NERA
ECONOMIC CONSULTING

Impact Assessment for CLASS – Supporting Annex

Prepared for Ofgem

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CONFIDENTIALITY

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Executive Summary

Ofgem has commissioned NERA to provide a supporting annex to its Impact Assessment on the regulatory treatment of Customer Load Active System Services (CLASS) as a balancing service in RIIO-ED2. CLASS is a technology that allows distribution network operators (DNOs) to remotely manage transformers and circuit breakers at primary substations to change the voltage on the downstream network. DNOs can use CLASS to provide balancing services to the electricity system operator (ESO) by changing effective electricity demand in response to supply-demand imbalances on the grid.

This annex estimates monetisable costs and benefits of DNOs offering CLASS as a balancing service under three different regulatory models:

- **DRS8**, in which DNOs deploy and offer CLASS commercially, and share in part of the profits through distribution use of system charges (DUoS);
- **DRS9**, in which DNOs can offer CLASS subject to a price cap based on reasonable costs, without profit-sharing; and
- **Price Control**, in which DNOs would provide CLASS as one of their price-regulated activities.

We assess the costs and benefits in three deployment scenarios (Conservative, Medium, and Large-Scale) relative to a counterfactual in which Ofgem prohibits DNOs from providing CLASS. Our analysis covers the following categories of impacts:

- The direct costs in the form of expenditure by DNOs to deploy equipment and operate CLASS as a balancing service;
- The indirect costs of CLASS through impacts on network asset health, or through impacts on network reliability; and
- The avoided costs of alternative balancing services technologies, including the avoided cost of carbon emissions.

Our analysis considers monetisable impacts which we can quantify with transparent, evidence-based assumptions. We have not assessed hard-to-monetise costs and benefits, which are outside the scope of this report.[1] We understand Ofgem will assess hard-to-monetise impacts as part of its Impact Assessment. The analysis in this report does not purport to be a comprehensive, detailed or bottom-up assessment of each of the costs and benefits. Instead, we examine whether on the basis of the above list of monetisable costs, the benefits of allowing CLASS are likely to be materially larger than its costs. We also analyse sensitivities to our baseline assumptions to check whether our conclusion regarding CLASS's net monetisable benefits is robust to reasonable changes in assumptions. CLASS is still early in the cycle of its operation and the full impacts on assets may not be fully known: the analysis is this report is based on the evidence available to date.

We find that, when considering the above monetisable impacts, there is an economic net benefit to each of the three regulatory models that allow CLASS to provide balancing

[1] This would include any effects on competition, market or investor confidence, or effects on consumers, appliances, or machinery due to voltage variations.

services across all deployment scenarios. The net benefit of the DRS8 regulatory model over a 30-year period ranges from £270 million to £1,052 million in net present value terms, as Table 1.1 shows. The benefit is similar (within £1 million of the DRS8 estimate) in the other regulatory models that allow CLASS deployment.

Table 1.1: Net Present Value of Economic Benefits in DRS8, £m 2020/21

Category	Conservative	Medium	Large-Scale
Direct Costs	-12.1	-67.9	-132.7
Indirect Costs	-1.8	-6.6	-8.3
Avoided Cost of Balancing Services	283.3	944.1	1166.5
Avoided Carbon Cost	0.0	13.9	26.5
Net Benefit	**269.4**	**883.4**	**1052.1**

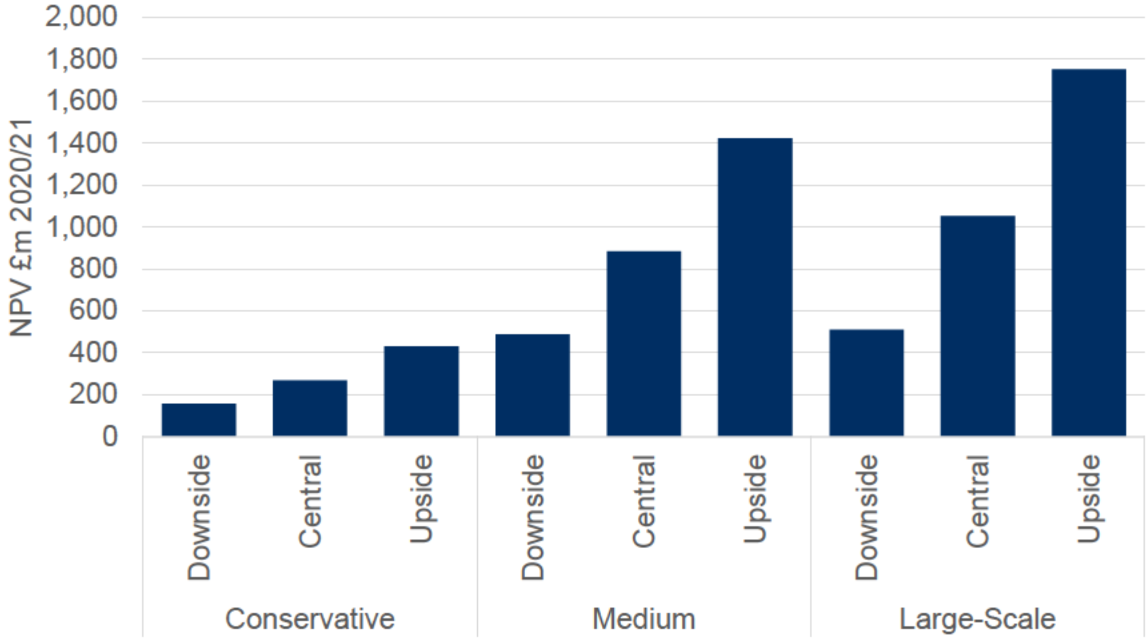
Notes: Net present value of benefits from 2023/24 to 2052/53.
Source: NERA Analysis.[2]

The impact on stakeholder groups varies more across regulatory models. We estimate that the total reduction in customer bills across DUoS and balancing services use of system charges (BSUoS) ranges from £0.30 to £0.56 per household per year in the Conservative scenario to £1.65 to £2.66 per household per year in the Large-Scale deployment scenario. The reduction in bills is greatest in the Price Control model and lowest in the DRS8 model: The DRS 8 model assumes sharing of the rewards from CLASS's deployment between DNOs and customers, whilst the price control model assumes that all the benefits of CLASS accrue to customers (after accounting for a return on investment cost). In each scenario there is a smaller reduction in the modelled profits of non-CLASS providers of balancing services than the benefit to customers.

We also model costs and benefits in two sensitivities. The sensitivities take account of uncertainty in estimates of the costs of CLASS, the types of indirect cost impacts, the cost of alternative providers, and the value of carbon emissions. We find that the net economic benefit of regulatory models that allow CLASS to provide balancing services is positive also in our modelled Downside and Upside scenarios, as Figure 1.1 shows.

