CLASS

Learning event, 27 April 2016

LCN Fund
Low Carbon Networks

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Steve Cox

Head of Engineering

Background & Recap

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Housekeeping

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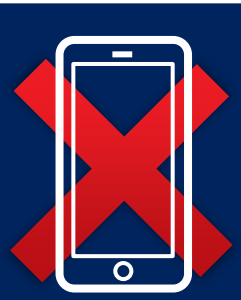

Mobile phones

Breaks

Fire alarms

Main Q&A
at end of day

Agenda

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CLASS
Customer Load Active System Services

Background & recap 10:00 – 10:20	Project extension 10:20 – 10:35	Market background & CLASS eligibility 10:35 – 11:20	Break 11:20 – 11:40
Overview of CBA tool & impacts 11:40 – 12:05	Results 12:05 – 12:25	Next steps 12:25 – 12:40	Q&A 12:40 – 1:00

Introducing Electricity North West

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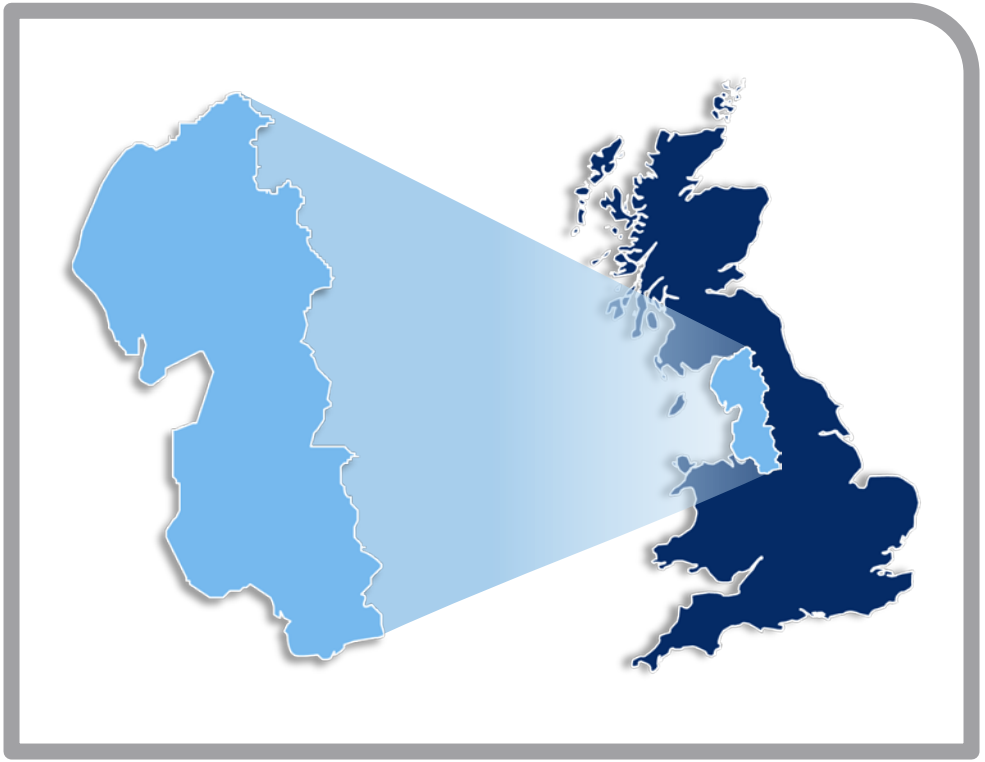
4.9 million

2.4 million

25 terawatt hours



£12 billion of network assets

56 000 km of network ● 96 bulk supply substations
363 primary substations ● 33 000 transformers

