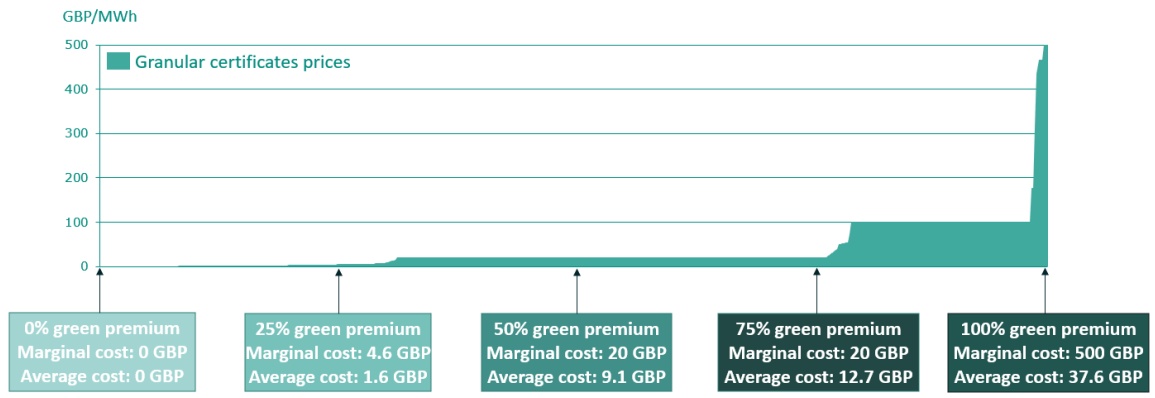


Figure 9: Distribution of 24/7 CFE EAC auction prices – February 2024

The chart shows:

- That the cost of purchasing a certificate rises, with the compliance rates, with a tipping point at around 75% of consumption being covered by a certificate.
- The marginal cost calculates the cost of having a certain percentage of demand covered by a certificate. For example, at 50% the marginal cost of a certificate is 20 GBP/MWh.
- The average cost shows the weighted average certificate price, to achieve a level of certificate coverage. For example, at 50% the weighted average certificate price (or the area under the chart to the left of 50%) is 9.1 GBP/MWh.
- The green premium for any level of demand is the average cost of the certificates to cover this demand.

Price duration curve for certificates and electricity prices have different drivers.

Figure 10 shows the overall 'green electricity price' considering both the certificate price and the electricity price. Below 75% certificate coverage, the green premium is small. Above this level the certificate is a major part of the overall green energy price.

Note that EAC prices and electricity prices are not perfectly correlated. The 'green electricity price' has been re-ordered from low to high.

Most of the time high EAC prices coincide with high electricity prices, as this involves shortage of supply relative to demand, but this is not always the case. For example:

- Peak demand periods will have high electricity prices, but EAC prices can often be zero during peak periods, on windy days.
- Low demand periods from 11 pm to 5 am with tend to have low electricity prices, but can have high EAC prices, as there is no solar availability, and often a certain level of baseload supply is available.

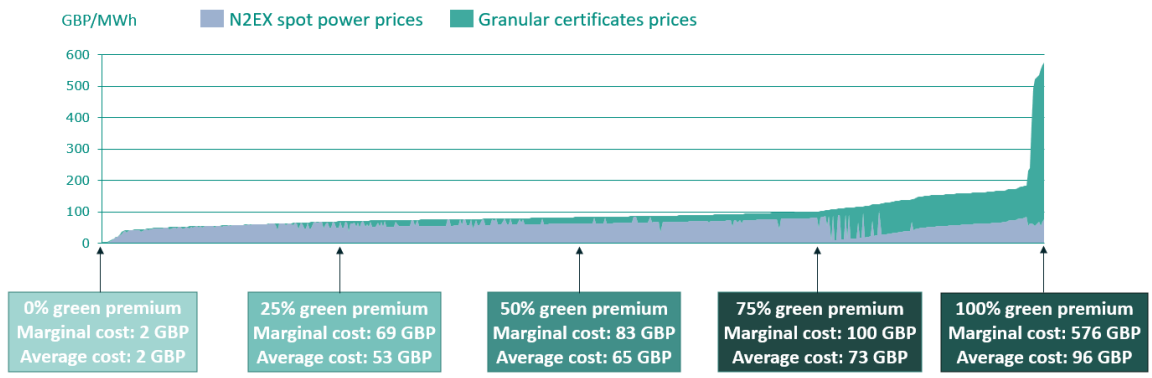


Figure 10: Overall green electricity price – February 2024

4. Modelling of electricity system impacts

Objectives and approach

The objective of the electricity market modelling was to deliver insights into how 24/7 CFE trading influences the market and system operation.

The modelling objectives were to address the following questions:

- How much might CFE certificates cost? (under a range of assumptions)
- Does CFE trading encourage investment in certain technologies?
- Is energy balancing and redispatch more difficult with a 24/7 CFE market?
- How would CFE trading impact stakeholders in the market?
- What would 24/7 CFE trading look like in markets with multiple trading zones?

AFRY has used the data from NESO's FES 2024 Electric Engagement Pathway to underpin the modelling in this study. This Pathway has high levels of storage and nuclear capacity additions. Sensitivities with lower storage availability and excluding nuclear from the CFE market were considered.

REGO trading is unregulated with limited data on overall demand and spend. According to research undertaken by Cornwall Insight, prices are typically too volatile to support investment in new build renewable assets[14]. The forward curve for REGO prices has varied by as much as 20% in a single day[15]. This makes an overall spend on 'the green market' by GB consumers and a counterfactual comparison of annual REGOs compared to 24/7 CFE EACs hard to assess.

[14] Insight Paper | Reviewing the Future of REGOs for Corporates

[15] UK REGO Prices Drop 45% Between August and November 2024

To model the impact of 24/7 CFE EACs a separate CFE market was established.

A separate CFE market is established to assess the 24/7 CFE prices, system implications and profitability of assets. The GB Electricity market was split into a 'Brown market' which contains all carbon producing generation assets, and a 'CFE market' which contains all CFE supply (Figure 11). This was modelled as follows:

- Total supply is equal to supply in the Brown market plus supply in the CFE market.
- Total demand is equal to demand in the Brown market plus demand in the CFE market.
- The demand for 24/7 CFE EACs is the total demand for carbon free electricity. For example, if 10% of the market signed up to 24/7 CFE EACs, then 10% of demand would sit in the CFE market.
- Unless otherwise stated, it was assumed that 60% of the market signed up to 24/7 CFE EACs in 2024 and 2030. This dropped by 5% increments over each 5-year period to 45% by 2045, as it is expected that as the market becomes more carbon free, fewer customers would purchase certificates.
- The CFE market can export any excess supply to the brown market at zero cost. However, the CFE market can only import supply from the Brown market at a penalty of £100/MWh, which was assessed by AFRY as a price at which customers might withdraw from the CFE market or accept lower matching percentages.
- Assumptions can be made about which assets sit in which market. In the base case, CFE supply includes, nuclear and all renewables, and excludes imports via interconnectors and carbon assets (mostly natural gas).

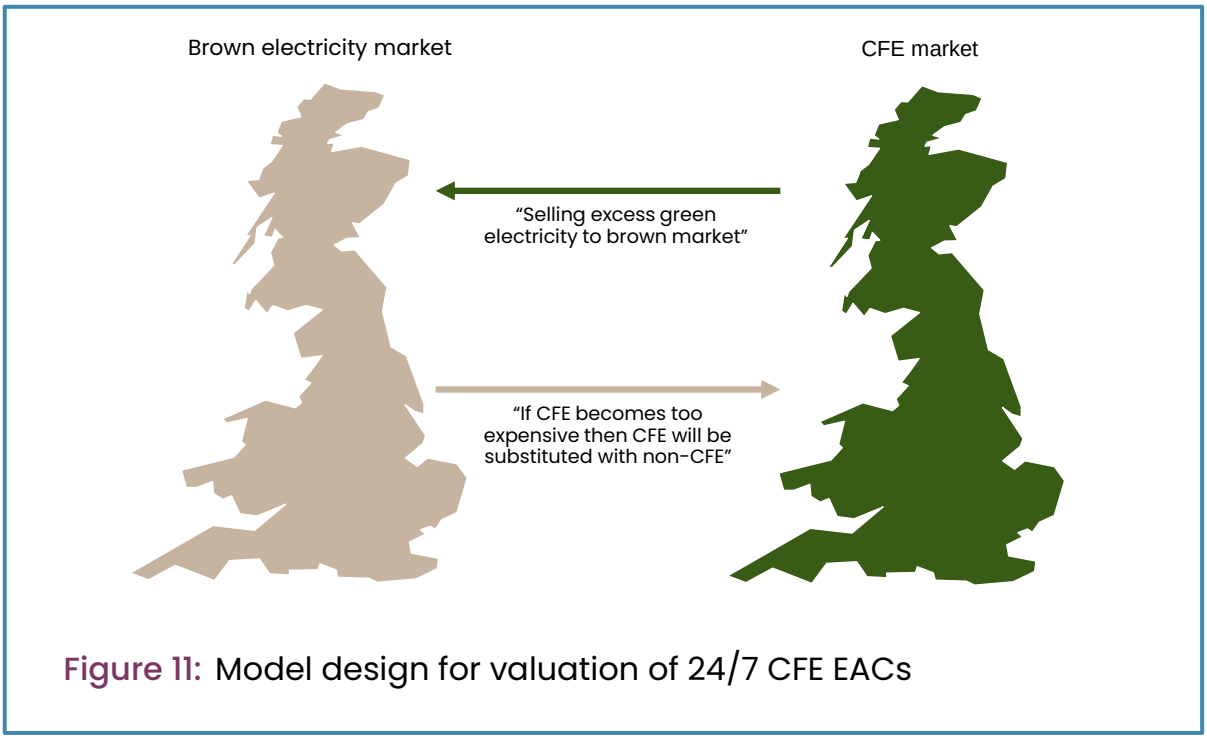


Figure 11: Model design for valuation of 24/7 CFE EACs

Storage can share its capacity though it must maintain a balance of 24/7 CFE.