[2] The estimated carbon benefit in the Conservative scenario is zero due to the allocation of capacity across services, which in this scenario does not include CLASS offering reserve products. Appendix A.4 describes our modelling of carbon costs.

Figure 1.1: Net Economic Benefits across Sensitivities in DRS8, £m 2020/21



Notes: Net present value of benefits from 2023/24 to 2052/53.
Source: NERA Analysis.

1. Introduction

Ofgem has commissioned NERA to provide a supporting annex to its Impact Assessment on the regulatory treatment of Customer Load Active System Services (CLASS) as a balancing service in RIIO-ED2. CLASS is a technology that allows distribution network operators (DNOs) to manage transformers and circuit breakers at primary substations to change the voltage on the downstream network remotely. DNOs can use CLASS to provide balancing services to the electricity system operator (ESO) by changing effective electricity demand in response to supply-demand imbalances on the grid.

ENWL is the only DNO to offer CLASS as a balancing service to date. A DNO uses its asset base as a price-controlled, licensed network operator when it provides CLASS. Ofgem therefore regulates ENWL's participation in and revenues from providing balancing services. For RIIO-ED1, Ofgem directed that ENWL could provide CLASS as a directly remunerated service, category DRS8.[3] Ofgem is now consulting on the regulatory treatment of CLASS as a balancing service in the RIIO-ED2 network price control.

This report estimates monetisable costs and benefits of DNOs offering CLASS as a balancing service under three different regulatory models. It covers the following categories of impacts:

- The direct costs in the form of expenditure by DNOs to deploy equipment and operate CLASS as a balancing service;
- The indirect costs of CLASS through impacts on network asset health, or through impacts on network reliability; and
- The avoided costs of alternative balancing services technologies, including the avoided cost of carbon emissions.

Our analysis considers monetisable impacts which we can quantify with a reasonable degree of confidence. We have not assessed hard-to-monetise costs and benefits, which are outside the scope of this report.[4] We understand Ofgem will assess hard-to-monetise impacts as part of its impact assessment.

This report proceeds as follows:

- The remainder of Section 1 sets out the regulatory models and deployment scenarios that we assess, as well as parameters we rely on throughout the analysis;
- Section 2 describes the categories of costs and benefits that we quantify;
- Section 3 presents results for the modelled economic costs and benefits of each regulatory model relative to the counterfactual;
- Scenario 4 describes distributional impacts on different stakeholder groups;

[3] Ofgem (March 2016), Direction issued by the Gas and Electricity Markets Authority to Electricity Distribution Network Operators for the purposes of Special Condition CRC 5C (Directly Remunerated Services) of the Electricity Distribution Licence.

[4] This would include any effects on competition, market or investor confidence, or effects on consumers, appliances, or machinery due to voltage variations.

- Section 5 explains our sensitivity analysis, covering a Downside and Upside scenario that capture key uncertainties in our modelling; and
- Appendix A providers technical detail on our modelling methodology.

1.1. Regulatory Options

Ofgem is consulting on four different regulatory options for the regulatory treatment of CLASS during RIIO-ED2. We model costs and benefits in each of the four regulatory models. The options are:[5]

- **Option 1A (DRS8):** Under DRS8 DNOs will be able to offer CLASS competitively, with the DNOs' bidding strategies and market outcomes determining charges to the ESO. The DNOs will share revenues net of costs with DNO customers according to their totex incentive rate;
- **Option 1B (DRS9):** Under DRS9 DNOs would offer CLASS competitively, but can only charge the ESO at a level that recovers their costs plus a reasonable margin. DNOs would not share any profits with DUoS customers;
- **Option 2 (Price Control):** In the price control model DNOs would provide CLASS to the ESO free of charge as part of their price control activities. Ofgem would determine the efficient level of costs that the DNOs would be allowed to recover from DUoS customers; and
- **Option 3 (Prohibit):** DNOs would not be allowed to offer CLASS as a balancing service. This option is our counterfactual. We report costs and benefits for the three other regulatory models relative to the case where Ofgem prohibits DNOs from using CLASS to provide balancing services

1.2. Deployment Scenarios

We model costs and benefits in three different deployment scenarios, as provided by Ofgem. The deployment scenarios are as follows:

- **Conservative:** ENWL remains the only DNO providing CLASS, with a total CLASS capability of 225 MW;
- **Medium:** A total of three DNO groups deploy CLASS, with a total CLASS capability of 1,193 MW; and
- **Large-scale:** All six DNO groups deploy CLASS, with a total CLASS capability of 2,161 MW.

We model the deployment scenarios as set out by Ofgem, and do not assess which combinations of assumptions and deployment scenarios may be most likely. Our analysis is agnostic on which DNOs would deploy CLASS, except that we account for ENWL's investment costs (which it has already incurred) differently from those of other DNOs. Where we calculate distributional impacts these are totals and averages across Great Britain and not estimates for individual licensees.

[5] Ofgem (February 2020), Consultation on the regulatory treatment of CLASS as a balancing service in RIIO-ED2 network price control, Section 2.

We assume that CLASS will be able to provide the secondary Firm Frequency Response (FFR), Dynamic Containment (DC), and optional FR (OFR) services in all deployment scenarios. We explain the allocation of CLASS capacity across services in Appendix A.

1.3. Appraisal Parameters

We model costs and benefits from the start of RIIO-ED2 in 2023/24 to the end of RIIO-ED7 in 2052/53. Except where otherwise noted we present estimates in 2020/21 prices and discount net present values back to April 2023 using a social time preference rate (STPR) of 3.5 per cent.[6] We assume that DNOs other than ENWL would deploy and start to offer CLASS from 2023/24 according to the modelled deployment scenario.

To model the impact on DUoS customers we draw on recent decisions as sources for regulatory parameters.[7] We use a 3.11 per cent real weighted average cost of capital (WACC) in line with Ofgem's sector specific methodology decision.[8] We assume a 45-year regulatory asset life in line with RIIO-ED1.[9] We capitalise totex at a rate of 68 per cent, in line with ENWL's and UKPN's assumption for RIIO-ED1.[10] We also assume a fixed efficiency incentive rate of 50 per cent.

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6 HM Treasury (2020), The Green Book, p. 119.

7 We have not assessed appropriate regulatory parameters for RIIO-ED2 or future regulatory periods as part of our analysis. The parameters we set out should be understood as our working assumptions and are neither NERA's nor Ofgem's views on appropriate parameters for RIIO-ED2.

8 We have not included the outperformance wedge in line with the Competition and Markets Authority's decision for RIIO-T2 and RIIO-GD2.
Ofgem RIIO-ED2 Sector Specific Methodology Decision: Annex 3 Finance: Appendix 1.
Competition and Markets Authority (October 2021), RIIO-2 Energy Licence Modification Appeals: Summary of final determination.