Our innovation strategy

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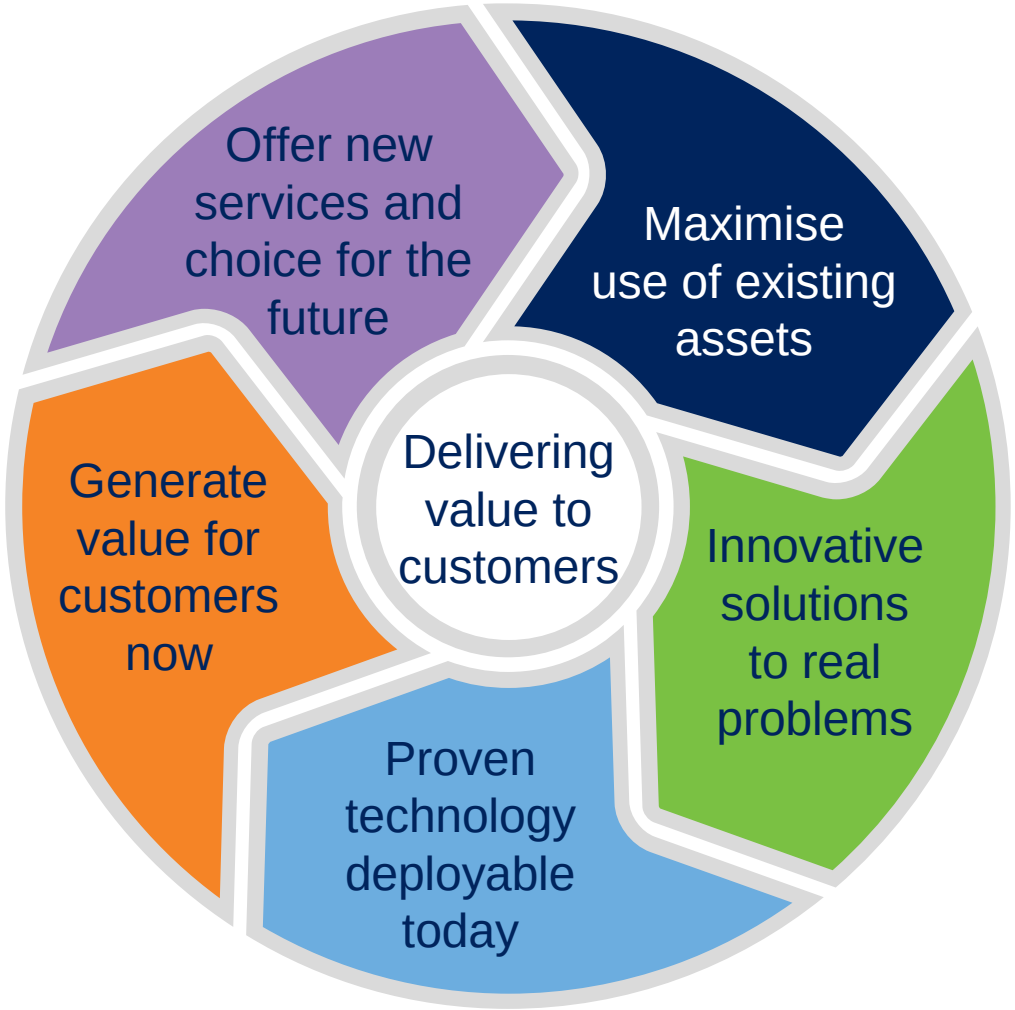

Our smart grid development

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Leading work on developing smart solutions

Deliver value from existing assets

Customer choice

LCN Fund Low Carbon Networks — Five flagship products (second tier/NIC) £42 million

C2C

SMART STREET

Celsius

CLASS

RESPOND

Background CLASS project

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Sought to demonstrate that electricity demand can be managed by controlling voltage…

…without any discernible impacts on customers

CLASS
Customer Load Active System Services

Customer Load Active Systems Services

CLASS project overview

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Objectives	Reduction of peak demand	Frequency response and voltage support	Voltage and demand relationship	No effect on customers
What?	Baseline measure: Spring 2014 Monitoring waves: Summer 2014 to Spring 2015 All **390 000** customers in test area received letter **696** customers recruited at **baseline** **1,357 monitoring** interviews			
Customer hypothesis	**“CLASS will be indiscernible to customers”** Customers will not see / observe / notice an impact on their supply quality when these innovative techniques are applied			

Results summary

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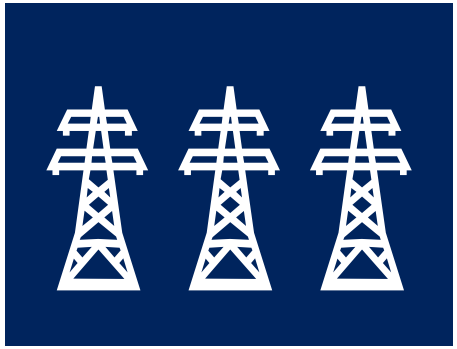
Statistical findings are that domestic customers did not notice the CLASS functions