Storage can store both 24/7 CFE and brown energy. For stored energy to qualify as meeting 24/7 CFE on discharge, it must have been charged from a 24/7 CFE source and maintained this energy in its store continuously from charge to discharge. This would mean that a storage operator must purchase a 24/7 CFE EAC when charging, and can sell the certificate, minus any losses after discharging.

The combined 24/7 CFE and brown energy storage must maintain the physical limits of the storage unit. This is shown in Figure 12 below. Storage can share capacity, with both CFE and brown energy flows entering the same storage unit. Storage can also operate separately filling entirely with CFE or brown cycles.

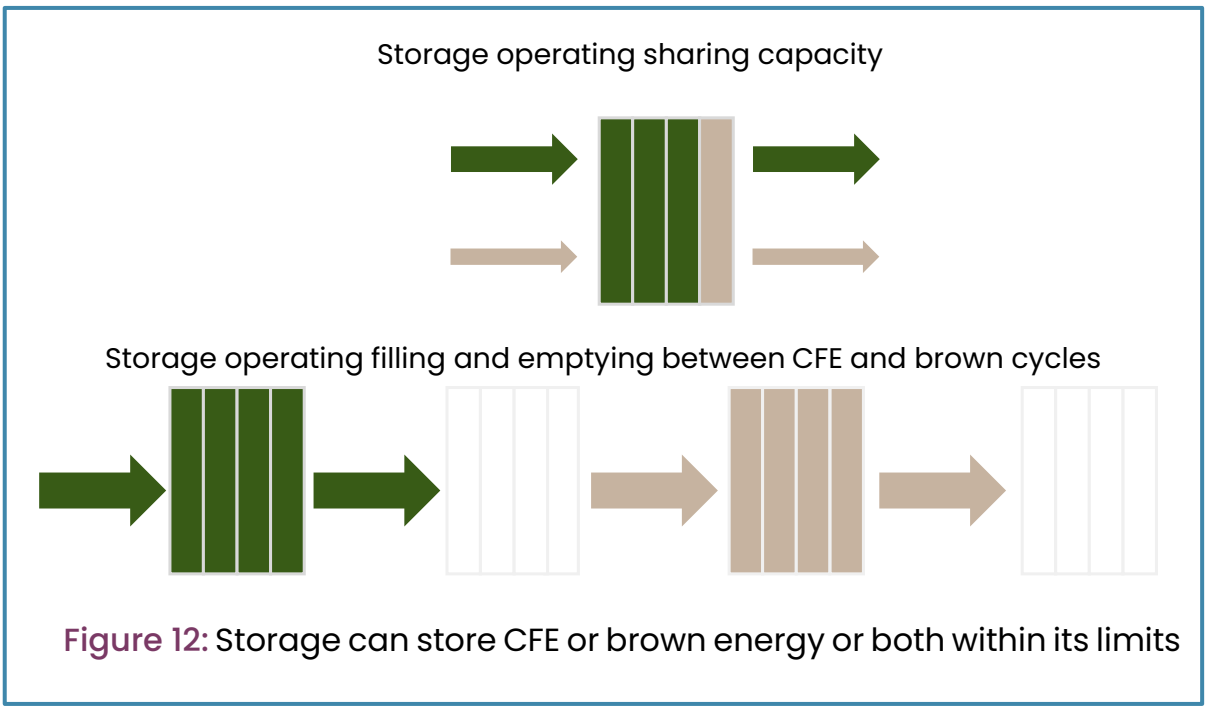


Figure 12: Storage can store CFE or brown energy or both within its limits

To avoid claims of green washing, the carbon free energy flows should align with energy flows across boundaries

The modelling of the integrated energy and 24/7 CFE market considers the implications of GB transmission constraints. In the current GB market, there is only a single price zone, but CFE supplies are limited to CFE energy that has been produced in GB in AFRY's modelling. As previously mentioned, this is different from REGOs which can be purchased from international sources.

In the case of a zonal market, or in the case that interconnectors were to be included in the scheme, then it is necessary to consider how CFE can move across boundaries between different pricing zones. AFRY considered a sensitivity where the GB market had been divided into 11 pricing zones. In this sensitivity the following rules was applied: **If a buyer purchases CFE from a different zone, there is a requirement for there to be an energy flow between the two zones.**

The modelling therefore disallows certain energy and 24/7 CFE flow combinations:

- The energy flow (brown + CFE supply) across a boundary cannot be less than the 24/7 CFE flow
- The energy flow (brown + CFE supply) across a boundary cannot be in the opposite direction to the 24/7 CFE flow

Pricing of 24/7 CFE EACs

24/7 CFE EACs enhance value of flexibility in times of scarcity with prices rising sharply in times when there is a shortage of supply relative to demand.

Shortages of 24/7 CFE occur when CFE generation is less than 24/7 CFE demand. At these times the scarcity creates competition for certificates. The higher demand for certificates relative to supply, the higher the certificate price will be.

Figure 13 illustrates how this translates into certificate prices. The chart on the topshows the demand for certificates, relative to supply of CFE. In the case of the 'very low' demand there are few hours where supply cannot meet demand, and most hours will have a zero price. As demand for certificates increases, the number of hours where demand exceeds supply increases. This means that there will be a shortage of certificates compared to demand and some buyers will be priced out of the CFE market, and prices will increase.

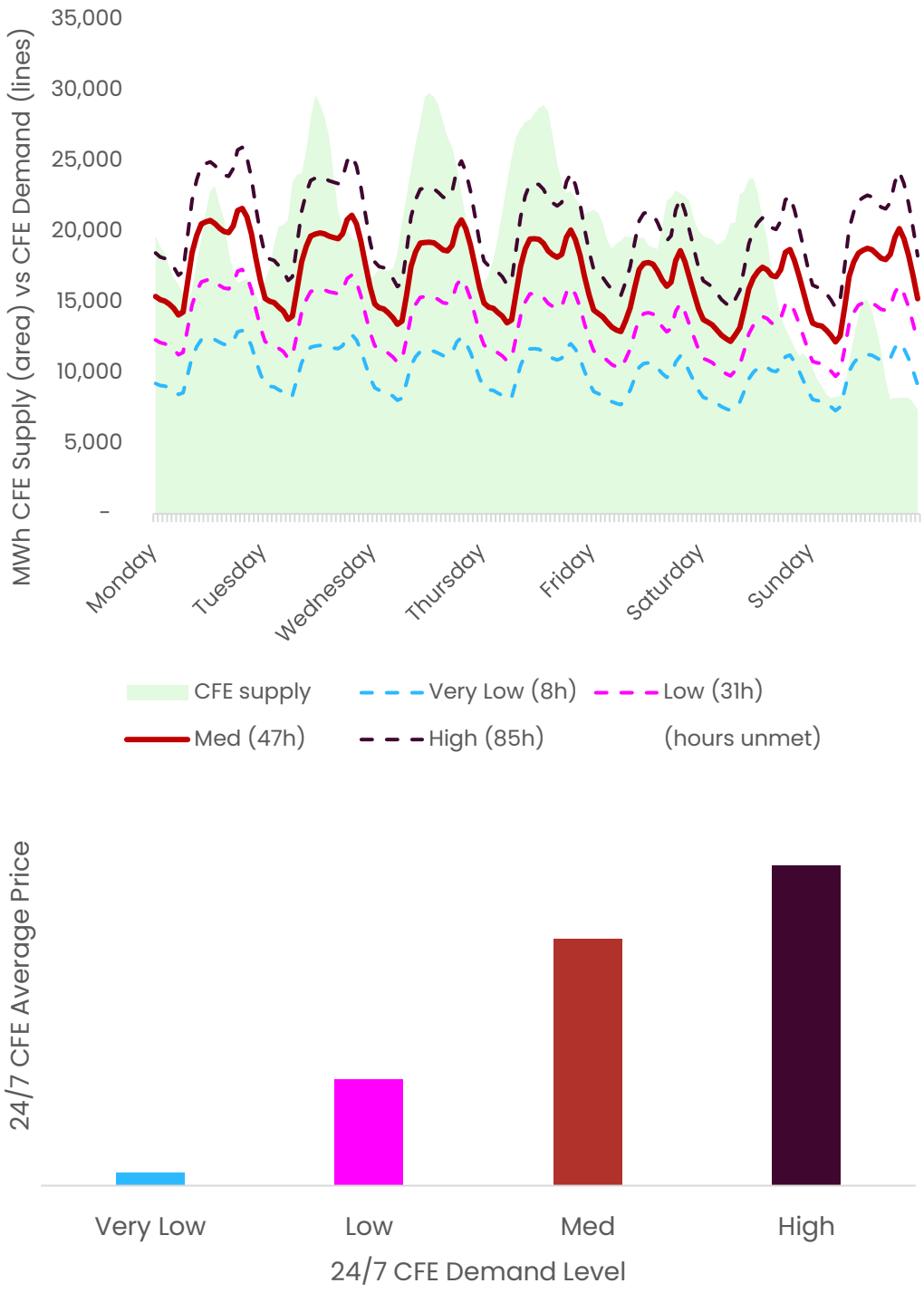


Figure 13: Pricing of granular certificates will depend on CFE supply relative to certificate demand

As the ratio of certificate demand to certificate supply increases, there are more hours where there is demand for a certificate but supply is not available. A tipping point occurs when certificate demand is around 40% of CFE supply. Before this tipping point, all CFE demand could be met. After this tipping point, the hours with unmet demand increase linearly, with every percentage increase in certificate demand resulting in more hours

where 24/7 CFE EAC demand cannot be fully met. The tipping point is driven by the availability of firm CFE supply, notably nuclear and biomass. Even in 'dunkelflaute' periods there is usually some availabilty of intermitent forms of CFE such as wind and solar. A

The tipping point was very similar for baseload, matched and off-peak weighted demand profiles, but the number of hours with unmet demand beyond this tipping point varies. The modelling presented in this section of the report uses matched demand, which means that in 2030, 60% of load in any hour is covered by a 24/7 CFE EAC.