9 Ofgem (March 2021), RIIO-ED2 Sector Specific Methodology Decision: Annex 3 Finance: Appendix 1.

10 Ofgem (November 2014), RIIO-ED1: Final determinations for the slow track electricity distribution companies: Overview, Appendices 2 and 4.

2. Categories of Costs and Benefits

This section sets out the categories of costs and benefits that the report assesses. It provides a conceptual introduction to what the categories are and explains how CLASS creates each impact. Appendix A describes our modelling, sources, and assumptions in greater detail.

2.1. Direct Costs of CLASS

The direct costs of CLASS cover the capital and operating expenditure DNOs incur to provide CLASS as a balancing service. We estimate the direct costs of CLASS based on the costs of ENWL's deployment, scaled according to each deployment scenario. Our estimates include the following categories of expenditure:

- The investment cost of deploying equipment enabling transformers to deliver CLASS, scaled by the number of CLASS-enabled sites. We model replacement expenditure for equipment after an asset life of 25 years;[11]
- One-off project management costs associated with each new DNO group deploying CLASS, scaled by the number DNO groups deploying CLASS;[12]
- The cost of an IT dashboard required to provide CLASS as a balancing service.[13] As ENWL has already developed the necessary IT infrastructure we assume that it would license its dashboard to other DNOs such that this cost is not duplicated. We include replacement expenditure after an asset life of 10 years;
- Fixed operating costs including control centre staff, a bid preparation team, and communications costs, scaled by the number of DNO groups providing CLASS.[14]

We differentiate between the costs that ENWL has already incurred, which are sunk costs, and the future costs that can be incurred or avoided by ENWL and other DNOs depending on whether they provide CLASS. We also include the terminal asset value of asset and IT expenditure that remains undepreciated at the end of the modelling period.

2.2. Indirect Costs of CLASS

We model two categories of potential indirect costs of CLASS. The indirect costs are potential adverse impacts on the DNOs' core network activities due to CLASS activation:

- Increased asset replacement and asset maintenance costs if CLASS negatively impacts the asset health of CLASS-enabled transformers; and
- The value of lost load due to reduced security of supply if providing some types of balancing services require configuring transformers in such a way that there is a loss of transformer redundancy at primary substations.

As part of the Low Carbon Network Fund (LCNF) CLASS trial, ENWL commissioned researchers at the Universities of Manchester and Liverpool in 2015 to assess the asset health

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11 Baringa (July 2021), Assessment of the impacts of CLASS deployment, p. 29.

12 Costs as submitted by ENWL in correspondence with Ofgem.

13 Baringa (July 2021), Assessment of the impacts of CLASS deployment, p. 29.

14 Costs as submitted by ENWL in correspondence with Ofgem.

impacts of CLASS. They found that some types of CLASS activation could risk the condition of transformer components associated with.[15] Should the risks materialise then transformer assets could age prematurely or require additional maintenance.

Ofgem and ENWL have carried out additional technical analysis of asset health impacts since the 2015 project. They do not find evidence that CLASS deployment has reduced asset health. Ofgem finds that ENWL's use of CLASS to date does not involve the transformer tripping or tap staggering operations associated with the worst-case scenarios that the 2015 technical report modelled.[16] ENWL finds that inspections of oil samples indicate no observable degradation of CLASS-enabled components beyond that found at non-enabled assets. ENWL has not had to alter its routine inspections schedule in response to the introduction of CLASS. However, the increased use of tap changers could potentially increase the frequency of site visits as reaching a threshold number of operations triggers additional inspections.[17]

Given the lack of the clear evidence of adverse impacts on transformer health, we do not model this impact as part of our central scenario. In our downside sensitivity we calculate the additional costs of a hypothesised reduction in asset health as an illustration of what the costs of an impact could be should there be an impact. We describe our sensitivity analysis in Section 5.

CLASS can also have an impact on network interruption, resulting in a loss of load. Where multiple transformers serve the same downstream network, each provides redundancy that can prevent an interruption should another transformer fail. Providing faster-acting response services can require CLASS providers to put transformers in a trip-state which prevents them from providing this back-up.[18] CLASS can therefore create situations where there is not the n - 1 redundancy there would have been in the absence of CLASS. The reduction in redundancy increases the likelihood of a loss of load should there be an incident that could be avoided with transformer redundancy. A DNO that uses CLASS to provide response services can therefore increase the number of interruptions. The value of the lost load during the additional interruptions is an indirect cost of CLASS.

2.3. Avoided Cost of Alternative Balancing Providers

The largest benefit of regulatory models that will allow DNOs to provide CLASS as a balancing service is the avoided costs of alternative balancing service providers. If CLASS provides balancing services, then the electricity system will require less capacity from other technologies to be dedicated to balancing services. The system will then either avoid the direct costs of deploying and operating the alternative capacity, or the opportunity cost of the capacity not being available to provide other services.

The economic benefit of CLASS is the difference between the total cost of the alternative providers in the deployment scenarios relative to the counterfactual. It is not the sum of

15 Wang et al (September 2015), WP3, Final Report, pp. 3-6.

16 Ofgem (March 2022), Impact Assessment of the regulatory treatment of CLASS as a balancing service in the RIIO-ED2 network price control, Section 4.

17 Ofgem (March 2022), Impact Assessment of the regulatory treatment of CLASS as a balancing service in the RIIO-ED2 network price control, Section 4.

18 Baringa (May 2016), Assessing the impact of CLASS on the GB Electricity Market, p. 49.

payments to alternative providers. The sum of payments includes the cost of providers but also profits, which are a transfer from BSUoS customers to alternative providers. We therefore only include the estimated costs of providers in the economic net benefits. We estimate the impact on the profits of alternative providers in our distributional analysis in Section 4.

2.4. Avoided Cost of Carbon Emissions

We quantify the avoided carbon cost of alternative providers in addition to the opportunity cost that we estimate based on tendered prices. CLASS is a zero-carbon technology. Alternative providers include generators that either emit carbon or could displace generators that emit carbon in other markets, and storage operators that draw electricity from the grid. We model the avoided carbon emissions based on government projections of the long-run marginal carbon intensity of generation.[19] Using the sector-wide marginal carbon intensity may result in a conservative estimate of the carbon benefit as some alternative balancing services providers could be carbon-intensive thermal generators.

[19] BEIS (2021), Green Book Supplemental Guidance Data Tables, Table 1.

3. Economic Net Benefit

We find that the net benefit of CLASS is positive across all deployment scenarios and regulatory models, as Table 3.1 shows for our Central estimate in the DRS8 regulatory model. The net present value of monetisable costs and benefits ranges from £269 million to £1,052 million depending on the deployment scenario.