Lessons have been learned during the installation phase, that can be integrated into any future ‘rollout’

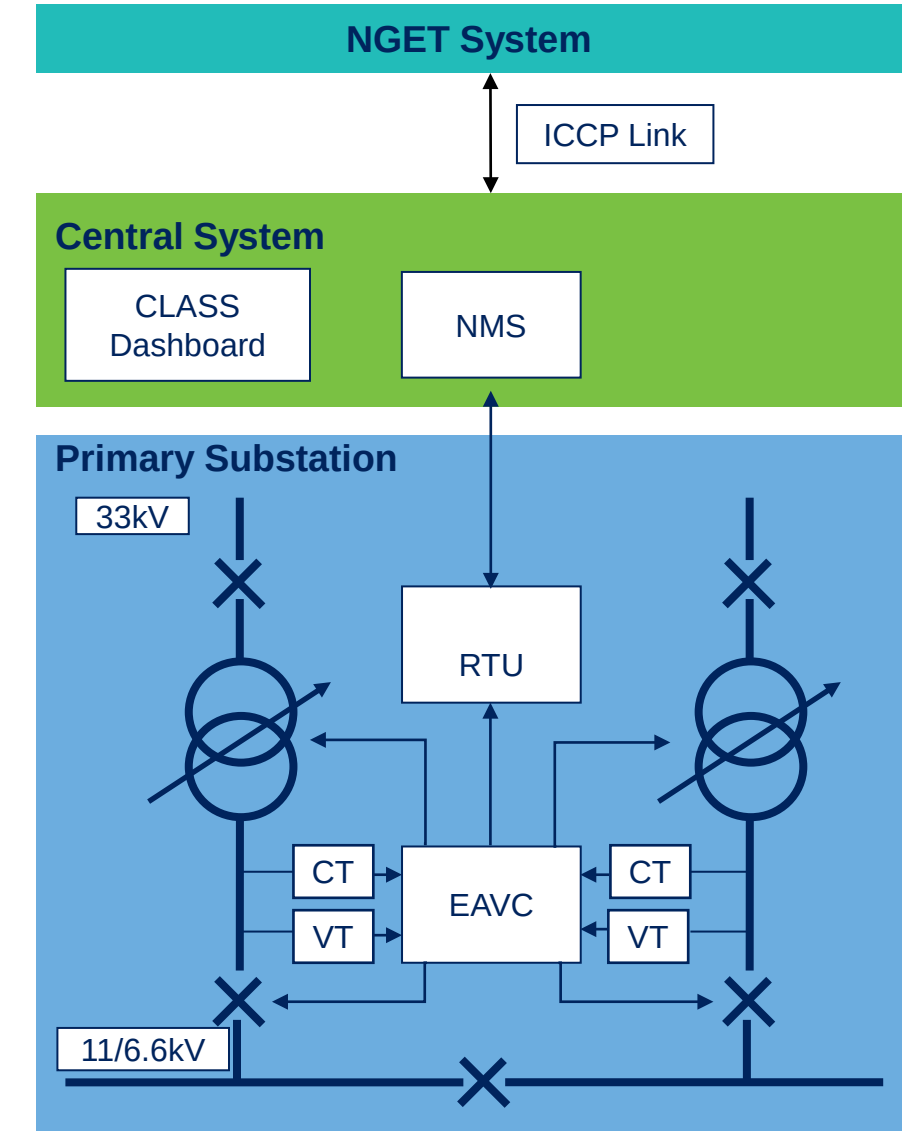
CLASS has provided National Grid with the ability to use an ICCP link which provides them with a demand response during a system frequency event

CLASS has shown an approximately linear relationship between voltage and demand

High level benefits

- Low cost high speed frequency support
- 3GW demand reduction or boost
- 2GVAr National Grid voltage control
- Reinforcement deferral
- 24/7 voltage/demand relationship matrix

CLASS system overview



NGET System	ICCP link will provide future capability for NGET to access the CLASS functionality directly for flexible whole system response
Central System (Dashboard)	Facility to specify service requirements Monitors the status of each CLASS substation and which should be armed or disarmed Monitor performance
Enhanced Automatic Voltage Controller	Measure performance. voltage, current, power, frequency etc Hold arm/ disarm flags for each of the CLASS services Trip or close circuit breakers or operate tap changers to implement CLASS services

