Constraints management options: Net Consumer Benefit

Constraints Collaboration Project

National Grid ESO
July 2024

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Foreword

Simple, ‘proof of concept’ modelling that does not represent a forecast of constraint costs

We have been commissioned by the ESO to quantify the Net Consumer Benefit for some of the options developed under the Constraint Collaboration Project. Baringa has assessed 3 options using a **simple, high-level quantitative methodology**, to assess impacts on annual cost, consumer benefit and greenhouse gas (GHG) emission savings. The intent of this analysis is a ‘proof of concept’ of these options before more detailed design and analysis of the options is potentially conducted.

We built a simple model of the energy system in Great Britain (GB) to measure the constraint management costs under the status quo and under different scenarios. No market modelling of the options nor any modelling of wider market reforms have been conducted. This simple model is underpinned by strong modelling assumptions. We have outlined our key input assumptions in this report.

The main objectives of this assessment was to identify relative monetary impacts of these options compared to a counterfactual scenario based on simple analysis drawn from a combination of datasets. **The modelling does not attempt to forecast accurate future constraint volumes or costs in GB**. All figures included in this analysis are **indicative only**. Outturn constraint costs will depend on a wide range of factors including build out of system assets and network infrastructure that are beyond the scope of this analysis.

Background

Growing constraint costs

Renewable energy sources, such as onshore and offshore wind, are playing an increasingly important role in Great Britain's (GB) electricity generation. To maximise wind availability, wind generation is often located away from centres of demand. A growing challenge facing the ESO is how to ensure that this renewable electricity can travel from where it has been generated to these locations of demand.

Network constraints arise when the transmission system is unable to transmit power to the location of demand; the ESO will take actions in the Balancing market (BM) to increase and decrease the amount of electricity at different locations on the network. Typically, constrained generation comes from wind in Scotland which would otherwise be transported to demand centres in England.

Network constraints between Scotland and England have been increasing. The ESO is having to curtail wind generation in Scotland, whilst simultaneously turning up generation in England to meet demand. In 2023, 4TWh of wind was curtailed, with total constraints costing consumers £1.3bn. These short-term constraint costs are forecasted to increase to £3bn by 2030[1].

Building more physical network infrastructure and/or introducing market reform are ways to reduce network constraints, however, these are longer-term solutions which will not address the short-term constraints in the interim period. Therefore, the ESO has established the Constraints Collaboration Project (CCP) to explore potential short-term market-based solutions to address the volume and costs of constraints within the next 5 years.

1 Thermal Constraints Collaboration Project | ESO (nationalgrideso.com)

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Options in scope for assessment

Three lead options identified for assessment

The Constraints Collaboration Project (CCP) aims to reduce the overall cost of constraints to consumers by either reducing the volume of constraints actions (MWh) and/or reducing the unit cost of managing constraints.

More than 20 options were originally proposed by the industry across six categories. Following consolidation and the ESO's initial market design framework assessment, three overarching options were defined as in scope for the net consumer benefit assessment.

In scope following ESO Market design framework assessment

1. Constraints Management Markets (CMM)

1A. Demand for Constraints
- amp: Increasing demand for power in constrained areas for electrification of heat
- eneus energy: Flex PtX to produce green H_2 and related derivatives
- Statkraft: Demand signal product
- ScottishPower: Incentivising new discretionary demand (H_2 production and electricity storage)
- Flexitricity: 'COOLER HEATING' – commercial heat loads as responsive assets (1A/1B)
- sse Business Energy: Long-term constraint management contracts (incentivising new demand)

1B. Long-term Constraints Management Markets
- TEL: Constraints management markets (CMMs) (1B/1C)
- Scottish Futures Trust: Long-term contract to manage a portion of the forecast constraint volumes
- sse Business Energy: Competitively allocated season ahead constraint management availability contracts
- EDF: Long-term auction of excess wind

1C. Short-term Constraints Management Markets
- ZENOBĒ: Pre gate closure constraint management product using scheme 7 trade
- sse Business Energy: Competitively allocated short-term constraint management contracts (D-7)
- EDF: Discounted demand turn up
- EDF: Weekly generation turn down market
- Flexitricity: The 'Big Friendly Battery' for ~8 hours duration

Out of scope following ESO Market design framework assessment

2. Increasing how much can flow over boundaries

2A. Extended intertrip scheme
- FIELD: Extended intertrip scheme
- ZENOBĒ: Intertrip scheme utilisation
- sse Business Energy: Enhance utilisation of the transmission network
- Eku: Battery for constraints: Reducing the line rating from 10 to 3 mins

2B. Grid Booster: Post-fault
- FIELD: Grid booster
- Kona Energy: Paired storage systems across key boundaries (2B/2C)
- ZENOBĒ: Flexibility for Active Network Management (ANM) zones and Generation Export Management (GEMS)

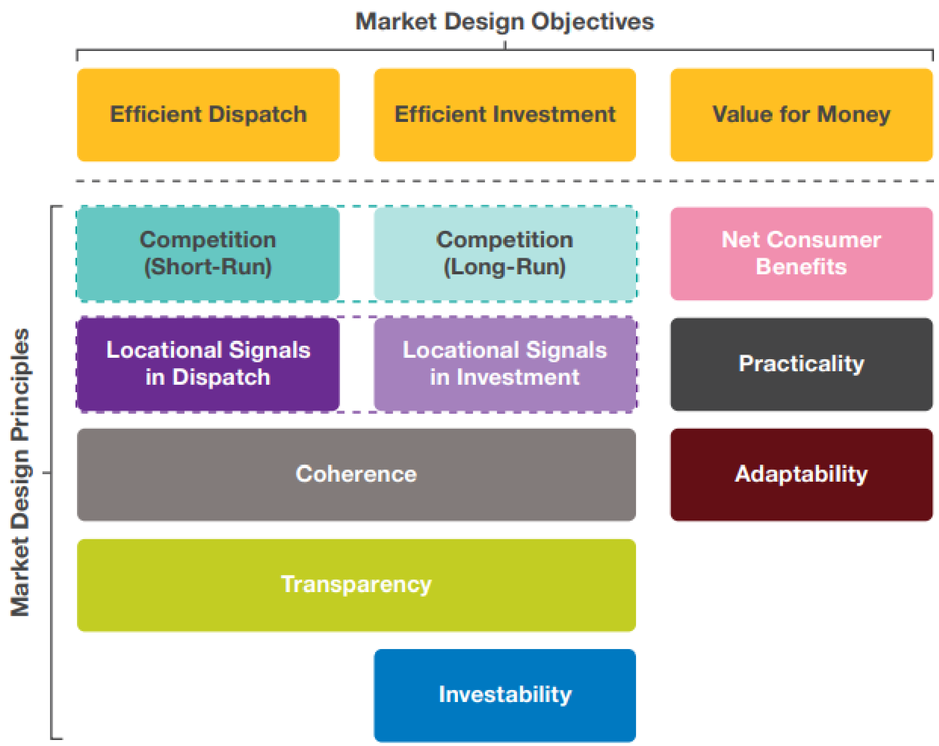
2C. Transfer Booster: Pre-fault
- ZENOBĒ: Transfer booster

Key: Demand for Constraints | CMM – Long term | CMM – Short term | Increasing how much can flow over boundaries

ESO's market design framework

Initial assessment of Net Consumer Benefit

The Market Design Framework underpins all of the ESO's market reform decisions. The ESO is assessing these options against the Market Design Framework – a framework which assesses how well an option meets the ESO's market objectives of (i) Efficient Dispatch, (ii) Efficient Investment and (iii) Value for Money. **Baringa assessed each of the options to determine the Net Consumer Benefit (NCB), which supports the overarching market design objective of Value for Money.**



The Value for Money objective aims to align with the energy trilemma challenges:

- **Lowest cost for consumers** – considers the overall financial impact to consumers and assesses value based on the extent to which consumers benefit from any cost reductions resulting from improved efficiency.
- **Enabling the transition to net zero** – ensures that ESO's procurement is flexible to, and compatible with, changes in technology mix required to facilitate decarbonisation.
- **Security of Supply** – ensures ESO's procurement is flexible to changing requirements such that the system remains secure.