Table 3.1: Net Present Value of Economic Benefits in DRS8, £m 2020/21

Category	Conservative	Medium	Large-Scale
Direct Costs	-12.1	-67.9	-132.7
Indirect Costs	-1.8	-6.6	-8.3
Avoided Cost of Balancing Services	283.3	944.1	1166.5
Avoided Carbon Cost	0.0	13.9	26.5
Net Benefit	**269.4**	**883.4**	**1052.1**

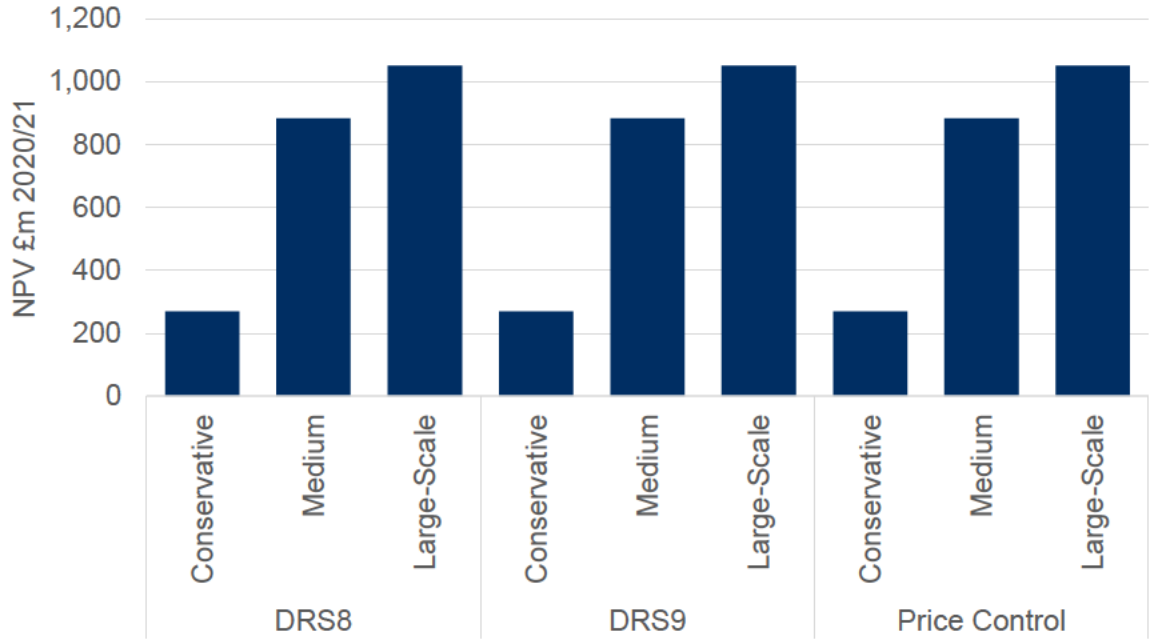
Source: NERA Analysis.

The highest-impact category is the avoided cost of alternative balancing services providers, ranging from £283 million to £1,167million in net present value terms according to deployment scenario. The average net benefit per unit of CLASS capacity is lower in the Medium and Large-Scale deployment scenarios as the marginal unit of CLASS capacity displaces less costly alternative providers.

There is less variation in net economic benefits across regulatory models than across deployment scenarios, as Figure 3.1 shows. CLASS capacity is generally the cheapest technology (and therefore procured) regardless of bidding strategy, and we assume that DNOs deploy the same capacity in each regulatory model. The amount of CLASS accepted and the amount of alternative capacity displaced is therefore similar across the regulatory models.

The estimates of the net benefit of allowing CLASS to participate relative to the counterfactual are therefore also similar (within £1 million of each other) across the regulatory models. The avoided cost of balancing services, and therefore the net benefit, could be lower in the DRS8 regulatory model. In the DRS8 model DNOs can bid to maximise profits. In a pay-as-bid auction their incentive is therefore to offer CLASS at a price below but close to what they expect the market clearing price will be. As the DNOs will not perfectly predict market clearing prices there could be instances where a DNO would bid too high, and CLASS would not be accepted despite being a lower-cost option. In such instances the benefit will be lower in the DRS8 model than it would have been in DRS9 or Price Control.

Figure 3.1: Net Economic Benefits across Regulatory Models, £m 2020/21



Source: NERA Analysis.

There is greater variation in distributional impacts, as Section 4 describes.

4. Distributional Impacts

We model the impact of each regulatory model on the cash flows to four different groups relative to the counterfactual:

- Bill impacts for DUoS customers;
- Change in BSUoS charges;
- Changes in profits for DNOs; and
- Change in profits for non-CLASS providers of balancing services.

The allocation of cost and benefits depends on the regulatory model, which determines how much DNOs can charge for providing balancing services and how they would share profits with customers.[20] The rules for each regulatory model are as follows:

- **DRS8:** We assume that each DNO bids CLASS capacity as a profit-maximising price-taker.[21] We model its bid as accepted if the clearing price is greater than the long-run marginal cost (LRMC) of CLASS, as DNOs can make a profit at any price greater than the LRMC. In a pay-as-bid auction, we assign CLASS revenues equal to the clearing price on the grounds that it could bid up to that amount and still be accepted.[22] DNOs share profits with DUoS customer.
- **DRS9:** We assume that each DNO bids CLASS capacity at a price equal to its long-run marginal costs, earning revenues such that DNOs break even.[23] There are therefore no profits or losses shared with DUoS customers.
- **Price Control:** We assume that each DNO bids CLASS capacity at a price of zero such that its bids are always accepted. We assign CLASS zero revenues in all auctions. We treat CLASS costs as totex which DNOs recover from DUOS customers as fast and slow money.

The highest-impact difference between the regulatory model is the ability for DNOs to make profits, shared with DUoS customers, in DRS8. DNOs and DUoS customers are therefore the largest beneficiaries in a DRS8 model, as Table 4.1 shows. In the other regulatory scenarios Ofgem would regulate the DNOs such that they could cover their reasonable costs, either through a restriction on their bidding behaviour (DRS9) or through the RIIO-2 price control framework (Price Control). In Price Control there would also be a loss for DUoS customers as DUoS charges rather than BSUoS charges would fund the direct costs of CLASS.

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[20] Carbon costs and impacts on network reliability are not financial impacts allocable to a particular group. We therefore do not include these in the distributional analysis.

[21] As price-takers DNOs would not exploit any monopoly power by restricting the quantity of CLASS offered to achieve higher prices. In auctions where CLASS is marginal, we assume the DNOs bid at a price equal to LRMC.