Pricing of certificates is sensitive to assumptions, with rules and definitions still to be defined.

If implemented like the current REGO system, purchase of the certificates would be voluntary, directing funds from electricity customers in support of decarbonisation. Customers would be able to report that they are purchasing CFE energy, via the use of these certificates. However, when modelling prices, it is important to note that there are a number of key uncertainties, as detailed in Figure 14.

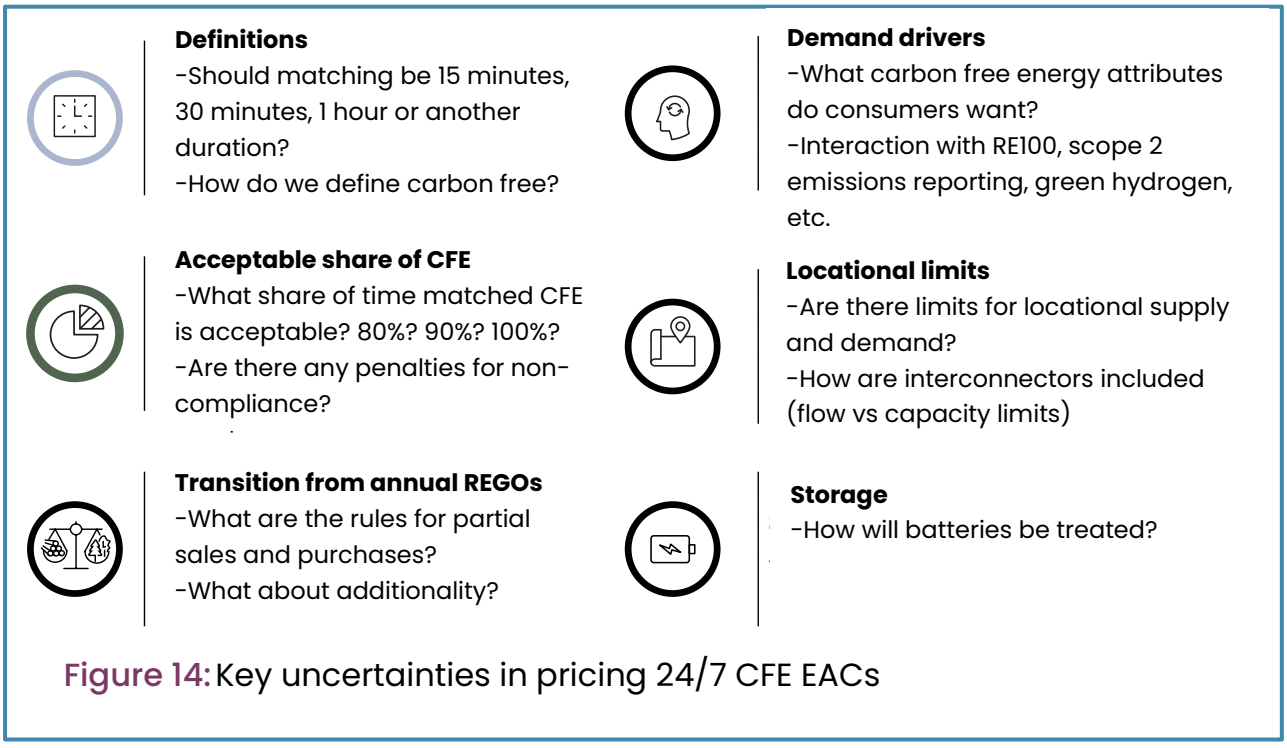


Figure 14: Key uncertainties in pricing 24/7 CFE EACs

It is worth noting that given the lack of evidence and clear data on consumer preferences in this area, the modelling assumptions are just that. The results, particularly around price levels of certificates should be considered as indicative. The modelling aimed to show price formation trends and impacts on different asset types. Ofgem may want to complete further stakeholder engagement ahead of any rollout of 24/7 CFE EACs.

As CFE supply increases, certificate prices should fall.

As the electricity system moves towards net zero, with increasing CFE supply, all else being equal prices for certificcates should fall over time. In the modelling we have assumed that demand for certificates is between 45 – 60% of the market. As shown in Figure 15, as capacity increases in the period to 2050, the price of 24/7 CFE EAC is expected to fall.

It is possible that the market could start with lower demand and acceptable matching percentages for certificates, with reporting standards tightening over time. Tougher corporate reporting standards for scope 2 emissions could prevent a price collapse as the system moves towards net zero.

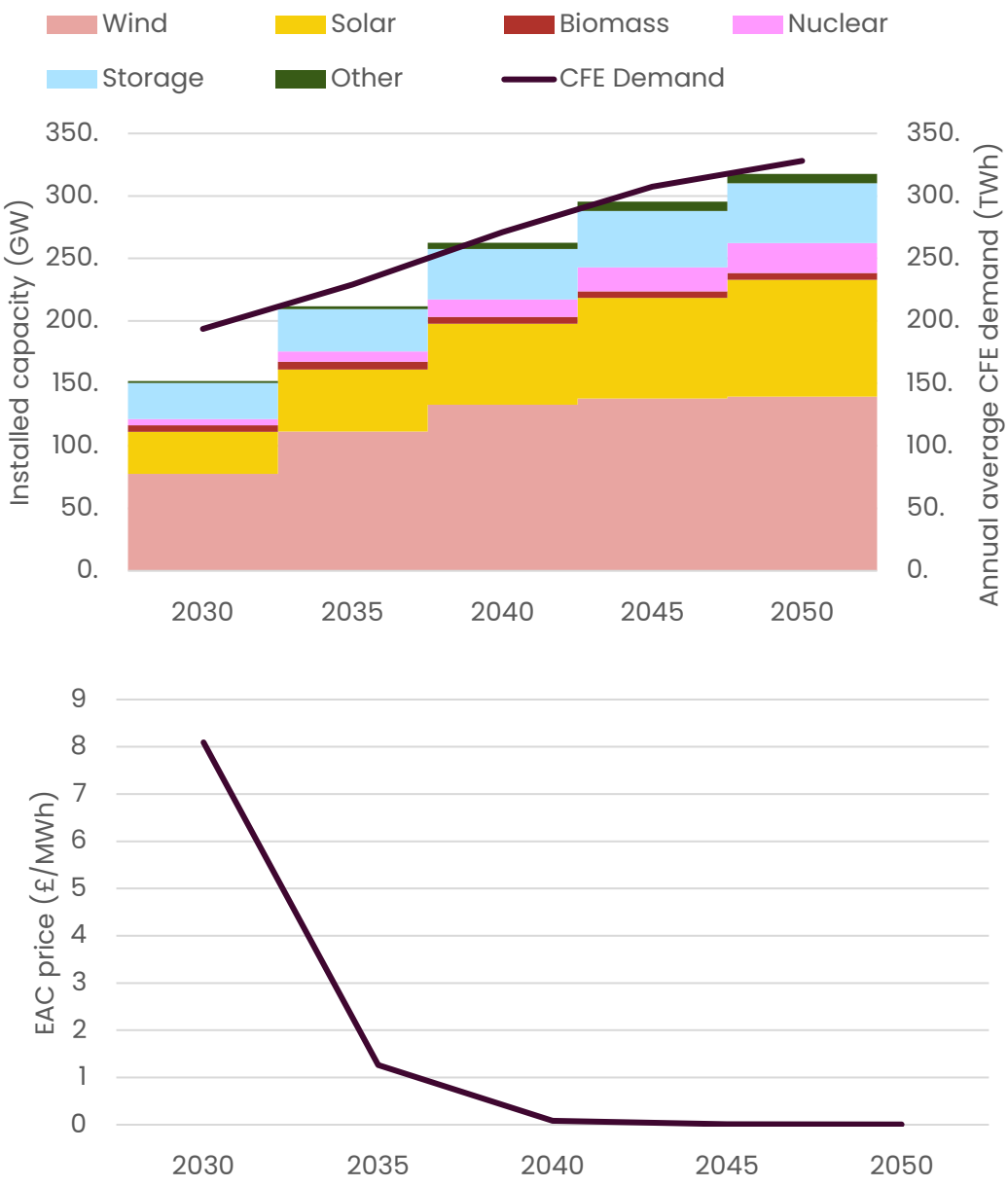


Figure 15: Capacity of CFE supply and Forecast Average EAC prices

Pricing will be volatile and sensitive to weather patterns and other input assumptions.

The highly variable and volatile nature of 24/7 CFE EAC prices expose those purchasing and selling certificates to uncertainty. This will make certificate prices hard to predict, particularly if demand varies year to year.

For a given level of demand, prices are highly sensitive to weather outcomes. AFRY modelled five weather years from 2012 to 2018. The range of average 24/7 CFE EAC prices depending on the weather outcomes were wide, as shown in Figure 16. The main driver of price was wind availability. Based on the generation mix, in a weather year with low wind, the price of CFE certificates are much higher than a weather year with high wind.