Net Consumer Benefits principle: the costs to consumers do not outweigh the benefits conferred by the procurement method.

Source: National Grid ESO Markets Roadmap, page 18

Analytical scope

Initial, indicative assessment of options benefits

Our analysis assessed potential impacts on annual cost (£) of resolving constraints, wider consumer benefits and GHG savings.
Our analysis was based in Excel with no market modelling (e.g. Plexos). A fuller quantitative assessment may be conducted on chosen options at a later stage.

Quantitative Assessment:

- The annual net consumer benefit and GHG emissions savings for each year between 2025-2035, versus the counterfactual:
  - Annual cost: costs to consumers of managing thermal constraints for each solution. This includes all costs on consumer bills i.e. balancing costs, wholesale electricity costs, network costs and renewable support costs.
  - Additional consumer benefits: whole system benefits like carbon savings.
- In each case, we outline the key assumptions and calculation method.

Qualitative Assessment:

- Other whole system benefits generated by each option, not captured in our modelling.
- Perverse incentives/unintended consequences - For example, gaming risk.

Overarching assumptions

Our assessment focused on constraint flows between Scotland and E&W (England and Wales):

- Our assessment models flows between Scotland and E&W as 'proof of concept'.
- Results from our modelling implicitly capture constraints that would be resolved internally within Scotland before reaching the B6 boundary.

Thermal constraints only.

- Rate of Change of Frequency (RoCoF) and Voltage are out of scope.

The timeframe of the assessment is from 2025-2035.

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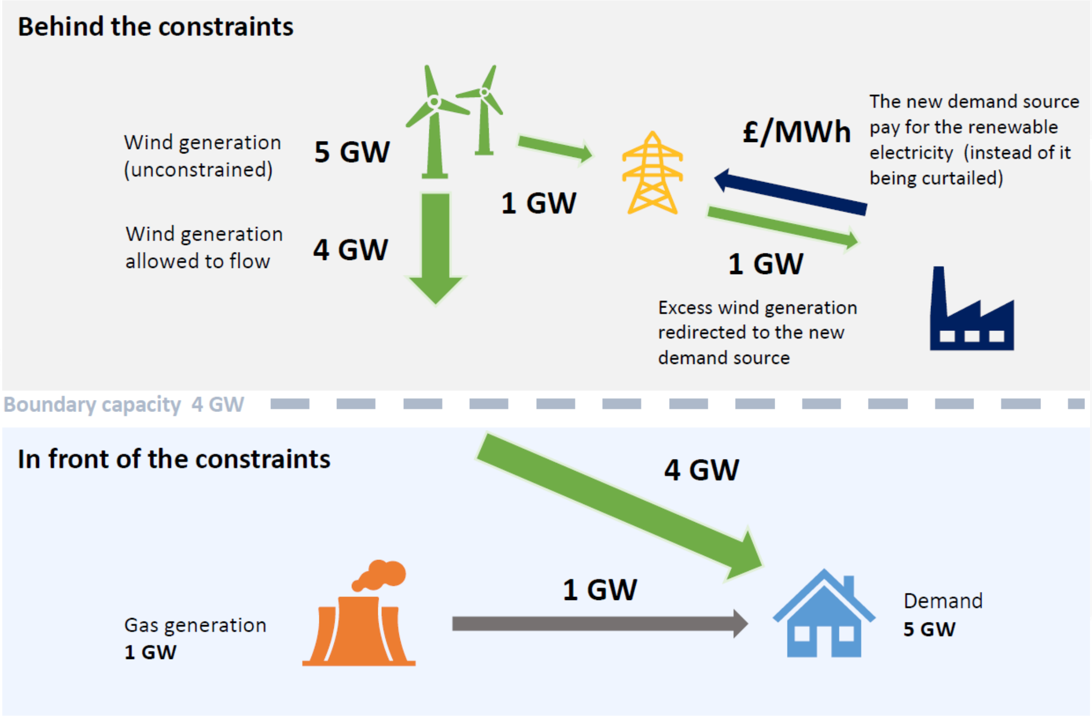
Options summary

Demand for Constraints (DfC)

Description: An ancillary service contract which offers electricity at a reduced price during periods of constraints to incentivise local sources of demand that can 'soak up' excess generation. This option is for customers behind the constraint, i.e. located in Scotland in our modelling. Use of the DfC would reduce curtailment costs and ensure productive use of otherwise curtailed generation but does not reduce the volume or costs of actions needed for generation turn-up in front of the constraint (i.e. in E&W).

Intended benefits:

1. Sending signals for increased local demand during constraint periods which **reduces volume of renewable curtailment**.
2. Demand pays to consume the otherwise wasted dispatch, thus returning value to ESO who can pass it through to **reduce BSUoS charges.**
3. Incentivises **strategic location of assets and may encourage additional demand.**



Source: ESO

Modelled Definition:

1. Only **new demand** is considered eligible.
2. Only **flexible demand** beyond that consumed during normal operation is eligible.

Options summary

Constraints Management Markets (CMM) (short-term and long-term)

Description: The CMM would allow the ESO to contract for assets to manage constraints, potentially including both generation turn up/demand turn down in front of the constraint and demand turn up/generation turn down behind a constraint.
The CMM would be procured ahead of BM timescales, through a competitive market. This in turn should reduce the volume of uncontracted actions that need to be taken closer to real time.
A short-term CMM would contract volumes day to week-ahead and a long-term CMM would contract volumes multiple years to a decade ahead.

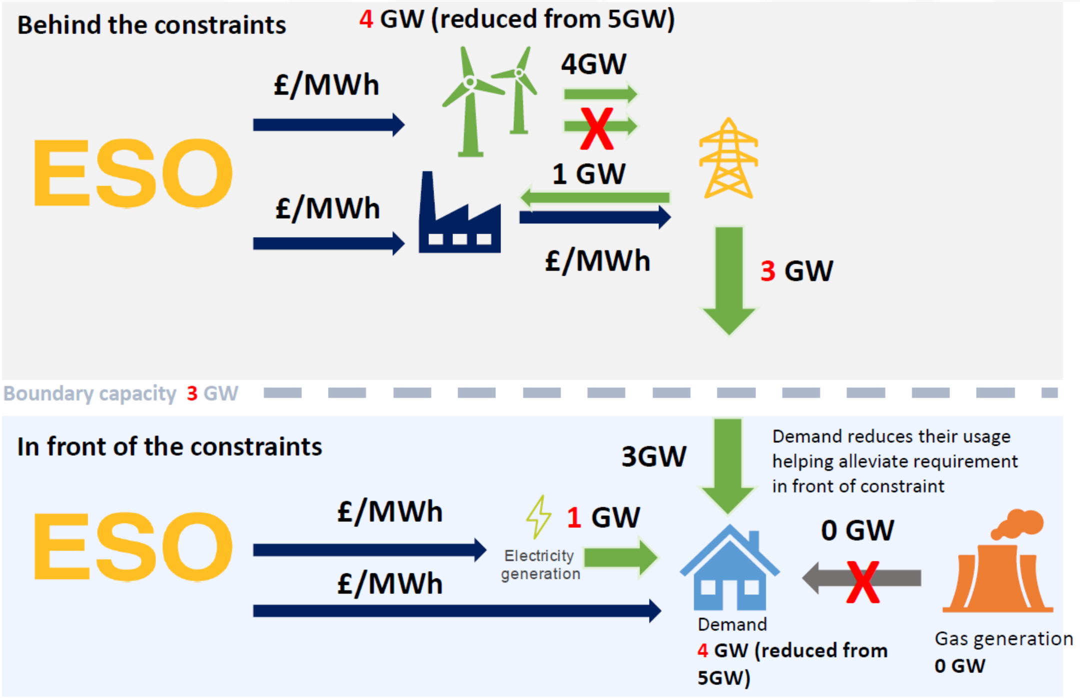
Intended benefits:

1. Forward contracting of flexibility volumes **allows ESO to secure better prices**, without appearing as a distressed buyer.
2. Particularly if contracted further in advance, the CMM may support a business case for **new flexibility providers to enter into the market**.