[22] In a pay-as-bid auction a bidder that is in the merit order maximises it profits by entering a bid at or just below the market clearing price. In practice a DNO would not be able to predict the exact clearing price in each auction. Our estimate of DNO profits will therefore likely be on the high side, with the estimate of BSUoS savings correspondingly low. In some years and scenarios, a consequence of the assumption that DNOs bid CLASS at exactly the market clearing price, which other providers in our data do not, is that there is a modelled increase in BSUoS charges.

[23] In pay-as-clear auctions we only assign CLASS revenues equal to its LRMC, not the market clearing price. We understand Ofgem is considering how DRS9 could apply if DNOs offer CLASS in pay-as-clear auctions.

Table 4.1: Net Present Value of Cash Flow Impacts by Group in Conservative Deployment Scenario, £m 2020/21

Category	DRS8	DRS9	Price Control
DUoS Customers	211.1	0.0	-11.8
BSUoS Customers	31.1	453.4	467.4
Profits for DNOs	211.1	0.0	0.0
Profits for Alternative Balancing Service Providers	-182.2	-182.2	-184.1

Source: NERA Analysis.

The total NPV reduction in customer bills (DUoS and BSUoS) ranges from £242 million to £456 million in the Conservative deployment scenario, as Table 4.1 shows. The reduction is equivalent to £0.30 to £0.56 per household per year across the modelling period.[24] The reduction is largest in the Price Control regulatory model as all cost savings, and the reduction in provider profits due to lower prices, accrue to BSUoS customers. The bill reduction is £2 million greater in the Price Control model than in the DRS9 model as the DNOs would offer CLASS to the ESO free of charge.[25] It therefore displaces additional alternative providers than in the DRS9 model where DNOs offer CLASS at the LRMC.

We model an NPV reduction in profits for alternative balancing services providers of £182 million to £184 million across the 30-year modelling period as CLASS would displace some providers. The reduction amounts to £6.1 million per year, or around 0.3 per cent of the ESO's £1,850 million expenditure on balancing services in 2020/21.[26] It could be a lower share of expenditure by the start of RIIO-ED2 given the upwards trend in balancing costs during 2021/22.[27]

Impacts are larger in the Medium and Large-Scale deployment scenarios, with a similar profile across groups in each regulatory model, as Table 4.2 and Table 4.3 summarise.

24 Based on 27.1 million households in Great Britain.
Office for National Statistics (March 2021), Households by household size, regions of England and UK constituent countries dataset. URL: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/datasets/householdsbyhouseholdsizeregionsofenglandandukconstituentcountries. Visited on 6 February 2022.

25 The short-run marginal cost of CLASS is zero.

26 National Grid ESO (March 2021), Monthly Balancing Services Summary 2020/21, Figure 2.

27 National Grid ESO (December 2021), Monthly Balancing Services Summary 2021/22, Figure 2.

Table 4.2: Net Present Value of Cash Flow Impacts by Group in Medium Deployment Scenario, £m 2020/21

Category	DRS8	DRS9	Price Control
DUoS Customers	679.5	0.0	-65.7
BSUoS Customers	81.0	1439.9	1521.2
Profits for DNOs	679.5	0.0	0.0
Profits for Alternative Balancing Service Providers	-562.1	-562.1	-576.9

Source: NERA Analysis.

The largest net bill impact is in the Price Control model and Large-Scale deployment scenario. Across DUoS and BSUoS we model a reduction in charges of £1,841 million, or £2.66 per household per year.

Table 4.3: Net Present Value of Cash Flow Impacts by Group in Large-Scale Deployment Scenario, £m 2020/21

Category	DRS8	DRS9	Price Control
DUoS Customers	807.7	0.0	-128.4
BSUoS Customers	204.9	1826.7	1969.1
Profits for DNOs	807.7	0.0	0.0
Profits for Alternative Balancing Service Providers	-782.9	-782.9	-802.4

Source: NERA Analysis.

5. Sensitivity Analysis

We model sensitivities around the estimates presented in Section 3 and Section 4. We model alternative assumptions such that the sensitivities take account of key uncertainties in our estimates. Our sensitivities include the following:

- Uncertainty in the costs of CLASS, in particular to account for potential optimism bias in estimates of the costs of deploying CLASS;
- Including the costs of asset health impacts. In Section 2.2 we describe the lack of evidence to quantify an impact. We therefore model a hypothetical impact based on an assumed increase in expenditure;
- Uncertainty in the future cost of balancing services. We model an annual growth rate in both costs and payments for non-CLASS balancing services providers to capture the greater uncertainty in costs at longer time horizons;
- A pay-as-bid adjustment to account for providers bidding strategically in pay-as-bid auctions (including the bilateral optional FR market), such that bids overstate the economic costs of the providers; and
- Different trajectories for the carbon cost of a tonne of CO2 equivalents, based on the three different trajectories forecast by the Department for Business, Energy, and Industrial Strategy (BEIS).

We combine the five sensitivities into one Downside and one Upside sensitivity, as Table 5.1 summarises. In the Downside sensitivity we combine the alternative assumptions that result in the lowest estimate of the net benefit in each regulatory model, and vice versa in the Upside sensitivity. The impact on individual stakeholder group may not follow the same ordering across sensitivities as the total NPV of benefits.

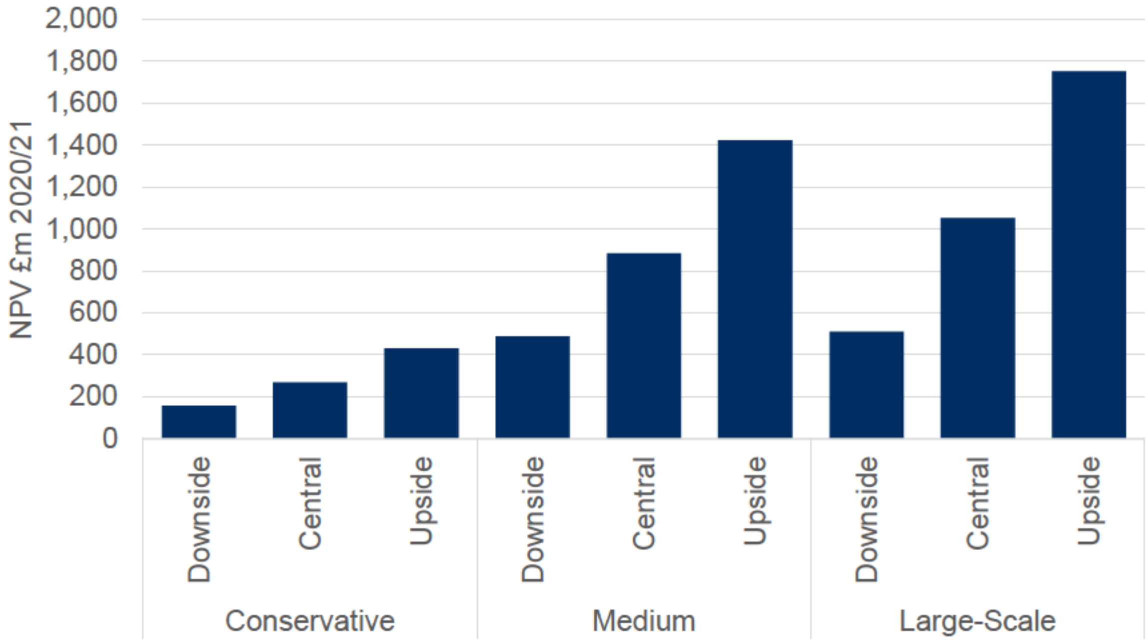
Table 5.1: Summary of Assumption in Combined Sensitivities