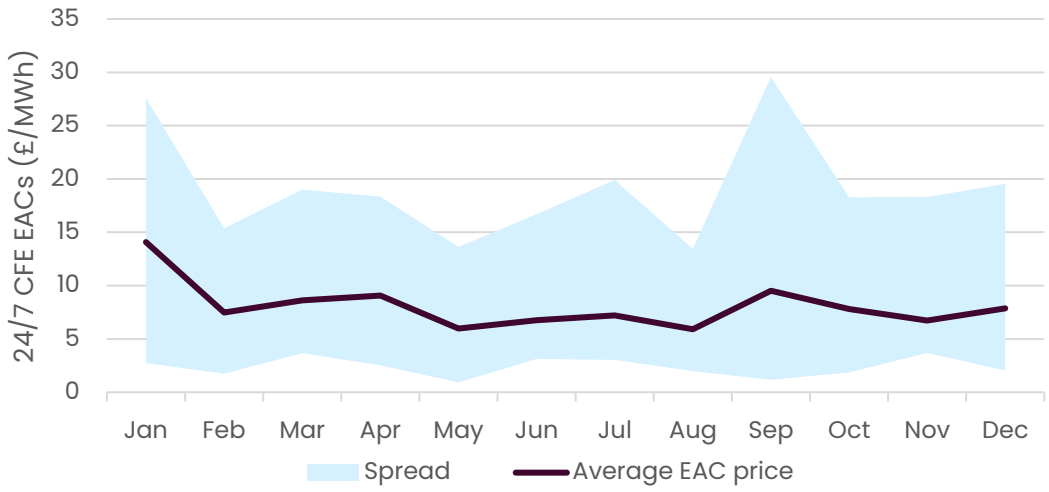


Figure 16: Average monthly certificate prices over a range of weather years in 2030

The definition of 'carbon free energy' matters, particularly for nuclear.

In the survey of consumers, it was noted that different consumers have different definitions of carbon free, with wind, solar and hydro more popular production than biofuels and nuclear. This means that certificate prices for EACs can and do vary across generation technology type.

In the current REGO market there can be different prices for REGOs, associated with different types of generation. According to the Renewable Exchange "Hydro, Wind and Solar are generally thought of as "greener" energy, as they have less biproducts in the production of

electricity. This means that the REGOs associated with this type of generation can have higher demand, and therefore higher prices"[16].

AFRY completed a sensitivity considering how certificate prices would be impacted in the case that nuclear was excluded from the CFE certificate market[17] limiting certificates to renewable energy supplies (like REGOs). In this case, the reduction in baseload nuclear supply means that that certificate prices would be higher in all periods considered (Figure 17).

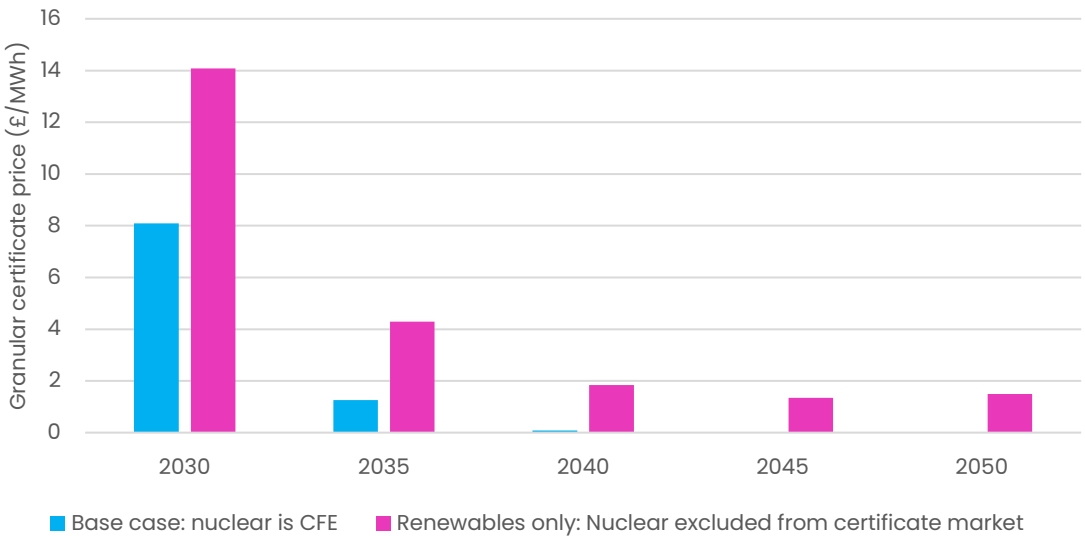


Figure 17: Forecast prices with and without nuclear included in the 'Carbon Free' EAC market

Prices are sensitive to storage capacity

In the FES 2024 Electricity Engagement Pathways (FES EE), storage capacity increases rapidly. In 2023, there was 4.7 GW of batteries. In the FES EE, this increases to 24.6 GW in 2030 and 31.8 GW in 2050.

AFRY completed a sensitivity analysis, shown in Figure 18, considering how certificate prices would be impacted in the case that storage capacity, specifically batteries, grew at a slower rate than in the FES EE Pathway, to only 16.9 GW in 2030 and 18.4 GW in 2050. In this sensitivity, average certificate prices are significantly higher than in the case where more storage is available.

[16] REGO Index Update – October 2023

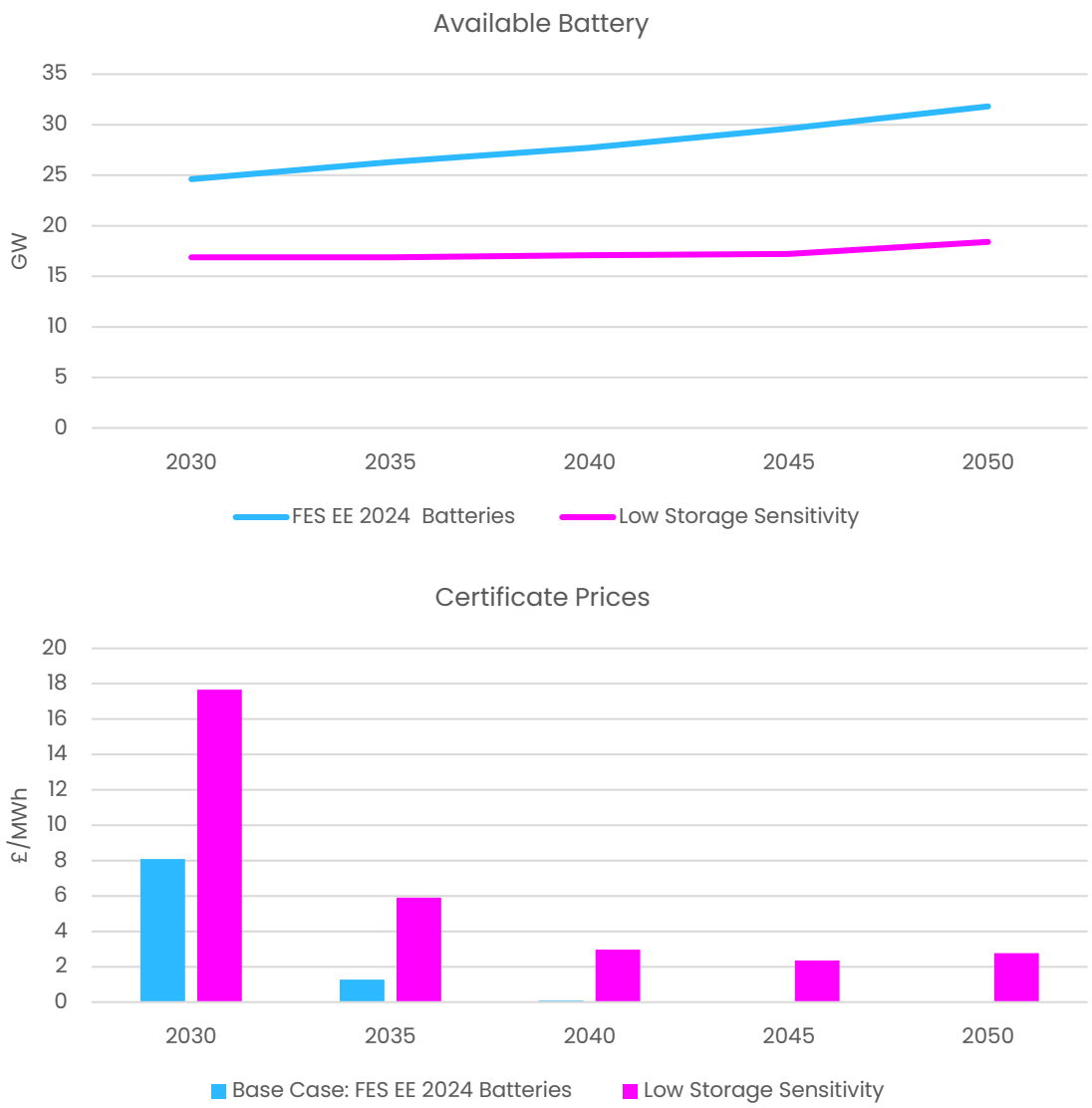


Figure 18: Forecast EAC prices in a low storage sensitivity compared to the FES EE Pathway

Impact on investments

24/7 CFE could provide incentives for market participants to deliver flexibility.

24/7 CFE trading enables the transfer of premiums paid by consumers for 24/7 CFE EACs to support various CFE technologies. The EAC capture price describes the average revenue a generator would receive from selling its certificates. This capture price is best for the most flexible assets.