Modelled Definition:

1. **The same set of providers and volumes participate in the CMM as in the BM.**
2. In practice, a longer-term CMM may provide more revenue certainty, increasing likelihood that **new flexibility providers** may enter into the market .

An example of a CMM contracting generation and demand on both sides of the constraints



Source: ESO

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Quantifying the Net Consumer Benefit

Overarching Methodology

- Our assessment measured the impact of each option on the total consumer bill, including any constraint management costs in the Balancing Mechanism, payments to contract holders, wholesale electricity costs and renewable support costs, if relevant. Our assessment also measures the GHG emissions impact associated with each option.
- Our modelling drew on several sources of data including the ESO's Electricity Ten-Year Statement (ETYS) and the Future Energy Scenarios (FES).
- We compared each option against a counterfactual status-quo (SQ) scenario to understand relative benefits of each option.
- We intend to capture the potential percentage reduction in costs associated with the options. Our analysis is not an attempt to accurately forecast future constraint costs. Outturn constraint costs will be influenced by a wide range of factors beyond the scope of this report.

Key input assumptions

Assumption	Detail
Concentrating on thermal constraints only	We focus our analysis on thermal constraints only. Implications for non-thermal constraints have been part of the ESO's technical analysis.
Focus on constraints between Scotland and England	Our analysis focuses on flows of electricity between Scotland and England. This captures constraint volumes and costs of constraints between Scotland and England. We model a single fleet of generation in Scotland. As a result, our analysis also captures 'intra-Scottish' constraints that would have been resolved separately before reaching the B6 boundary.
Adopting the ESO's Future Energy Scenarios (FES 2023[1])	We have drawn on the Leading the Way (LW) scenario from FES 2023 for generation capacities, volumes and demand profiles for the timeframe under consideration. The LW pathway is the most ambitious decarbonisation scenario, achieving a decarbonised power system by 2035 and net zero by 2046.
Using unconstrained data	For proof of concept and simplicity, we have assumed that the B6 boundary is the only constrained boundary on the GB system, with the rest of the system in balance. We have used unconstrained FES23 data and mapped over the B6 boundary capacity to calculate the volume of electricity which cannot flow over the boundary.
Unidirectional electricity flows	Our model assumes that there is always excess generation in Scotland and a surplus of demand in E&W, resulting in a unidirectional flow of electricity southward. We do not account for any instances of electricity flowing in the opposite direction.

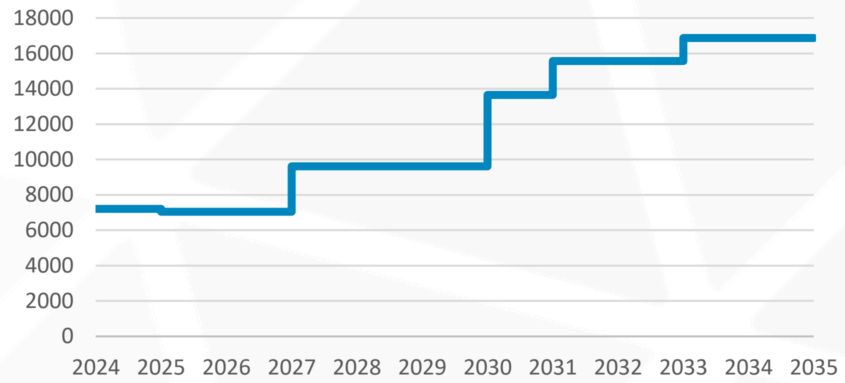
[1] *FES 2024 has now been published. However, FES 2024 data was not available for the purposes of this assessment*

Quantifying the Net Consumer Benefit

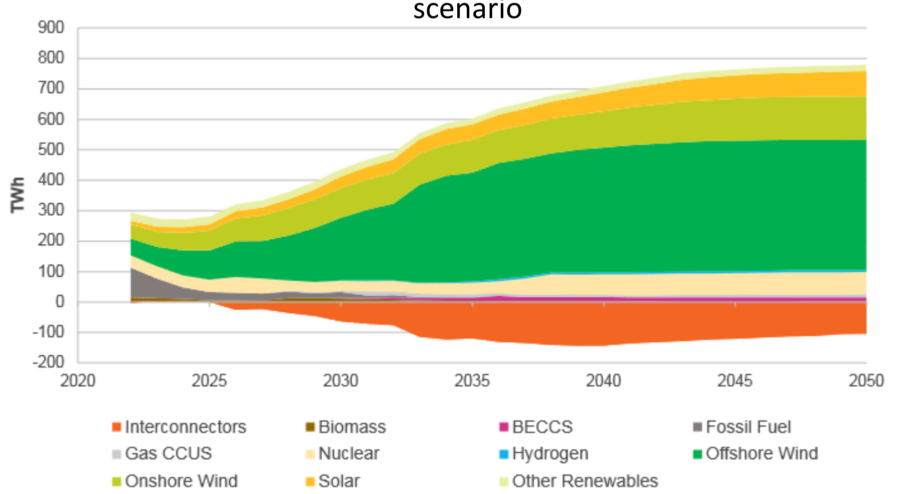
Key input assumptions (continued)

Assumption	Detail
B6 boundary capability	As 'proof of concept', we model flows between Scotland and E&W. We adopted the ESO's Electricity Ten Year Statement (ETYS) assumptions for B6 boundary capability based on the Beyond 2030 report which uses the 2023 FES and ETYS data. However, our modelling also captures constraints that would be managed within Scotland before reaching the B6 boundary
Renewable support costs	We assume that renewables projects are paid the top-up to the CfD strike price or bid into the BM to compensate them for their lost CfD payment.
Policy Targets	The LW scenario assumes that rapid power system decarbonisation is supported by strong government policy and regulatory frameworks. For example, policies which expedite the development of renewables, strong incentives for widespread electric vehicle adoption, and implementation of strong energy efficiency standards. In addition to these, the Government aims to have 1GW of electrolytic hydrogen in construction or operation by 2025, with the Hydrogen production business model support aiming to achieve the Government's goal of up to 10GW of low carbon hydrogen production capacity by 2030.
BM bid/offer stack and premiums	Baringa has an in-house Balancing Mechanism model, GB-BM, calibrated to historical data. We used this model to estimate the cost of actions in Scotland and E&W, create a bid/offer stack for various technologies, and estimate the premiums on bids and offers for each technology in the BM.
Wholesale electricity prices	We use data from ESO's FES 2023 for wholesale electricity prices between 2025-2035.
Social Discount Factor	We apply the HMT Green Book social discount factor of 3.50% to calculate the net present value of our cost and benefits.

B6 thermal capacity, MW



Electricity generation by technology under FES 2023, LW scenario



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The Status Quo scenario

High level overview of the Status Quo scenario

The Status Quo (SQ) scenario aims to reflect the current situation where the ESO resolves constraints on the GB electricity system through the Balancing Mechanism (BM), and the costs of these actions are passed onto consumers. We compare costs and benefits of the DfC and CMM options against this SQ to understand relative impact of options against the counterfactual.