Tony McEntee

CLASS Implementation Manager

Project extension

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CLASS extension objectives

To assess the market for each CLASS service	To assess the impact for each CLASS service	To determine the benefits for GB customers
		
Market structure, entry qualifications and service price Size of market in 2015 and potential size annually to 2031 Current and potential future competitors – no, type and size of players	Market structure and service price Competitors – number, type and size of players	Costs and benefits for GB customers Potential winners and losers in each market Whole market impact Sharing of DNO Revenues with customers

CLASS extension deliverables

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Learning & Dissemination	Closedown	Customer benefits
		
Webinar and learning event held by 30 April 2016	Publish addendum to closedown report on CLASS website by 31 May 2016	Publish report detailing the methodology and results of the benefits modelling and associated tool(s) by 31 May 2016

Regulatory treatment clarified

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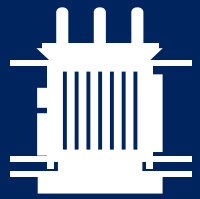
Revenue and costs classified as Value Added Services (DRS8)

Services described generically as: ‘distribution network voltage control and network management services procured from the licensee by NGET for the purposes of its system operator residual balancing activity’.



The reasons for this decision:

These services utilise DNO assets

Licensees incentivised to provide services to NGET: should benefit consumers by more efficient procurement of system balancing requirements;

Consumers should benefit by sharing any net revenue received by the licensee

Baringa

Analysis and findings

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CLASS impact assessment

Contents

- Overview of Balancing Services and CLASS' eligibility
- Market dynamics - Current and future
- Methodology for Impact Assessment
- Results

Overview of Balancing Services

Introduction to Balancing Services

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What are Balancing Services?

- Range of energy and capacity products designed by National Grid Electricity Transmission (NGET) – the System Operator
- Used to maintain the balance of supply and demand after gate closure, to maintain stability, and ultimately ensure security of supply

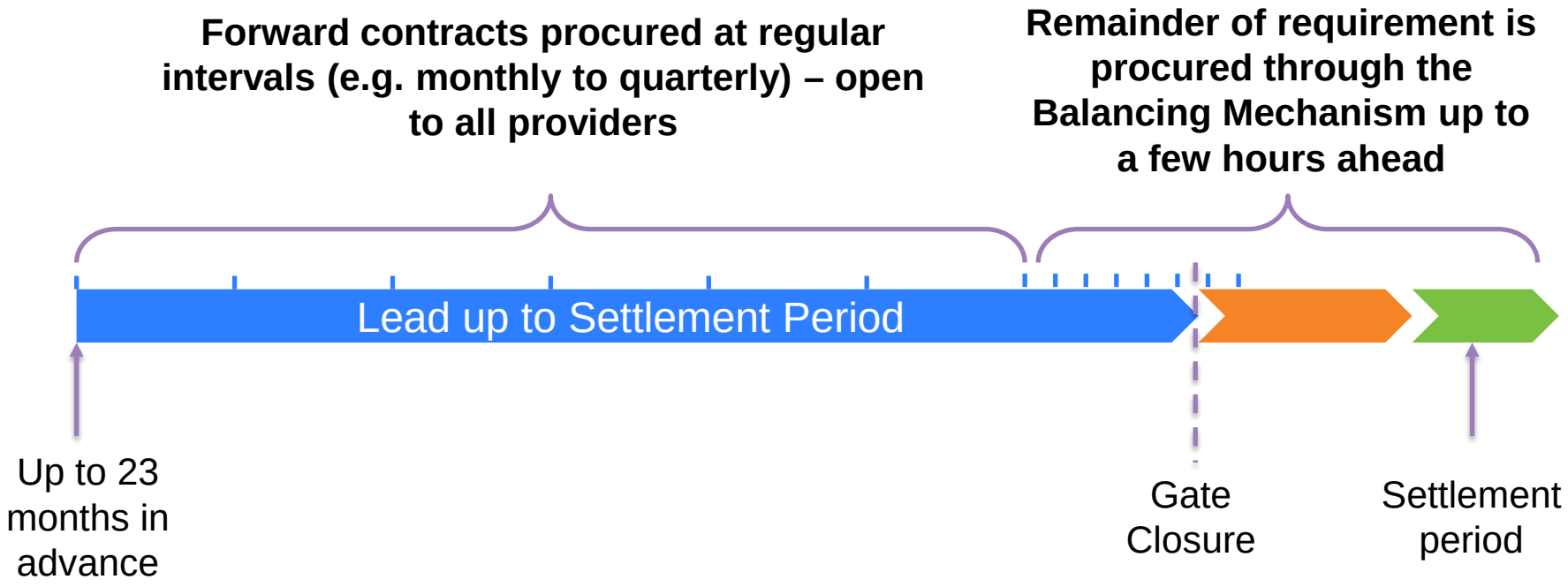
Who provides Balancing Services?