It is likely that this scheme will replace REGOs, however the pricing of 24/7 EACs cannot be directly compared with REGOs as the product is different. In the case of granular certificates, it is likely that wind and solar would receive a smaller share of the 'green energy' pot, while more flexible soloutions like batteries would gain most. This means that if the same amount of money was spent on granular EACs, as is currently spent on REGOs, then wind and solar generators would be worse off, while storage operators and flexible CFE generators would be better off. However in reality, the money spent on REGOs is varying year to year.

It is likely that some consumers will pay more for granular certificates than they would for annually matched certificates. This is evidenced both by the survey and the existence of premium matched tariffs. The additional revenue would benefit CFE assets that cannot currently access REGOs, notably DSR, storage, and potentially nuclear.

Storage cannot currently benefit from REGOs so has the most to gain from granular certificates.

Time matched certificates would allow storage operators to access a new revenue stream, by purchasing granular EACs and storing energy when certiciate prices are low, and selling EACs and discharging when prices are high. This could trigger additional investment in storage, especially if longer term trades or contracts emerge.

The analysis shows that 24/7 CFE EACs could account for a significant portion of the revenues for storage operators. As shown in Figure 19, based on the assumptions made by AFRY, the revenues could account for around half of battery revenues.

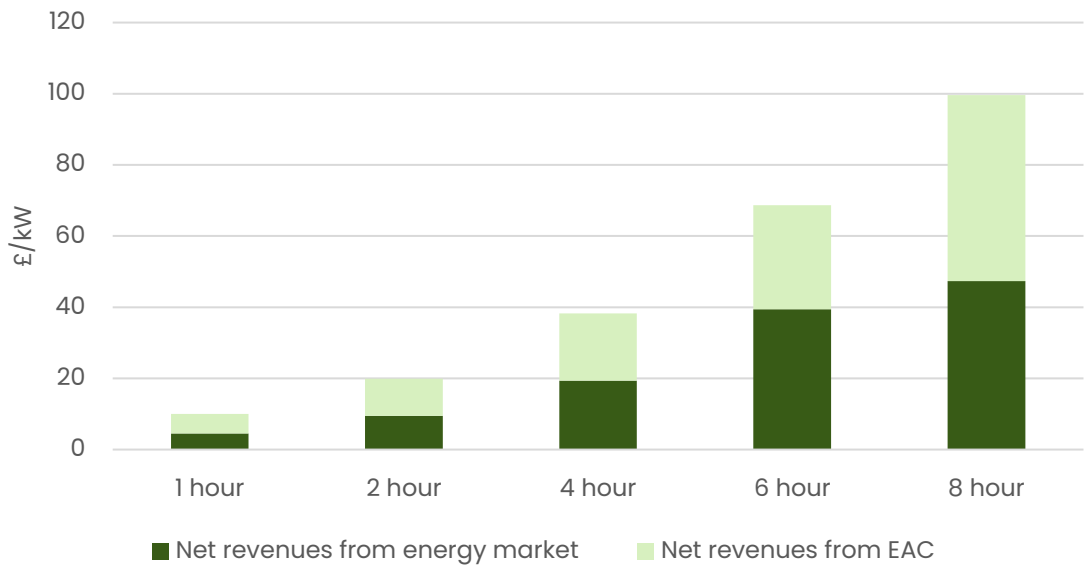


Figure 19: Revenues from energy and certificate sales for different durations of batteries

As future revenues from certificates are hard to predict, and likely to be highly volatile, as we have seen for REGOs, this could reduce the effectiveness of the certificates in supporting storage investments.

24/7 CFE could provide a strong incentive for engaged consumers via DSR

Compared to electricity prices, certificate prices have a much sharper price duration curve, as shown in Figure 20. 24/7 CFE EAC prices are expected to be zero most of the time, but when there is a shortage of available supply certificate prices will rise quickly.

The modelled price duration curve for EACs was similar in shape to outcomes seen in the trading pilot with generally low prices in the majority of periods and a sharper curve than electricity prices. However the trading pilot had significantly more hours with non zero prices, with about 75% of hours having a positive, albeit low price in the trading pilot. The difference in hours with zero prices could be due to the impact of lower liquidity in a trading pilot with a limited number of participants.

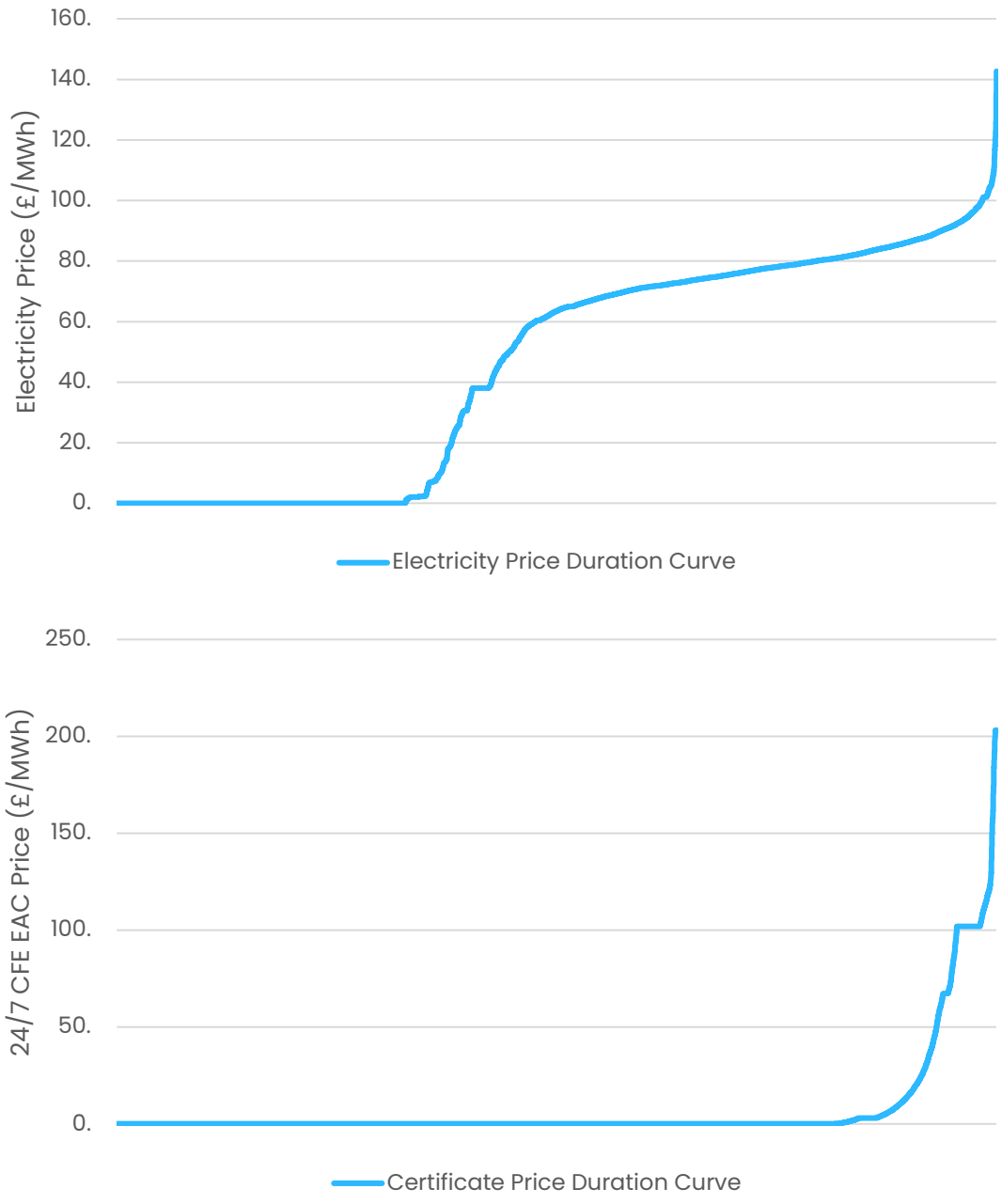


Figure 20: Price duration curve for Day-ahead electricity and certificate prices

This sharp price duration curve creates strong incentives for customers on a matching tariff with flexibility to switch off or down at times of low wind and other CFE supply.

Flexible 24/7 CFE demand can help to balance the CFE supply and demand requirements. Examples of flexible 24/7 CFE demand include:

- Price responsive 24/7 CFE demand (e.g. end-users who have a price above which they do not wish to pay for CFE so they switch off when CFE prices reach a certain level)

- Load shifting 24/7 CFE demand (e.g. data centres who can use different locations for their operations on an hour-by-hour basis and can actively control their load, adjusting timing of electric vehicle charging)
- Generation of Green Hydrogen through electrolysis, when CFE prices are low

Flexible 24/7 CFE demand allows for the CFE requirements to be met on an hourly basis and reduces the need for CFE matching with storage.

Solar and wind capture a fraction of the 24/7 EAC certificate price while baseload supplies capture around the average price.

Assuming the national electricity market is maintained, the certifcate price for intermittent renewable generators will depend mostly on how electricity is generated. All wind generators would capture a similar 24/7 CFE EAC rate to other wind generators. Solar producers would capture similar price to other solar generators. There would be minor variations for location due to weather conditions. Certificates could encourage optimisation of maintenance scheduling.

Modelling suggests that nuclear and other baseload assets secure around the average certificate price. In the case of flexible biomass plants, it would encourage operations at times of low CFE availability, and these assets could optimise to secure above average certificate prices. The range of capture prices across generation technologies is shown in Figure 21.