Sensitivity	Central	Downside	Upside
Direct Costs	No adjustment	+50 per cent	No adjustment
Asset Health Costs	Not included	+10 per cent	Not included
Balancing Services Costs	No adjustment	-2 per cent p.a.	+2 per cent p.a.
Pay-as-Bid Adjustment	Costs are 75 per cent of bids	Costs are 50 per cent of bids	Costs are 100 per cent of bids
Carbon Cost	Central	Low	High

Source: NERA analysis.

We find that the modelled net benefit remains positive across all sensitivities, as shown for the DRS8 regulatory model in Figure 5.1. The net benefit is 42-52 per cent lower in the Downside sensitivity than in the Central estimate depending on the deployment scenario. It is 60-67 per cent higher in the Upside sensitivity. The modelled net benefit is similar across regulatory models, as we describe in Section 3.

Figure 5.1: Net Economic Benefits across Sensitivities in DRS8, £m 2020/21



Source: NERA Analysis.

Appendix A. Modelling Methodology

This appendix provides additional detail on our modelling approach and our assumptions across each of the cost and benefit categories.

A.1. Direct Costs of CLASS

We estimate the direct costs of CLASS based on the costs of ENWL's deployment. We scale the direct costs according to the deployment scenario. Our modelling includes replacement expenditure at the end of the asset life of the asset and dashboard investments, as well as terminal asset values at the end of the modelling period. Table A.1 sets our or assumed CLASS costs.

Table A.1: Calculation of Direct Costs of CLASS

Cost Category	Cost	Cost Scaler
Asset Capex	[redacted]	Per CLASS-enabled site Asset life of 25 years
Project Set-Up Costs	[redacted]	One-off per DNO group
Dashboard Costs	[redacted]	Asset life of 10 years
Fixed Opex	[redacted]	Per year per DNO group

Source: ENWL and Baringa.[28]

In the Downside sensitivity we increase the costs that Table A.1 shows by 50 per cent to account for uncertainty and possible optimism bias in the deployment costs.

A.2. Indirect Costs of CLASS

We include an estimate of the increased expenditure on transformers in the Downside sensitivity. We model a 10 per cent increase in the Asset Replacement, Faults, Inspections, and Repair and Maintenance expenditure allocated to 33kV ground-mounted transformers or the smallest category of expenditure containing 33kV ground-mounted transformers. We calculate average expenditure from 2010/11 to 2020/21, and scale costs by the share of 33kV transformers that deploy CLASS in each scenario.[29]

We estimate the value of the increase in lost load due to a loss of redundancy from transformer providing CLASS. We calculate the loss based on the total CLASS capacity accepted for DC.[30] Our assumption will result in a higher estimate of the indirect cost than assuming that there is a loss of redundancy only part of the time that a DNO provides DC. We calculate the total substation capacity as the DC capacity scaled up assuming a 3 per cent voltage reduction and a 1.36 unit reduction in demand for each unit reduction in voltage.[31] We assume a 3.5 per cent network failure rate per year, and a 3-minute restoration time in the

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28 Costs as submitted by ENWL in correspondence with Ofgem.
Baringa (July 2021), Assessment of the impacts of CLASS deployment, p. 29.

29 We use data from companies' Business Plan Data Template Submissions.

30 We understand from Ofgem that transformer tripping has not been required for CLASS to provide secondary FFR and OFR but could be required to provide DC.

31 Technical assumptions provided by Ofgem.

event of an outage.[32] We monetise the loss of reliability at the value of lost load that Ofgem assumed for RIIO-ED1, uprated to £22,000 per MWh in 2020/21 prices.[33]

A.3. Avoided Cost of Alternative Balancing Providers

A.3.1. Modelling Framework

We use auction data released by National Grid ESO to calculate the avoided cost of alternative providers of the three balancing service products that CLASS can deliver:

- Secondary Firm Frequency Response (FFR)
- Dynamic Containment (DC)
- Optional Fast Reserve (OFR)

We estimate the cost of alternative balancing service providers, the revenues that accrue to CLASS and alternative providers, and in turn BSUoS payments for each product. Our objective is not to replicate the auction rules and outcomes specific to each historical tender as both auction rules and product definitions may evolve.[34] We instead estimate the cost of alternative technologies that can provide the same services as CLASS. We estimate the cost curve of alternative providers through bid data, which we use as a measure of the costs of alternative balancing service providers.

We model outcomes in each market on the principle that the ESO will procure a set volume of each balancing service in the least-cost fashion. Under this assumption, if CLASS tenders a megawatt of capacity at a lower price than other providers, then the ESO procures CLASS instead of the highest-cost alternative provider. We cap the amount of CLASS capacity accepted at the total capacity of CLASS and the total capacity that the ESO in fact procured for each auction.[35] We tailor our approach to each balancing service product to account for the different procurement rules in each market.

We describe the pricing decision of DNOs offering CLASS according to each regulatory model in Section 4. In each deployment scenario we allocate the total CLASS capacity to set the marginal revenue of an additional unit of capacity equal across all three markets. In the regulatory model where DNOs bid competitively, the rule maximises DNO profits. In the Price Control model, the rule minimises the ESO's payments to providers and by extension BSUoS charges.

Our modelling indicates a reduction in the annual cost of alternative providers ranging from £15 million in the Conservative deployment scenario to £63 million the Large-Scale scenario, as Table A.2 shows. The average net benefit per unit of CLASS capacity is lower in the

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32 Baringa (May 2016), Assessing the impact of CLASS on the GB Electricity Market, p. 49.

33 Ofgem (July 2020), RIIO-ED2 Sector Methodology Consultation: Annex 1 - Delivering value for money services for consumers, Table 26.

34 For example, there are cases where our model accepts bids that are rejected by NG ESO on non-cost grounds, which we do not aim to model.