- Balancing Mechanism (BM) providers – large, often transmission-connected generators
- Non-BM (Distributed resources)
- Demand Side Response
- Other TSOs (via interconnectors)

How are Services procured?

When does NGET buy Balancing Services, and how long for?

- NGET uses both forward contracts (“firm contracts”) and short term products
- Forward contracts can be up to 23 months long, while short term products can be just the length of a settlement period



How does payment work?

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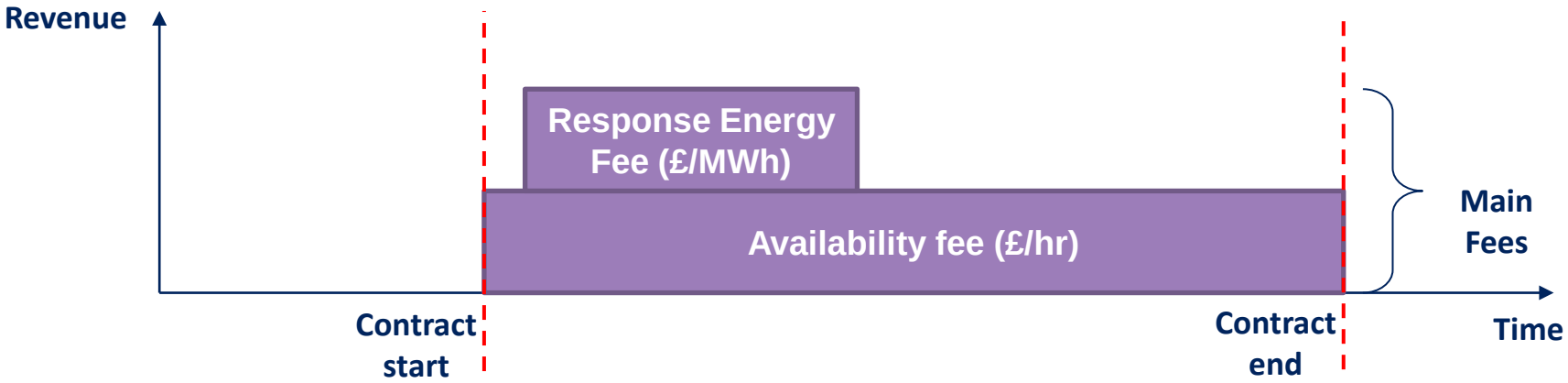
How are providers paid for Balancing Services?

- Forward-procured Balancing Services are structured as availability fees and energy fees
- Successful providers are paid the availability fee for their “window” and energy fee for any utilisation
- Balancing Services procured in the Balancing Mechanism are paid according to bids and offers for energy utilised, though other fees can also be payable (positioning, holding, availability)



What products is CLASS interested in?