Input assumptions for the SQ

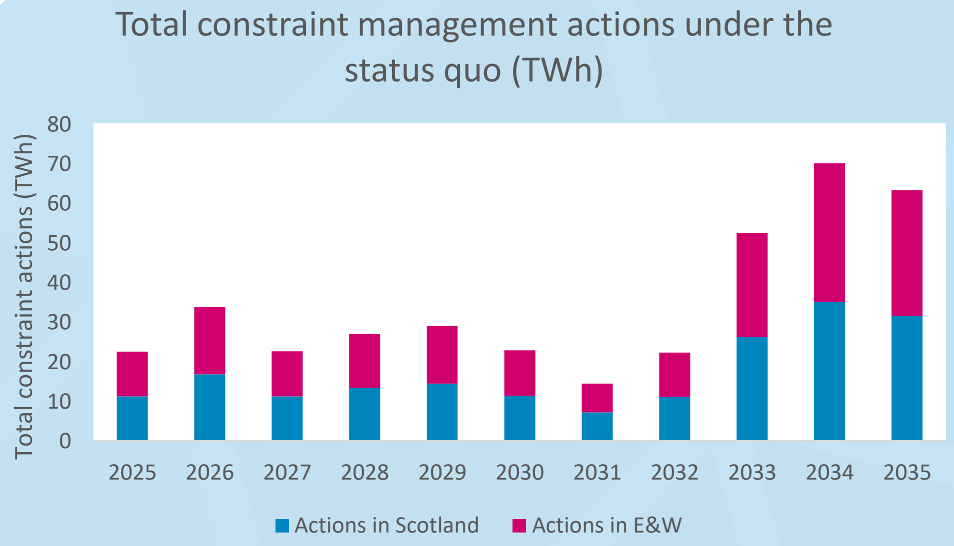
Assumption	Detail
Focusing on periods of excess supply in Scotland only	In addition to the unidirectional flow of electricity, we assume that constraints only exist where there is excess supply in Scotland with constraints north of the B6 boundary.
Demand profile (MWh)	ESO FES2023 3-hourly data for demand for each region between 2025-2035.
Generation profile (MWh)	Generation technology; Type, capacity (MW), and split by region from the LW FES Interconnection; Total generation capacity also includes net imports from interconnection in Scotland Net output for each region; Difference between total generation/interconnector net import and demand
Demand and generation bid and offer stack	Simple bid/offer stack for turn-up/turn-down service provision from the GB BM model.
Curtailing generation in Scotland	Curtailing generation from cheapest £/MWh to most expensive £/MWh technology type (from solar PV to last resort options like Demand shedding).
Short Run Marginal Cost (thermal generation)	Calculated based on assumed operation and maintenance costs, fuel and carbon prices from the FES. Determines the available actions in the BM.
Merit Order Curve	For each year, generation technologies are ordered based on their Short Run Marginal Cost (SRMC). The merit order varies every hour depending on the Day Ahead market price and varies annually due to changes in gas and carbon prices.
BM premiums	Using historical data from our GB-BM model, we reflect an assumed 15% premium[1] on the costs of bidding off generators in Scotland relative to their SRMC and a 25% premium on offers from generators (or demand) in E&W relative to SRMC.

[1]*Strictly speaking this would be a mark-down in the negative bids of renewables generators in most cases but we refer to premiums for ease of interpretation*

The Status Quo scenario

Constraint costs under the status quo

- Taking this combination of inputs, illustrative Scottish constraint costs reflected in the model range between c. £1bn and c. £3bn from 2025 to 2032.
- In parallel with constraint management volumes, constraint costs increase significantly in the period between 2033 and 2035.
- This is driven by a set of specific assumptions used for this modelling.
- Under FES 2023 LW scenario, a large amount of Scottish generation comes online in the period between 2033 – 2035 (primarily 'Scotwind' projects).
- This represents a significant volume of new offshore wind generation capacity connecting into Scotland. In practice, some of these projects could be connected directly into E&W, or this may drive additional demand/storage in Scotland which is not reflected in the dataset we used.
- In practice, we would not expect this level of constraint costs (nearly £5bn in 2034) to materialise.
- However, these results do allow us to assess potential upside benefits of the DfC and CMM options in the context of very high constraint cost outlook towards the end of our modelling period.



Baringa

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Demand for Constraints

High-level modelling approach

We modelled the Demand for Constraints (DfC) option as follows:

- We identified the relevant demand customers who were eligible for the Demand for Constraints service
- We introduced an alternative to reduce constraints through demand turn up in Scotland, used ahead of the BM
- This service allows eligible demand in Scotland to 'soak up' excess generation in return for an assumed discounted electricity price

Additional Input assumptions

Assumption	Detail
Demand additionality only	Demand treated as **additive relative to the counterfactual**, i.e., does not represent a change in location, or an intertemporal shift of consumption. No additional demand outside constrained hours.
Types of flexible demand	**Types of flexible demand** expected to participate would need to meet additionality requirements and be able to come forward within the modelling horizon. Our model includes electrolysis and flexible I&C demand as eligible
Payment structure	Demand pays a **fixed £5/MWh** to consume a given volume during constrained periods. Starting point: Fixed price **must be cheaper than CfD strike price/RES cPPAs commercially available**.
DfC used for a maximum of 50% of constraint volumes over 200MW (the rest is resolved through the BM)	**Procured capacity:** We assume that the DfC is used to resolve no more than 50% of forecasted annual hours of constraints. The DfC option will be used for constraint volumes of 200MW or more, we have assumed that any volumes less than 200MW are not material enough to make use of the DfC.
Available flexible capacity (MW in a given hour) and volumes over the year (number of hours)	We draw directly on **FES assumptions** on electrolysis and flexible I&C demand locating in Scotland between now and 2035 to define available capacity and volumes.

Demand for Constraints

Results of illustrative modelling

We find that the DfC option can reduce constraint costs by an average of 3.1% over the period.

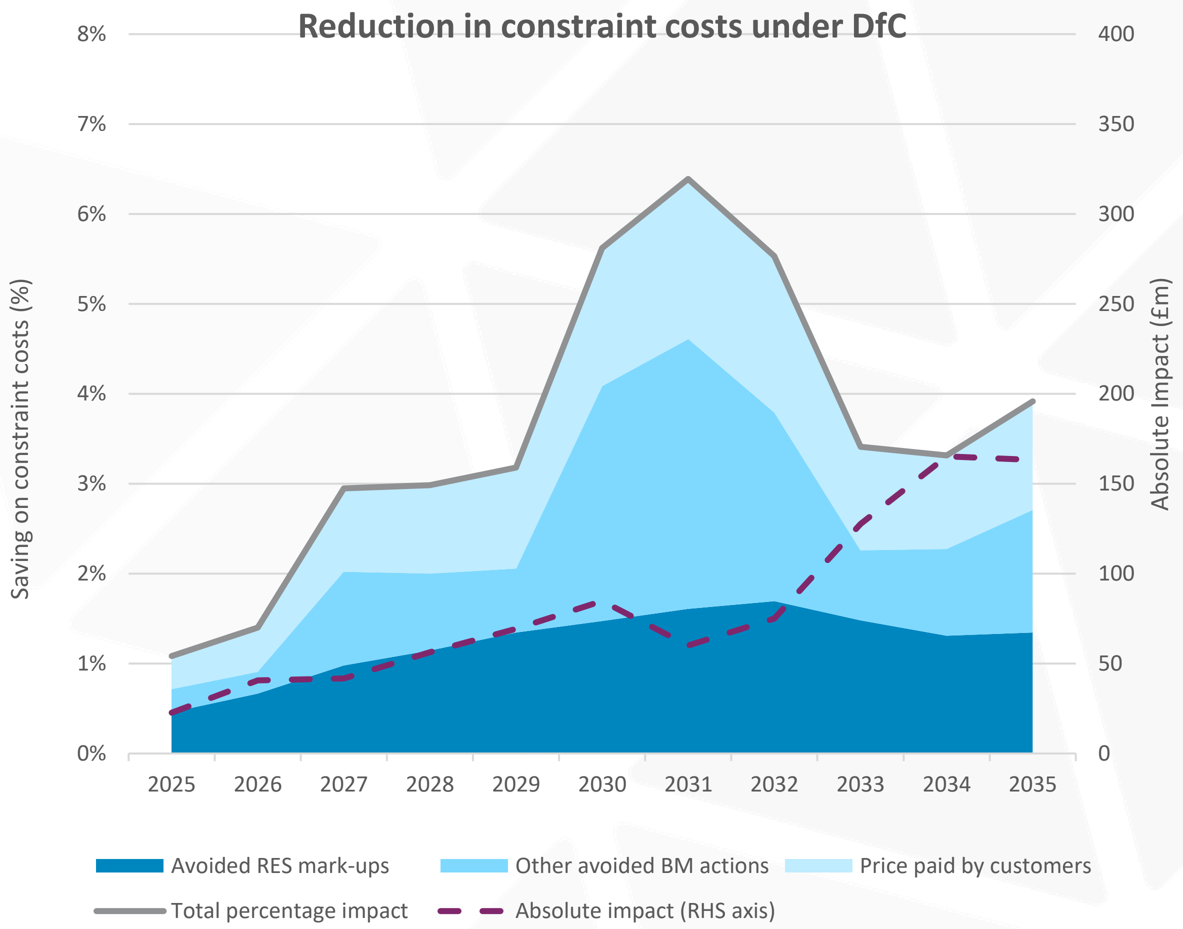
This is made up of a combination of:

1. A 1.1% reduction in costs driven by reduced premiums[1] paid to RES generators thanks to avoided curtailment.
2. A 1.0% reduction in costs driven by avoided non-RES constraint actions.
3. The ESO will receive payment from DfC customers who consume using the service. If passed through to Balancing Services Use of System (BSUoS) charges, this would result in a further 1.0% saving in costs.

Over our modelling horizon, eligible DfC capacity grows as additional consumption enters the market – particularly hydrogen electrolysers – leading to greater impacts.

Constraint costs also grow over this period, allowing the benefits provided by the DfC product to grow in parallel.

Between 2033-2035, the absolute benefit is higher than in previous years but the percentage benefit is lower given large constraint costs driven by Scotwind projects under LW.



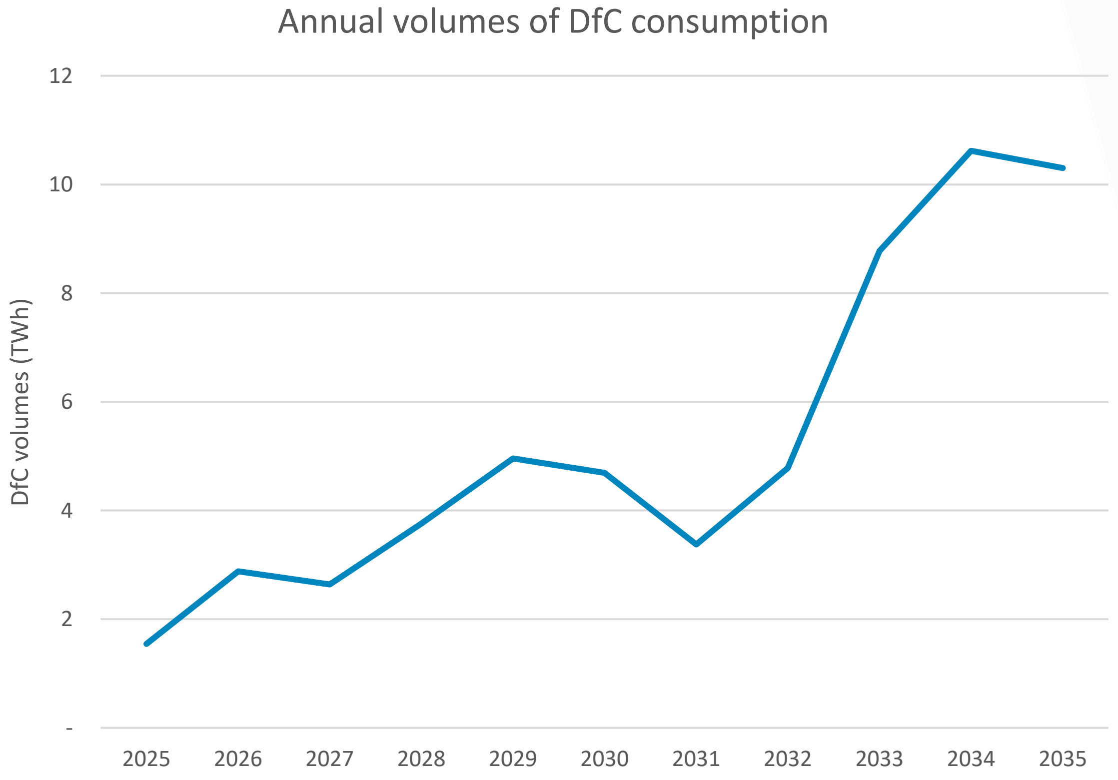
Note: All impacts relate to Scottish constraint costs and actions (all shades of blue), i.e., north of the B6 boundary.

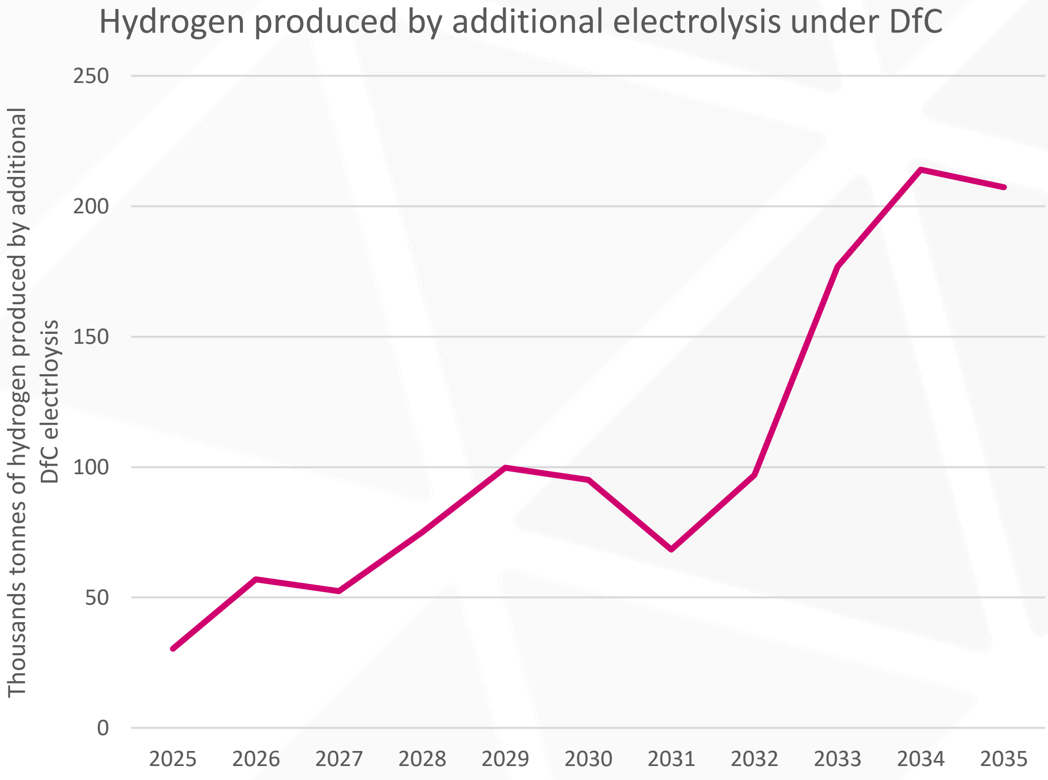
[1]Note that the only monetary benefit to consumers resulting from avoided RES curtailment is through avoidance of the premiums paid to RES. This is because consumers will still pay for the CfD top-up to the agreed strike price where RES curtailment is avoided.