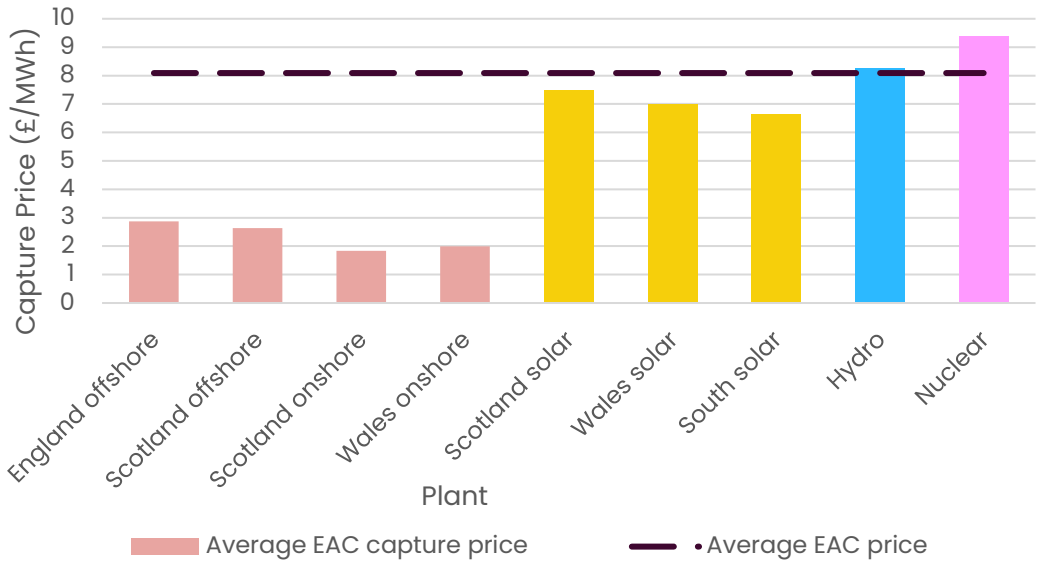


Figure 21: Capture prices for CFE technologies

Unpredictability and volatility could undermine investment benefits of 24/7 CFE EACs.

The new revenue stream associated with 24/7 CFE EACs should add a financial incentives for investments in CFE assets. However given the volatile and unpredicable nature of these revenues, there is a risk that CFE generators will find future revenues difficult to forecast, and therefore these potential revenues will be either excluded or discounted heavily when making investment decisions. As previously highlighted the volatile prices of REGOs has limited their effectiveness in supporting renewable energy investments, despite high REGO prices in recent years. For intermittent generators, such as wind, the value of these certificates is even harder to to predict, and they would have less certainty than in an annual REGO market.

The introduction of 24/7 CFE EACs can add incentives to make a CFE generation investment, but will not make a business case for an investment alone. Further work on implementation is recommended to understand how the introduction of granular certificates can work alongside other market arrangements to support the development of carbon free generation.

Implications for NESO

Trading of 24/7 CFEs is generally beneficial for system operation.

The emergence of 24/7 CFE is not foreseen to introduce any major risks for NESO and could provide behavioural benefits in the operational timeframe and additional benefits in the investment timeframe. The stronger price signal in times of scarcity could lead to helpful behaviours, particularly for storage and DSR.

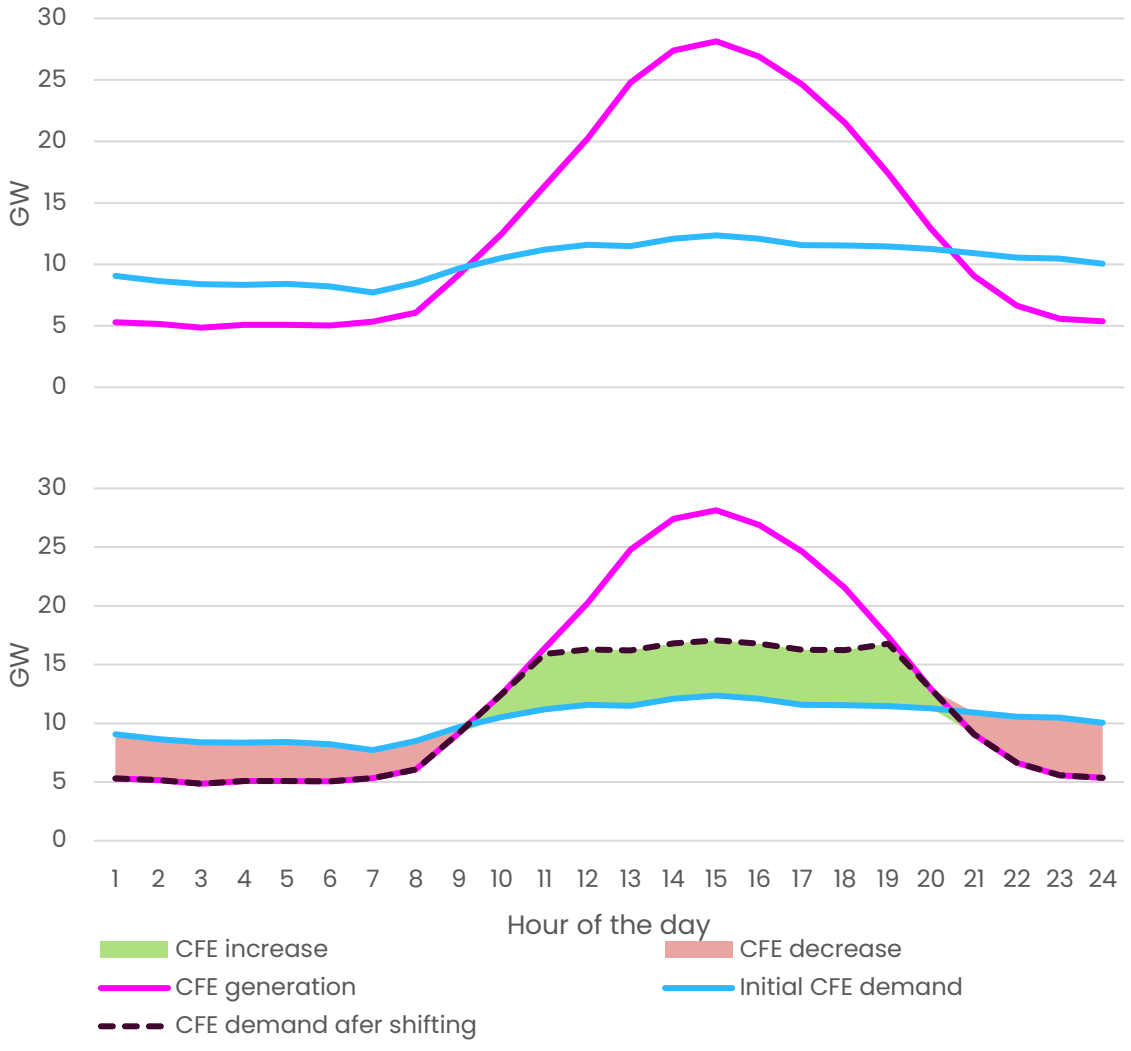


Figure 22: Example where flexible CFE demand can reduce system impacts

As shown in Figure 22, a summer day was highlighted as a day where system operation can change as the 24/7 CFE demand exceeds the CFE supply. Flexible 24/7 CFE demand

allows for the CFE requirements to be met on an hour-by-hour basis and reduces the need for system storage for CFE matching.

Congestion would not be materially impacted.

A 24/7 CFE market is not expected to lead to material changes in the level of constrained boundaries within a national GB system. Congestion is generally associated with windy periods. For example, the B6 boundary limits the ability to transport energy between Scotland and England. Congestion on this boundary is largely associated with windy periods. As shown in Figure 23, when flows are high, 24/7 CFE EAC prices are low. When there are lower flows across the boundary, there is a wide range of certificate prices.

A 24/7 CFE market will have little impact on transmission as when the CFE market is tight (leading to an EAC price) there is reduced wind output. Assuming no changes to market arrangements, constrained boundaries continue to occur at a similar rate with or without a 24/7 CFE market.

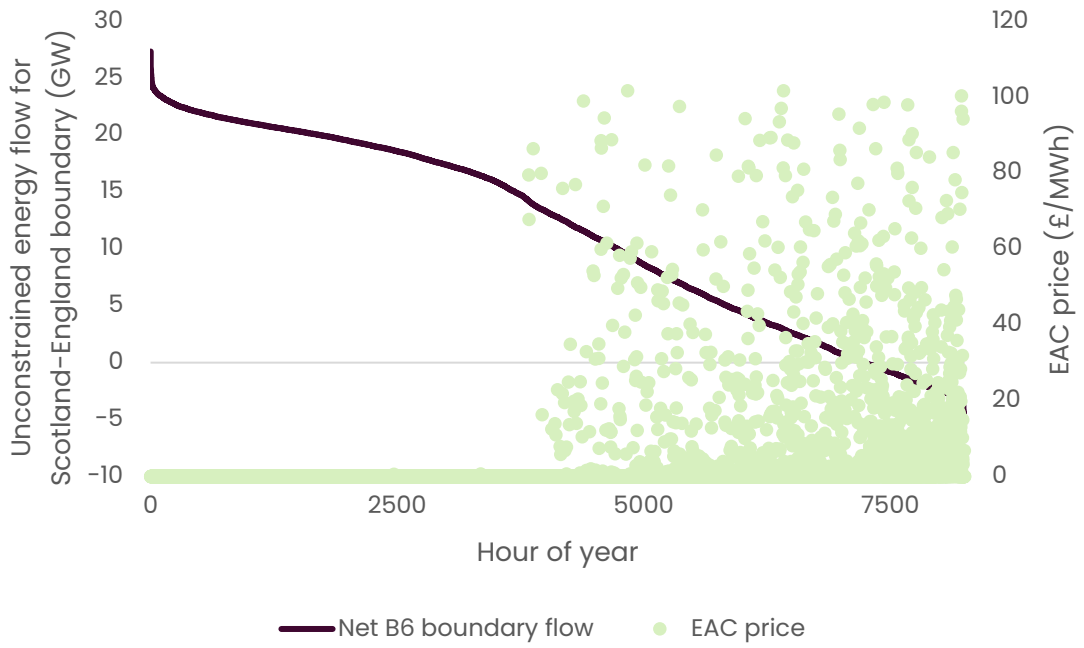


Figure 23: Unconstrained energy flow levels across B6 boundary in national integrated energy and CFE prices in 2030

24/7 CFE should not create additional costs for redispatch.