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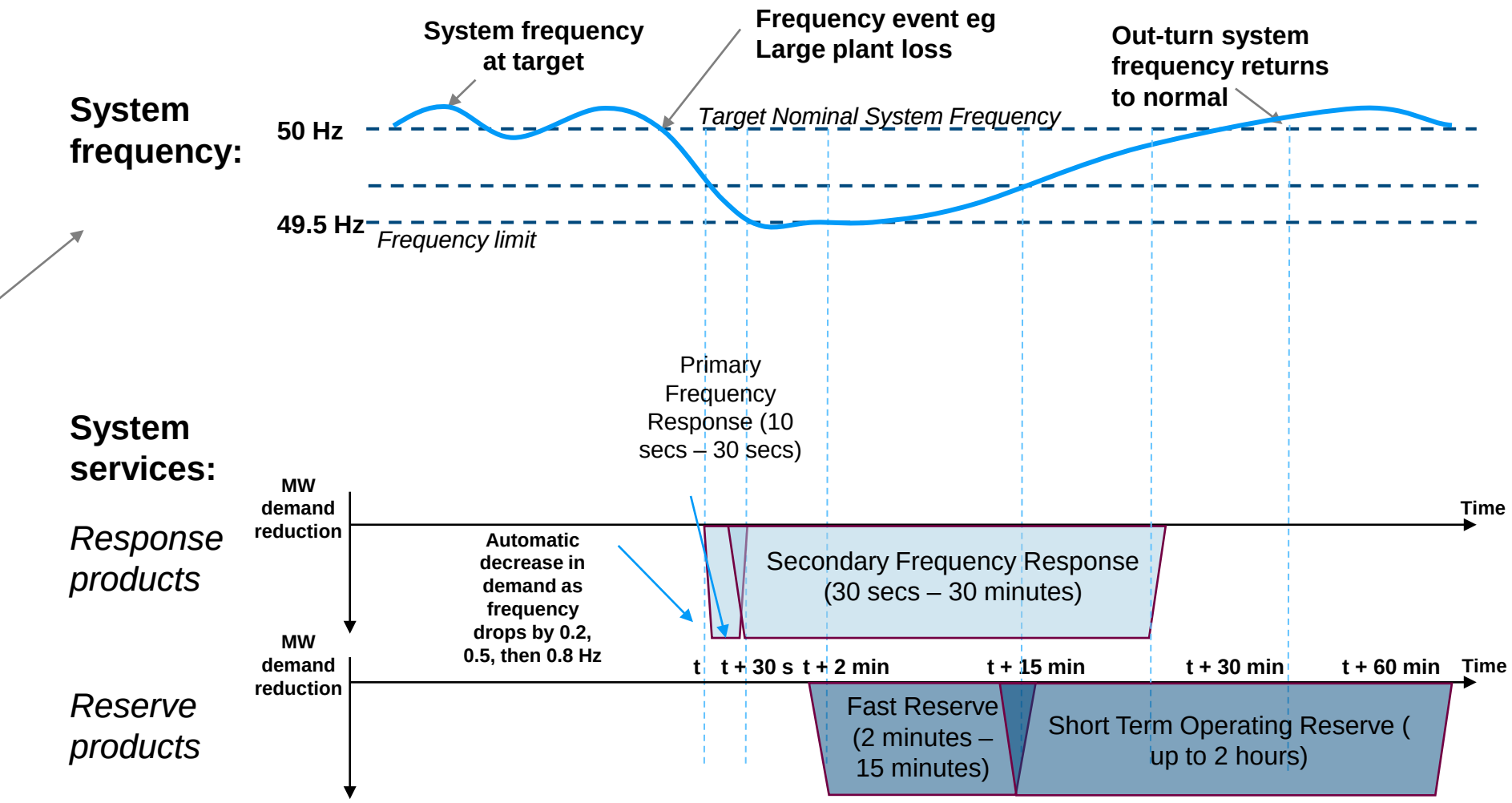
Product	Sub-product	Ramp time	Duration
Frequency Response	Primary (increase in active power)	10 seconds	30 seconds
	Secondary (increase in active power)	30 seconds	30 minutes
	High (decrease in active power)	10 seconds	Indefinite
Fast Reserve	Fast Reserve	2 minutes	15 minutes
STOR	(Committed, flexible, premium flexible products)	Up to 4 hours, though sub-20 mins preferred	2 hours
Reactive Power	Enhanced Reactive Power Service (EPRS)	2 minutes from instruction	Indefinite

How are the products used together?