Demand for Constraints

Results of illustrative modelling – DfC consumption and hydrogen production

- DfC consumption increases over time. In our modelling, this represents additional economic output in the wider economy that would not have otherwise been observed.
- For example, the increase in DfC potential over time is largely driven by additional electrolysis capacity. Our modelling estimates that over 200,000 tonnes of hydrogen could be produced through electrolysis under the DfC by the end of the period.





Constraints Management Market

High-level modelling approach

We modelled the CMM option as follows:

- We assume that a proportion of the volume offered into the BM would instead participate in the CMM.
- We assume a reduction in the bid and offer premium that would be needed under the CMM relative to the BM for two reasons (1) additional certainty through forward contracting allows more competitive bidding (2) the ESO avoids acting as a distressed buyer closer to real time
- We assume that the **exact same set of providers would participate in the CMM as the BM** – i.e. that the CMM would not lead to any new volumes of flexibility coming forwards. This scenario may more closely reflect the short-term CMM.
- In practice, forward contracting under a longer-term CMM may support the business case of new providers, incentivising additional volumes of flexibility.

Additional Input assumptions

Assumption	Detail
Demand and generation bid and offer stack	**Simple bid/offer stack added** for turn-up/turn-down service provision under the CMM is assumed to be consistent with the BM
Assumed bid and offer premium *We note that the assumed reduction in bid/offer premia under the CMM relative to the BM is based on simple analysis, in line with the current 'proof of concept' stage rather than detailed modelling. Further investigation is needed in the next phase to refine the CMM benefits case.*	Under the status quo, we assume a 15% and 25% premium on BM bids in Scotland and offers in E&W respectively (slide 17). **We assume that forward contracting under the CMM will reduce the premiums on bids and offers to 5%** in both regions. This is assumption was informed by a comparison of prices in the daily STOR auctions of the last three financial years, to BM bid/offer prices for thermal constraint management actions. The daily STOR auctions were chosen as a proxy because of: • **Data availability:** publicly available daily auction data from 2021 to provide a large enough sample set for the initial analysis, • **Comparability to thermal constraint management actions:** being a reserve service, and • **Similar stacking opportunities:** limited stacking opportunities for STOR assets (beyond 'jumping' between markets in different days) which we presumed would align well with the need for dispatch certainty of a day ahead CMM during constraint hours.[1]
Potential volumes procured	We take potential volumes as per the BM stack under the counterfactual. In practice, a longer-term CMM may bring forward additional flexibility, e.g., from hydrogen electrolysis, vehicle-to-grid flexibility and peak demand flexibility.

[1] Other day ahead markets were less suitable candidates for different reasons, for example: balancing reserve is a very recent product, Demand Flexibility Service (DFS) is demand-side only, and the Local Constraint Market (LCM) is focused on non-balancing market distribution-level resources and suffers from low volumes (and currently high prices).

Constraint Management Market

Results

Under the CMM with no additional volumes, we find an average reduction in constraint costs of 6.4% over the full period. This is made up of a combination of:

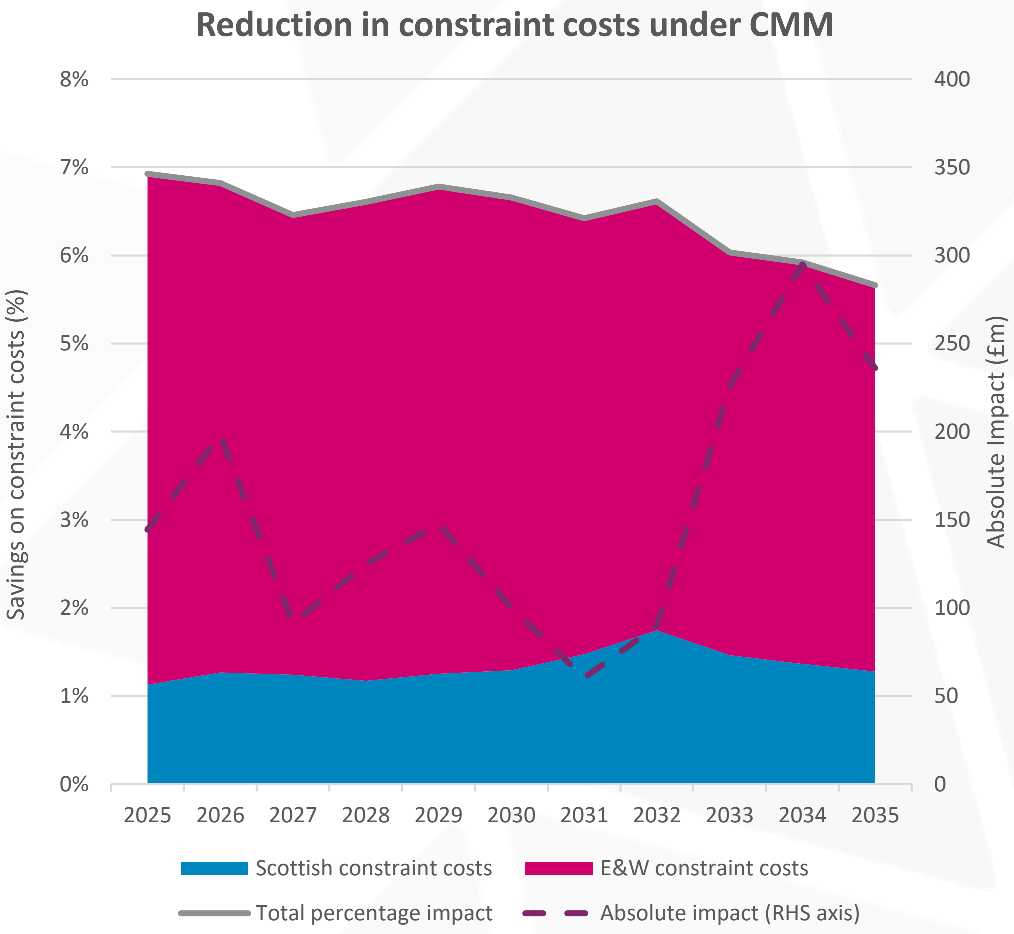
1. A 1.3% reduction in constraint costs in Scotland, including from avoided bid premiums paid to RES generators.
2. A 5.1% reduction in costs from avoided constraint costs in E&W.

CMM benefits generally scale with overall constraint costs under the status quo:

- The saving on bid and offer premiums from using the CMM ahead of the BM allows a similar percentage of cost to be avoided in each year.
- Percentage savings are similar, even in later years when the absolute costs of managing constraints increase in the period from 2033-2035.

There are two important caveats:

1. Code change P462 has not been modelled. If this is introduced, it is expected to affect BM prices (as CfD subsidies are removed from bids), which would likely have an impact on the value case outlined here.
2. Recent experience with the Local Constraints Market has shown that procurement at day ahead does not necessarily result in significant savings vs. the BM. However the LCM is restricted to non-BM assets above the B6 boundary, so further investigation is needed in the next phase to refine the benefits case of a more holistic CMM.



Note: Scottish (blue) and E&W (pink) constraint costs represent actions north and south of the B6 boundary, respectively.

Our results are based on strong modeling assumptions, provided for illustrative purposes only.

Wider benefits

CO_2 emissions

CO_2 Emissions savings

Demand for Constraints	Under our modelling, all DfC customers represent new demand. There is therefore no impact on the need for demand turn-up in E&W. CO_2 emissions are therefore equivalent to under the SQ. In practice, where the DfC product leads to relocation of demand from E&W to Scotland, there may be avoided CO_2 emissions due to a reduction in flows across the boundary needed to meet demand. There may also be broader decarbonisation benefits from producing green hydrogen under the DfC should it displace fossil fuels in other applications, as well as decarbonisation benefits beyond the power market, should the DfC product encourage demand electrification.
Constraint Management Market	We have assumed that the same providers participate in both the CMM and BM and with an equivalent merit order, such that the same actions are taken. Given this assumption, CO_2 emissions do not change. In practice, earlier procurement could lead to a different/more efficient use of resources to resolve constraints – but hard to forecast or quantify.