35 We cap the amount of capacity accepted at the volume the ESO procured historically to be consistent with the amount of capacity that alternative providers offered in the tenders, which may depend on their expectation of how much the ESO would procure. Our assumption may result in a conservative estimate of the benefits to CLASS compared with an estimate based on the capacity that the system may require in the future, which may be greater.

Medium and Large-Scale deployment scenarios as the marginal unit of CLASS capacity displaces less costly alternative providers. For the same reason our modelling does not include any CLASS capacity bid into OFR in the Conservative scenario as the initial unit of capacity are more valuable in FFR and DC. As the CLASS capacity increases the marginal revenues of an additional unit falls and it becomes optimal for DNOs to bid capacity into OFR.

Table A.2: Reduction in Annual Cost of Alternative Providers in DRS8, £m 2020/21

Service	Conservative	Medium	Large-Scale
Secondary FFR	7.1	17.2	21.0
DC	8.3	28.9	32.4
Optional FR	0.0	5.2	10.0
Total	**15.4**	**51.3**	**63.4**

Source: NERA analysis

We use a hybrid approach to model the impact of CLASS participation on prices when modelling the revenues to balancing services providers. In the short-term, market clearing prices will fall if DNOs bid cheaper CLASS capacity into balancing services markets. However, in the long-term prices will be such that they incentivise the entry of the marginal additional capacity needed to meet system requirements. It is therefore the long-run marginal cost of technologies required to enter the market that determine the long-term price. As our modelling shows that CLASS is an inframarginal technology, it will not impact the market clearing price in the long run (assuming it remains inframarginal as demand for balancing services grows).

If we modelled revenues in the long-term that embedded the full short-term price effects as modelled based on the historical tenders, we would overestimate the reduction in BSUoS charges from CLASS participation. Instead, we model market clearing prices that converge from the level modelled for each deployment scenario participates, to the level without CLASS participation over a 10-year period. Our hybrid approach captures some short-term price effects from CLASS participation but embeds the assumption that CLASS has no effect on prices in the long-term to avoid overestimating savings.

The core of our analysis of balancing services is static rather than dynamic. We model the merit orders for balancing services across our modelling period based on historical bids. Historical bids are evidence on the opportunity cost of technologies that can provide the same services as CLASS. We add dynamic elements such as sensitivities in the evolution of the costs of alternative providers and a hybrid approach to modelling clearing prices which acknowledges that market entry determined prices in the long-term. However, the elements are adjustments to a static analysis. It does not include dynamic impacts such as the effect of regulation on investment signals for non-CLASS (or CLASS) capacity.

A.3.2. Firm Frequency Response

The ESO tenders Firm Frequency Response on a month-ahead basis.[36] We model the supply curve for the Secondary FFR market across weekdays between January 2021 and January

[36] FFR is sub-categorised by the *service day* (participants can bid different prices and quantities between weekday, Saturday and Sundays/Bank Holidays) and *technical requirements* (participants can bid into three sub-categories of

2022, inclusive, given that Ofgem has identified this service as one CLASS can deliver and historically has delivered.[37]

We construct a merit order for each auction and each EFA block by ranking all bids by the tendered price (£ per MW) of each provider. There are six EFA blocks per twenty-four-hour period, each with a duration of four hours, with EFA Block 1 commencing at 23:00. This sorting procedure yields an ordered list of providers by cost, from which FFR bids are accepted in merit order until the accepted bids fill the capacity requirement of the ESO.[38]

For each tender, we input a hypothetical 'bid' for CLASS based on our analysis of CLASS costs and capacity levels. An auction with a CLASS capacity of zero MW results in a cost curve equivalent to the original auction. For positive MW capacity bids, CLASS enters the supply curve in each tender and displaces more expensive providers in the merit order.[39] In cases where CLASS is cheaper than the marginal supplier, NG ESO 'avoids' paying the bid price for the equivalent MW of FFR from the more expensive providers. We estimate the total cost of all non-CLASS balancing service providers by summing the tendered price of all accepted bids in each modelled scenario. The difference between the total cost of alternative providers in the policy and counterfactual scenarios gives the estimated cost savings to NG ESO from procuring CLASS at lower costs than was available from alternative providers.

Figure A.1 shows a simplified representation of our modelling. In deployment scenarios CLASS takes the place of some alternative providers in the merit order, shifting the supply curve downwards. The total cost of providers therefore reduces from A+B in the counterfactual without CLASS, to B only when CLASS participates. The total cost reduction is the area A between the two supply curves.

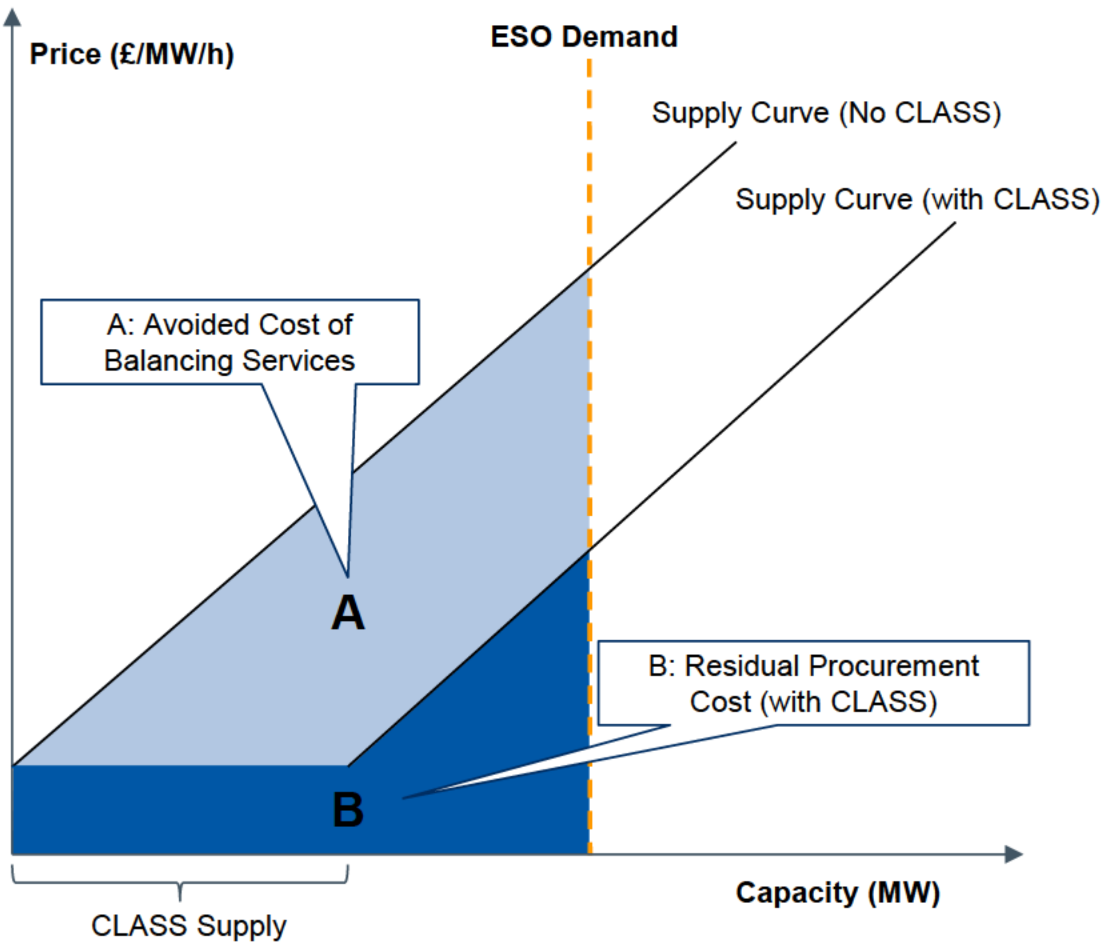
Dynamic FFR and into Static FFR).
NG ESO (2017), Firm Frequency Response Frequently Asked Questions.