In the operational timeframe, the impact of 24/7 CFE EACs on wind redispatch and bidding patterns is expected to be limited. While in theory an additional revenue stream could add to redispatch costs, in practice, when CFE supply is being curtailed, there would be an

abundance of CFE supply[18]. When CFE supply is plentiful, certificate prices tend to zero. This compares favourably to the current scheme where the annualised REGO price is always positive, even at times of abundant CFE.

Figure 24 shows the average 24/7 CFE EAC price, over a distribution of available CFE supply during Febuary 2024. There is only a positive price in under 30% of periods, and these are all when there is limited availability of CFE supply, typically due to low wind output.

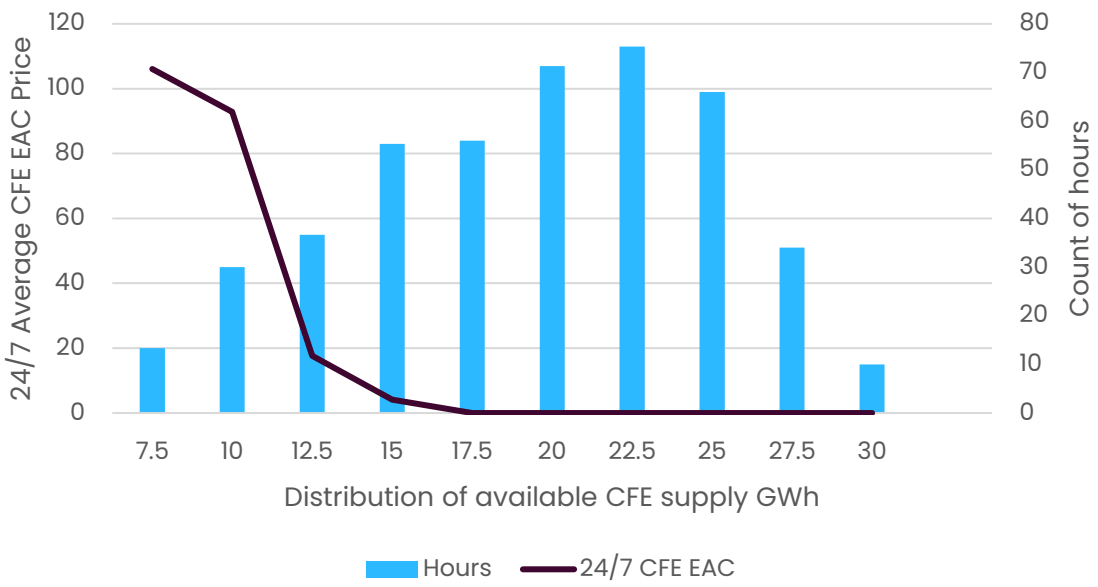


Figure 24: Distribution of CFE Supply compared to forecast certificate prices during Feb 2024

Further work on implementation is required.

Ofgem and DESNZ who will ultimately be responsible for any decision in changing the EAC market in the GB, but it would make sense to involve NESO in further work on this topic.

Lack of liquidity, imperfect co-optimisation, and uncertain behaviours are risks that should be considered, as potentially influencing NESO. As discussed previously, this could boost investment, particularly in long duration storage. Rules should be carefully designed, tested and monitored to ensure benefits are maximised, and risks to NESO, especially those that could increase redispatch costs are minimised.

[18] While it is theoretically possible that localised wind conditions could mean that curtailment of specific wind generators happens at times of generally low wind conditions, this is unlikely. A more likely scenario is that there are site specific reasons for curtailment of less dominant CFE generators such as biomass or solar.

Consideration should be given to actions that could support liquidity and therefore preditiability of the 24/7 CFE EAC market, such as mandatory reporting and price forecasting.

24/7 CFE EACs in a zonal market

In a zonal energy market the ease with which CFE demand could be met varies significantly between zones. AFRY considered a sensitivity where the GB market had been divided into 11 pricing zones (see Annex). However, the learnings from this sensitivity can also be applied to flows through international interconnectors.

Impacts are amplified in the case of a move to a zonal market.

In each zone there is a brown market and a CFE market. As described earlier, If a buyer purchases CFE from a different zone, there is a requirement for there to be an energy flow between the two zones.The boundaries between zones are benchmarked against NG ESO publications of planned grid reinforcement. Interactions with transmission capacity and intra-zonal congestion management have not been considered in this study, but remain an issue for future consideration dependent on the arrangements which buyers and sellers agree for the delivery of 24/7 CFE between price zones. As shown in Figure 25, in the case of a zonal market in GB, the supply and demand for CFE varies significantly between zones.

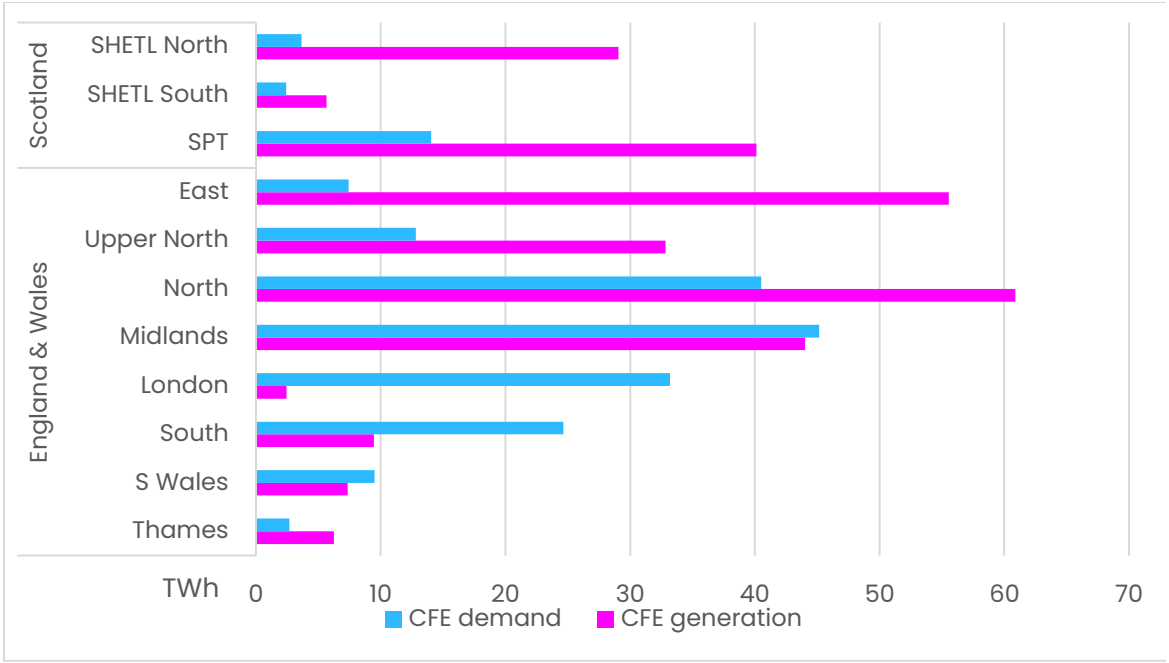


Figure 25: Availability of CFE supply compared to CFE demand in different regions in 2030

24/7 CFE EAC trading could happen earlier than zonal pricing.

Based on experience in other markets, it is expected that 24/7 CFE EACs could be implemented within 2 years, whereas a transition to a zonal market is unlikely to happen at that speed. Establishing a granular certificate scheme early would provide plenty of time to establish market rules and trading for a national granular certificate. These learnings could be beneficial when considering rules for storing, transporting and trading CFE energy across zonal boundaries.

EAC prices would vary by zone.

In a zonal market the dominant factor for the ability to meet CFE demand is the wind generation output. Areas with a high penetration of wind have lower EAC prices. Based on AFRY's assumptions of zonal splits in GB, Scotland and the East of England have lower prices over the year.

Limitations to the transportation ability of CFE leads to areas with high EAC prices, particularly in the south of England and South Wales. The Figure 26 shows forecast outturn electricity prices and 24/7 CFE prices by zone on average in 2030.