DfC – Challenges and unintended consequences

There are several challenges in the design of the DfC, and the potential for unintended consequences in its introduction

Providing certainty vs retaining flexibility

- To bring forward additional volumes of flexibility in Scotland, customers will look for long-term certainty of volumes that can justify their business case – i.e. long-term contracts
- However, long-term contracts may result in the ESO locking in volumes that are ultimately not needed. Shorter-term contracts would provide additional flexibility for the ESO to profile use of the service against need

Over incentivising demand

- If the price discount is too strong then the DfC may result in over procurement of demand, cannibalising benefit, and potentially transforming export constraints into import constraints across some boundaries

Confidence in volumes that demand side response can provide

- Given the novelty of the service, it may take time to develop confidence in the volumes of demand side response it would bring forwards

Regulatory challenges of implementation

- Complexity of administration, given that the ESO cannot act as a supplier
- Additional consumption from some customers during constraint periods could have implications for supplier imbalance

Baselining

- Particularly if targeted at flexible demand, some form of baselining would be needed to ensure that flexible volumes are additive.
- Baselining is challenging and subject to inaccuracy and gaming risk. Any administrative baseline is unlikely to reflect heterogenous system assets

CMM - Challenges and unintended consequences

There are several challenges in the design of the CMM, and the potential for unintended consequences in its introduction

Providing certainty vs retaining flexibility

- To deliver additional volumes of flexibility, customers will look for long-term certainty of volumes that can justify their business case – i.e. long-term contracts and availability payments
- However, long-term contracts may result in the ESO locking in volumes that are ultimately not needed. Shorter-term contracts would provide additional flexibility for the ESO to profile use of the service against need

Liquidity and participation

- Participation of volumes of capacity in the CMM could have knock on impacts on liquidity in the day ahead and intraday markets
- There are questions surrounding who could participate in the CMM – e.g. should interconnectors be able to participate?

Forecasting Capability

- Economic use of the CMM will depend on matching up procured volumes to those needed to mitigate constraints.
- However, forecasting constraints is very challenging. This could drive over-procurement (regret spend) or under-procurement (sub-optimal use)
- This is of course is more difficult when forecasting constraints further ahead (e.g. under a longer-term CMM)

Gaming risk

- Publishing or revealing expected constraint volume requirements ahead of time could introduce a risk of gaming in the wholesale market and the BM
- For example, providers could withhold capacity from the wholesale market and/or the CMM to drive up the accepted bid and offer price in the BM

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Limitations of this analysis

The scope of this analysis is high-level, indicative quantification of benefits to determine whether options should be taken forward to more detailed design and assessment.

Limitation	Impact
Detail of options	The options are currently defined at a very high level. This limits the detailed definition of assumptions for the quantitative analysis and the detail possible within the qualitative analysis
Simple assumptions	As a result of the level of detail, we use simple assumptions for the prices of the DfC consumption and for the reduction in bid and offer premia as a result of the CMM. For example, in practice, any reduction in CMM bid/offer premia would depend on the detailed scheme design, depending on allocation mechanism, timing, certainty offered to participants, etc. This limits the accuracy of the benefits identified from the analysis
Combination of datasets	Datasets are not fully internally consistent, meaning that future generation assumptions and network build out are based on different scenarios. This drives very high constraint costs in later years of the analysis
Single scenario	We only estimate benefits under one scenario. Therefore, the potential for different magnitudes of benefits and costs under alternative future pathways (e.g. alternative FES scenarios and under alternative market designs such as zonal pricing) is not assessed
No market modelling	Does not incorporate interactions between wholesale market, BM and other constraint management options. Does not assume any wider market reforms, such as a zonal market design, which would impact the benefit of these options.
Lack of market sounding exercise	For more detailed analysis, certain assumptions such as the value required to bring forward additional volumes of flexibility should be tested and informed by potential market entrants

Summary of findings

Benefits and challenges

- Initial 'proof of concept' analysis suggests modest potential benefits from the DfC and CMM under assumptions used
- More detailed design work and analysis would be needed to develop a more accurate of potential benefits and costs

Option	Average cost savings (% of total constraint costs)	Cost savings profile over period	Wider benefits	Key challenges
DfC	**3.1%**	Savings grow as potential participation grows (e.g. with deployment of electrolysis)	Additional economic activity, e.g. through industrial demand and production of hydrogen through electrolysis	Uncertainty of volumes that may come forwards and practical challenges such as baselining and control room processes
CMM	**6.4%**	Savings estimated to be a relatively stable percentage of total constraint costs as main benefit is through reduced bid and offer premiums	Potential reduced carbon emissions should the earlier procurement lead to more efficient use of resources to resolve constraints – but hard to forecast or quantify	Forecasting capability, gaming risks and trade-offs between forward certainty of volumes and revenues with flexibility for the ESO to shape profile of use

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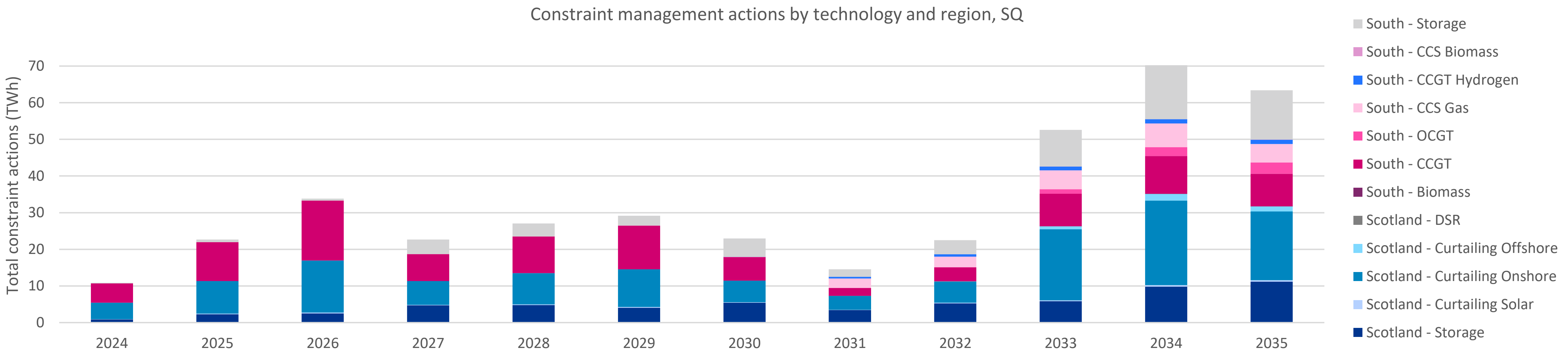
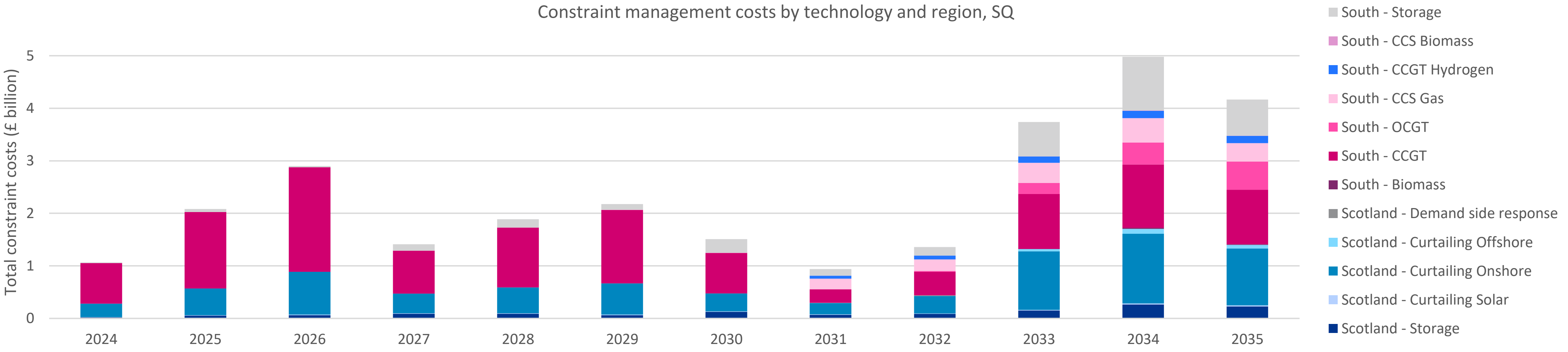
Appendix A: SQ actions and costs by technology and region