37 FFR Data is available from the Firm Frequency Response (FFR) Post Tender Reports. URL: https://data nationalgrideso.com/ancillary-services/firm-frequency-response-post-tender-reports.
Ofgem (February 2020), Consultation on the regulatory treatment of CLASS as a balancing service in RIIO-ED2 network price control.

38 We model the ESO accepting partial bids, such that itcompensates the marginal provider in proportion to the residual ESO requirement relative to the MW the provider tenders.

39 Some providers who are accepted in a model without CLASS are subsequently rejected in cases where CLASS bids at a lower price than the marginal provider.

Figure A.1: Illustration of the Avoided Cost of Balancing Providers



Source: NERA illustration.

Because FFR is structured as a pay-as-bid auction, providers do not have an incentive to bid prices equal to their opportunity cost. Instead, we assume that providers bid strategically such that their economic costs are only a fraction of their tendered prices to avoid overestimating the benefit of CLASS displacing other balancing services providers. We vary the assumed costs as a share of tendered prices according to the sensitivities that Section 5 sets out.

A.3.3. Dynamic Containment

The ESO tenders dynamic containment on a day-ahead basis.[40] As with FFR, providers bid into any combination of EFA Blocks to provide between four and twenty-four hours of DC per day. We model low-frequency response DC (DCL) for four months between 16 September 2021 and 20 January 2022.[41] We note two differences from our analysis of FFR tender outcomes:

40 NG ESO (August 2021), Procurement Guidelines.

41 We source data from NG ESO Data Portal. DC Block Orders Master Data 2021-2022. URL: https://data.nationalgrideso.com/ancillary-services/dynamic-containment-data.

- DC is paid on a pay-as-clear (rather than pay-as-bid) basis, so each market participant is paid the price of the highest-cost provider accepted. Whilst we assess the revenues to CLASS and non-CLASS providers on the market-clearing price, we estimate the cost of alternative providers based on each provider's bid, as a proxy for their true costs.
- Prior to September 2021, DC was paid on a pay-as-bid basis.[42] Due to under-subscription in the DC market, providers in the pay-as-bid auction faced an incentive to bid close to the £17 per MW per hour price cap. Bids therefore did not accurately reveal the true opportunity costs of the providers. In the pay-as-clear format, accepted capacity receives the price of the marginal provider regardless of the price of their bid. Thus, providers do not have a strategic incentive to bid at the market-clearing price but rather at a level that reflects their costs. We therefore model the supply curve beyond September 2021 as bid data provides direct evidence of the costs of alternate balancing providers.

All other modelling assumptions and steps are similar to those described for FFR above.

A.3.4. Optional Fast Reserve

The data structure and availability for Optional Fast Reserve differs from FFR and DC. In the case of FFR and DC, the ESO runs either a month- or day-ahead auction, with the bids of all units, both accepted and rejected, published by the ESO. The structure of the auctions enables us to construct a merit order into which we endogenously bid CLASS for each tender round. Instead, the ESO procures OFR through bilateral agreements. It publishes monthly data on the capacity contracted (MW), volume metered (MWh) and utilisation rate (£ per MWh) for each provider that the ESO contracts with.[43] The nature of the auction and the dataset does not enable us to model a merit order.

Instead, when CLASS's utilisation rate is lower than the average of alternative providers, we model that CLASS displaces the MW capacity contracted by the alternative OFR providers one-for-one. We assume that each unit of CLASS capacity provides the same energy volume as the average unit of capacity for alternative providers.[44]

We estimate the total cost of OFR providers for each month between January 2019 and February 2021 by multiplying the metered MWh and the average utilisation rate of non-CLASS providers. Because OFR is not structured as a pay-as-bid auction we apply the same adjustment for the difference between prices bid and economic costs as we do for FFR. We compare the estimated costs between deployment scenarios and the counterfactual to calculate NG ESO's average savings per month through the provision of CLASS in OFR.

A.4. Avoided Carbon Costs

We model the avoided carbon costs of alternative balancing services providers based on the energy volume CLASS provides for optional FR. We focus on OFR as energy volumes are greater for reserve than response product but note that the resulting estimate for the carbon costs benefit may be conservative. The modelled carbon benefit in the Conservative

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42 Ofgem (2021), Decision on Dynamic Containment in relation to an update to the Terms and Conditions related to Balancing.

43 We source data from NG ESOs Data Portal: Fast Reserve Market Information. Available from: https://data nationalgrideso.com/ancillary-services/fast-reserve-market-information-reports.

44 Over the sample period CLASS and non-CLASS providers have had similar utilisation (MWh metered for each MW contracted) at 32.6 and 31.2 MWh per MW, respectively.

deployment scenario is zero as profit-maximising CLASS bidding does not allocate any capacity to OFR.

We model avoided carbon emissions as the energy volume scaled by the long-run marginal carbon intensity of generation as projected by BEIS.[45] Using the sector-wide marginal carbon intensity may result in a low estimate as some alternative balancing services providers could be carbon-intensive thermal generators. We value the avoided carbon emissions in line with BEIS' carbon values for appraisal.[46] As electricity is a traded sector, we subtract the average price of a UK Emission Trading Scheme certificate in 2021 from the carbon cost to avoid double-counting carbon prices embedded in bids.[47]

[45] BEIS (2021), Green Book Supplemental Guidance Data Tables, Table 1.

[46] BEIS (2021), Green Book Supplemental Guidance Data Tables, Table 3.

[47] ICE Website: UK Emissions Auctions. URL: https://www.theice.com/marketdata/reports/278. Visited on 5 February 2022.

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