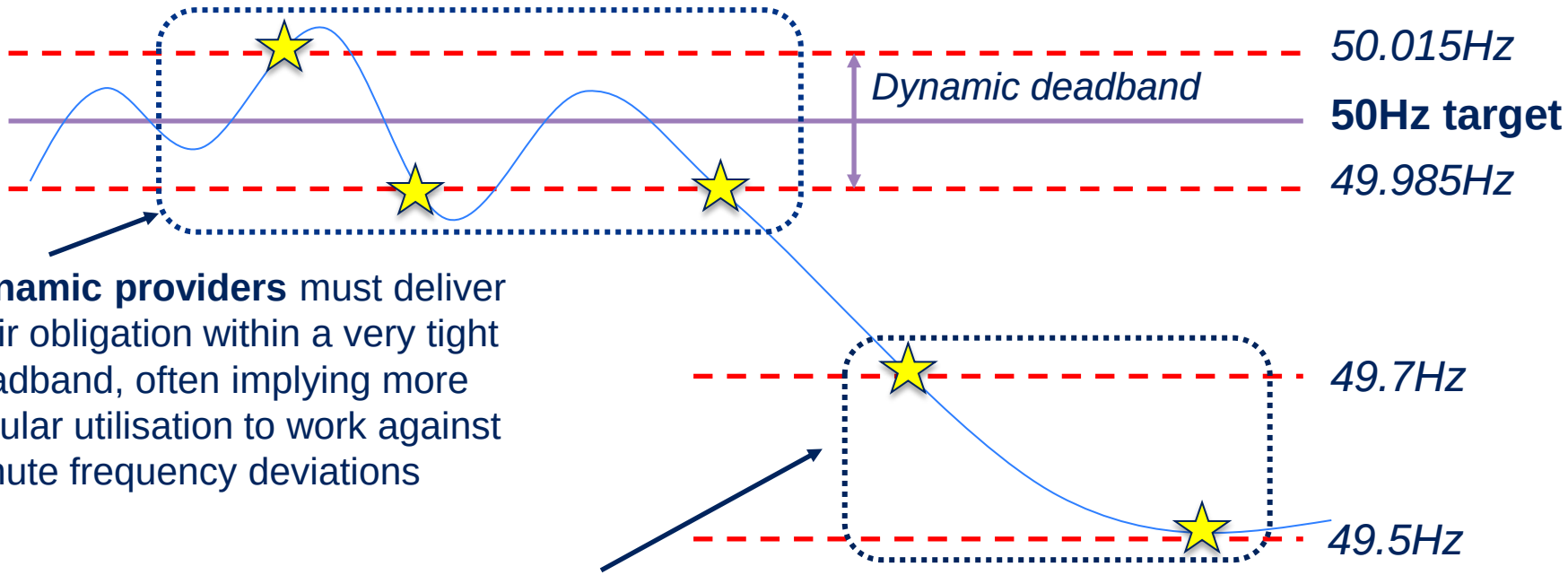
Is CLASS eligible?

Product	CLASS eligibility (indicative)	Notes
Frequency Response Primary	Yes	• Through switching out a single transformer • **Dynamic/static treatment still tbc – affects size of market**
Frequency Response Secondary	Yes	• Through tap changes • Dynamic/static treatment still tbc – affects size of market
Frequency Response High	Under review	• Potential to use tap stagger to provide High when switched out • Dynamic/static treatment still tbc – affects size of market
Fast Reserve	Yes	• Through tap changes • 50MW de minimis appears deliverable through aggregation
STOR	Yes	• Through tap changes • Though duration of service could make consistent profile of performance difficult on full capability
Reactive Power	Yes	• Through use of tap stagger

Dynamic vs static Frequency Response

NGET needs to maintain a proportion of dynamic response at all times

- CLASS' treatment as either static or dynamic will determine the size of its Frequency Response market, and have knock-on effects into other markets



Dynamic providers must deliver their obligation within a very tight deadband, often implying more regular utilisation to work against minute frequency deviations

Static providers must deliver their obligation where the frequency hits a certain trigger point, potentially increasing response as the size of the deviation increases

Market dynamics – current and future

Current market (2014/15)

Note that "Current" in this context refers to FY 2014/15 (one of the focus years for the impact assessment, for which we have a full year's worth of data)

Significant contribution from BM providers

Significant contribution from Pumped Storage

Signs of stronger engagement from DSR participants

Highly competitive STOR market

- Note – recent changes in the markets – (since September 2015):
  - New entry of Non-BM participants (DSR, Diesel) in Frequency Response
  - New entry of Non-BM participants in Fast Reserve (Gas Engines)

Future market (2027) context

Why 2027? To account for changes in Balancing Services requirements resulting from an increase in largest infeed loss, and to allow for sufficient deployment of new technologies into balancing services markets.