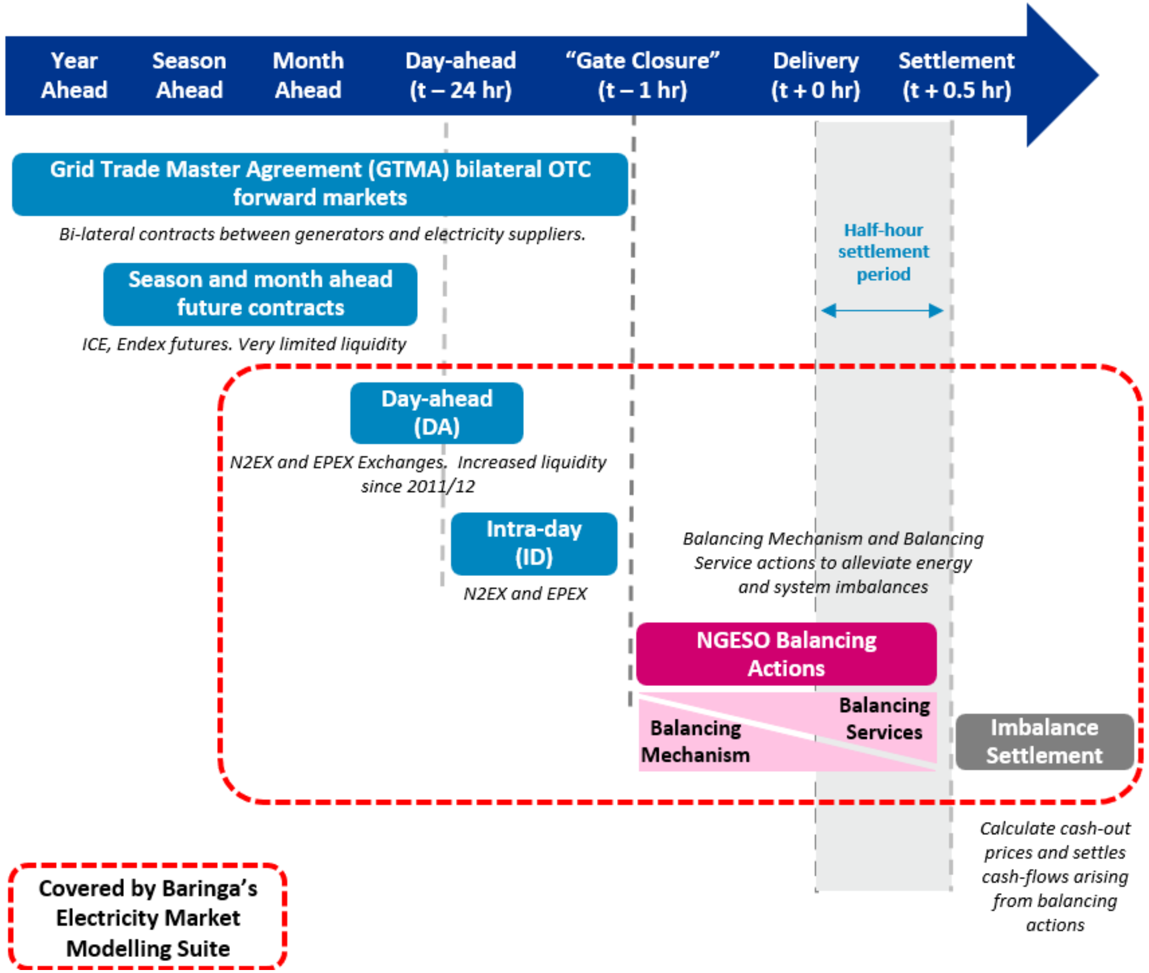
Appendix B: Summary table of % impacts on constraint costs relative to the SQ under each option

DfC Net Consumer Impact relative to SQ, as a % of total BM costs under the SQ		NPV	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Reduction in BM costs – avoided RES curtailment premiums	**%**	**1.1%**	0.5%	0.7%	1.0%	1.1%	1.3%	1.5%	1.6%	1.7%	1.5%	1.3%	1.3%	0.5%
Reduction in BM costs – other avoided actions	**%**	**1.0%**	0.3%	0.2%	1.0%	0.9%	0.7%	2.6%	3.0%	2.1%	0.8%	1.0%	1.4%	0.3%
Saving for the rest of the consumers due to DfC payment	**%**	**1.0%**	0.4%	0.5%	0.9%	1.0%	1.1%	1.5%	1.8%	1.7%	1.2%	1.0%	1.2%	0.4%
Total Impact	**%**	**3.1%**	**1.1%**	**1.4%**	**2.9%**	**3.0%**	**3.2%**	**5.6%**	**6.4%**	**5.5%**	**3.4%**	**3.3%**	**3.9%**	**1.1%**

CMM Net Consumer Impact relative to SQ, as a % of total BM costs under the SQ		NPV	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Impact in Scotland	**%**	**1.3%**	1.1%	1.1%	1.3%	1.2%	1.2%	1.3%	1.3%	1.5%	1.7%	1.5%	1.4%	1.3%
Impact in E&W	**%**	**5.1%**	5.9%	5.8%	5.6%	5.2%	5.4%	5.5%	5.4%	5.0%	4.9%	4.6%	4.6%	4.4%
Total Impact	**%**	**6.4%**	**7.0%**	**6.9%**	**6.8%**	**6.5%**	**6.6%**	**6.8%**	**6.7%**	**6.4%**	**6.6%**	**6.0%**	**5.9%**	**5.7%**

Appendix C: GB BM model

The Baringa GB-BM suite spans the wholesale Day ahead and Intra-day markets through to real-time energy and system balancing



The GB BM uses an integrated and internally consistent approach to model intertemporal markets in GB, through market optimisation software PLEXOS and is supported by data processing via bespoke Python scripts.

The GB-BM uses historical data to:

- Model intertemporal markets through interleaving/batch process
- Reflect the stochastic nature of energy imbalances
- Model different assets across these markets, including battery storage
- Asset behaviour reflects realistic actions and trading behaviour
- Reflect specific constraints including inertia and thermal constraints
- Model Energy Balancing and System Balancing actions

Appendix C: GB BM model

What does the PLEXOS BM model achieve?

We used the GB-BM model to:

- Generate a simple demand and generation bid and offer stack for each region
- Assume a % premium in the BM for each region
- Understand the relationship between Day ahead forecasts, Intraday forecasts and outturn.
- Forecast error – linear regression between historical DA forecast and Intraday forecast for wind, solar and demand.

Key Outputs
Intra-Day wholesale market price series
Imbalance volumes by plant and technology type
Imbalance costs by technology types
BM Gross Margins by plant and technology type, by both Energy Balancing and System Balancing actions
Bid/Offer Stacks and how they change over time
Evolution of **system constraint costs**

The GB BM presents opportunities and challenges for plant operators:

- CCGT – providing flexibility and stability services
- RES – imbalance exposure due to forecast error, opportunity to alleviate network constraints
- Flex – NIV chasing, trading across multiple markets and timeframes (DA vs ID vs COP), increasing BM participation from DG, constraint management
- Demand – locating demand for constraint management

Baringa

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