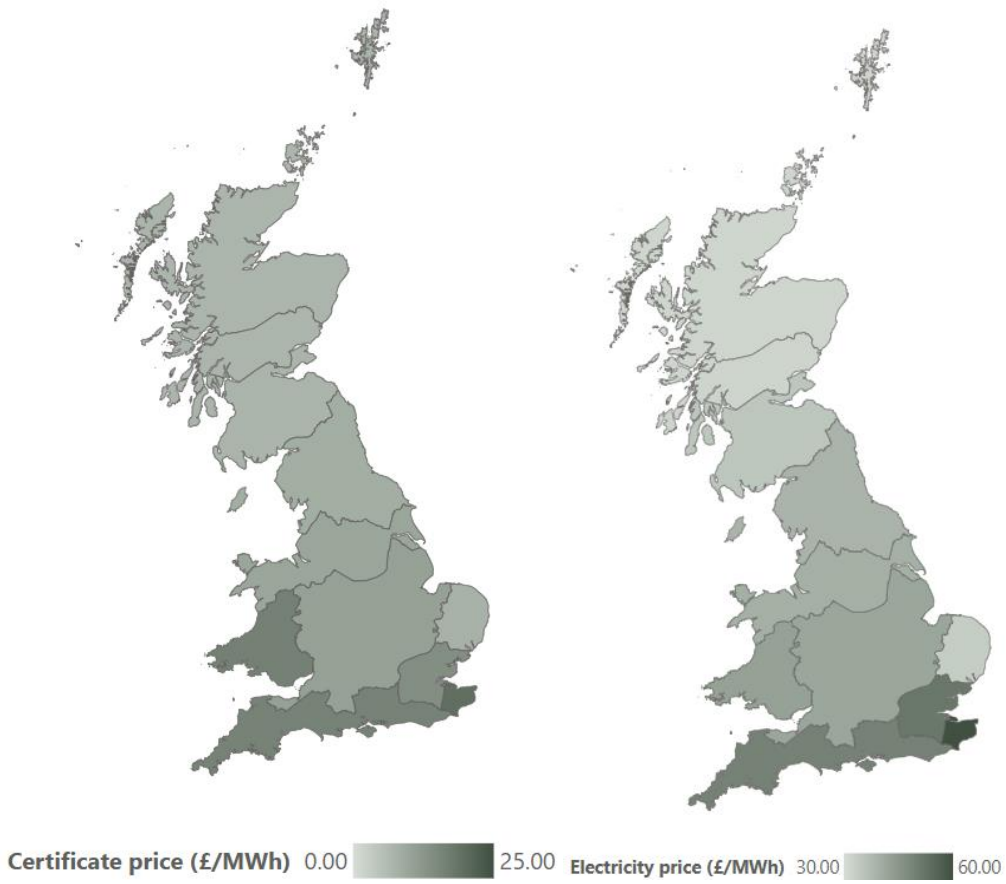


Figure 26: Average annual zonal prices for electricity and 24/7 CFE EACs in 2030

24/7 CFE encourages regional investment.

A zonal market would see regional CFE prices which can encourage the locational siting of CFE generation and storage. Capture rates for CFE generators and storage operators would vary by zone. Margins for storage would improve most in zones with CFE supply and capacity constraints. This is likely to encourage investment, particularly of storage, in areas that need it most, amplifying zonal price signals.

Annex

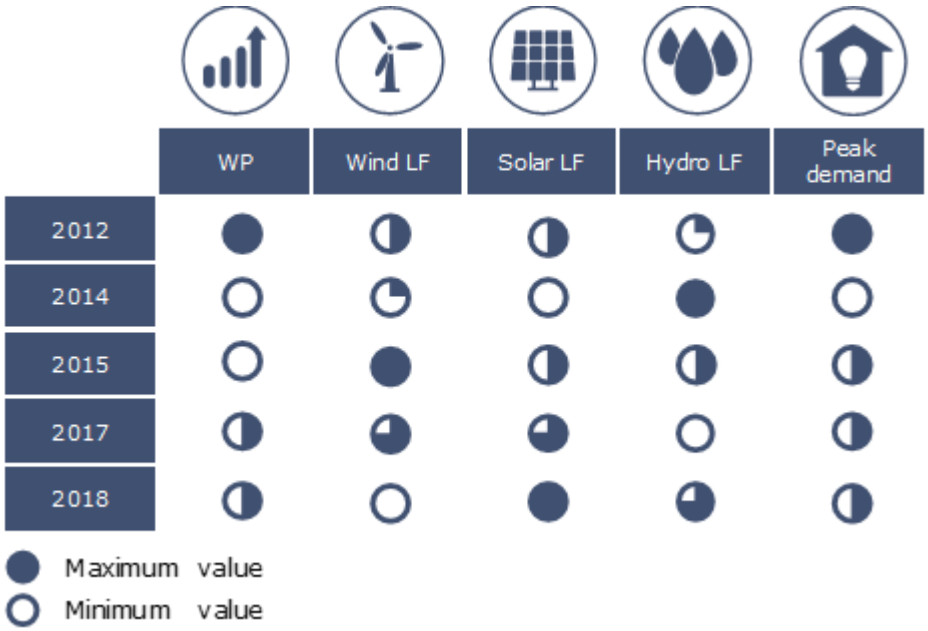
Glossary

Glossary	
24/7 CFE	Hourly or sub-hourly Carbon Free Energy
24/7 CFE EAC	Hourly Carbon Free Energy Electricity Attribute Certificate. In this study, AFRY modelled hourly energy attribute certificates as a theoretical replacement for the current Guarantees of Origin certificates
24/7 CFE EAC Price	The value of an 24/7 CFE EAC is equal to the wholesale price in the CFE market less the price in the GB wholesale market
Brown market	AFRY BID3 model set up which includes all assets that are not considered to be CFE
CFE	Carbon Free Energy or "energy produced from resources that generate no carbon emissions"
CFE Market	The wholesale electricity price in the 24/7 CFE market
Clean Power 2030	A government target that specifies by 2030, Great Britain will generate enough clean power to meet its total annual electricity demand, backed up by unabated gas supply to be used only when essential.
Counterfactual Market	AFRY BID3 modelling results for the wholesale electricity price without a 24/7 CFE EAC market (status quo)
DESNZ	Department for Energy Security and Net Zero
DSR	Demand side response. This involves reducing consumption and times of supply constraints and high prices. This can include both shifting and destruction of demand. Shifting happens when consumers change when energy is consumed, for example avoiding peak hours. Destruction happens when beyond a certain price demand is reduced, for example switching off.

Dunkelflaute	A term used to describe low availability of intermittent CFE, due to being dark and windless. Dunkelflaute is a German term, with Dunkel meaning 'dark' and 'Flaute' meaning calm. Usually shortages or 'Dunkelflaute events' occur in the British system at times of low wind generation.
EAC	Energy Attribute Certificate
GB	Great Britain
GB Wholesale Market	AFRY BID3 modelling results with a 24/7 CFE market
GHGP	Greenhouse Gas Protocol. GHGP supplies the world's most widely used greenhouse gas accounting standards and guidance. The standards and guidance are designed to provide a framework for businesses, governments, and other entities to measure and report their greenhouse gas emissions.
Ofgem	Energy Regulator for Great Britain
REGO	Renewable Energy Guarantees of Origin – the current system used in Britain to underpin green energy claims
REMA	Review of Electricity Market Arrangements, an ongoing study into the market design of the electricity market in Great Britain
Scope 2 emissions	Scope 2 emissions refer to indirect emissions through purchased electricity, steam, heating and cooling, under the GHGP

Weather year characteristics

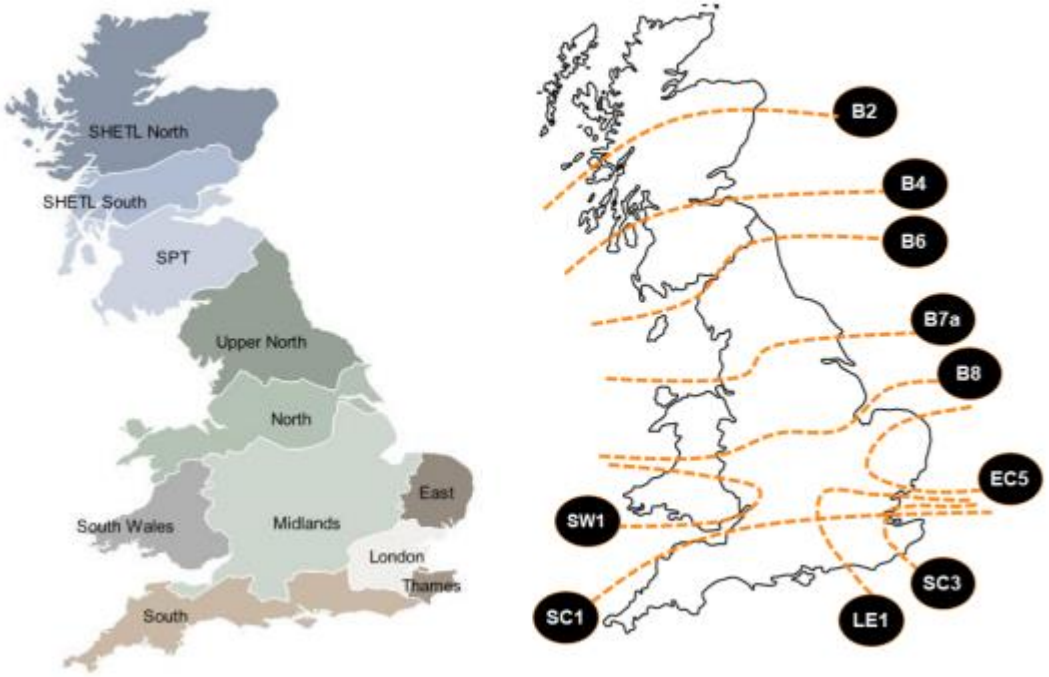
Unless otherwise specified, we show data based on 2012 as the weather year. However, as AFRY models a set of 5 weather years, we have pulled results from weather years that exhibit high wind generation and low wind generation to show the impact on the CFE certificate price. Other weather years can be considered for variations in wind, solar and hydro values. Maximum and minimum values represent the extreme weather years for each parameter, with the other weather years falling somewhere inbetween.



Zone assumptions

AFRY split GB into 11 zones, based on 10 major transmission boundaries. The number and location of possible zones is an AFRY assumption.

Zone	Boundaries
East	Behind EC5
London	Behind LE1, Outside SC1 and SC3
Midlands	Below B8
North	Above B8
South	Behind SC1, Outside SC3
SWales	Behind SW1
Thames	Behind SC3
UpperNorth	Above B7a
SHETL_N	Above B2
SHETL_S	Above B4
SPT	Above B6



National Energy System Operator
Faraday House
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA

www.neso.energy