Increased market size (driven by increased infeed loss)

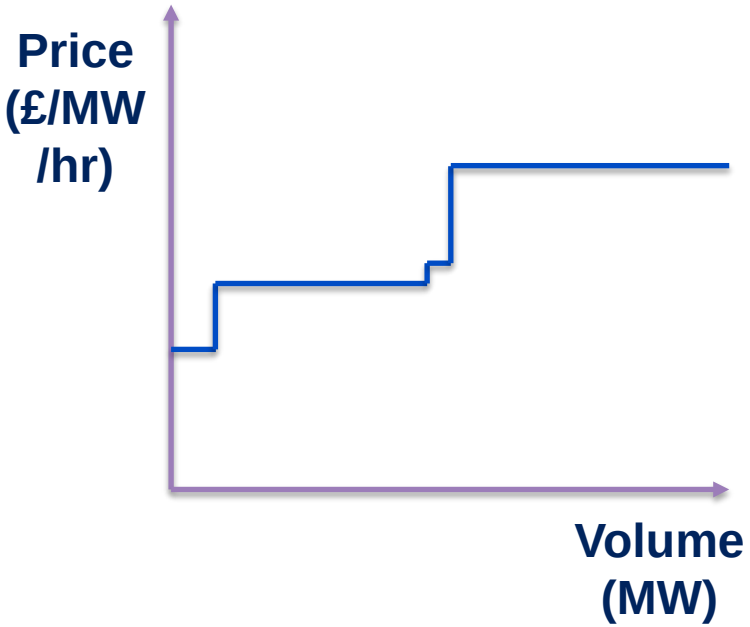
Reduced reliance on BM providers of reserve

Increased participation of small scale new entrant technologies

Resources used:

- Lazard capital cost assumptions for generating technologies and storage technologies
- DECC Electricity Generation Costs (2016 Commissioning used to represent existing installations), and Parsons Brinkerhoff update (also 2013)
- DECC UEP 2015 (Electricity and Carbon Prices)

Building baseline market supply stacks



2014/15: Actual participant data and corresponding bids used as baseline stack, as reported by NGET

2027: New entry assumptions derived from CM results, and through deployment rates

Baseline bids calculated from one of two methodologies:

- **Opportunity cost**
- **Long run marginal cost (less other fixed revenues)**

Frequency Response baseline 2014/15

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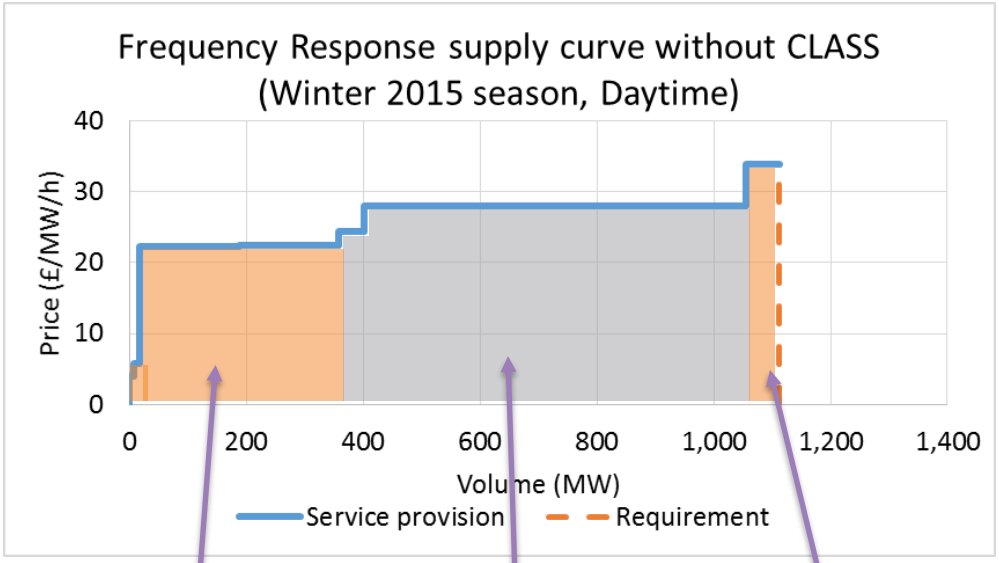
Supply of Frequency Response in 2014/15

- Sized for NGET's Secondary requirement, meaning surplus Primary and High was procured
- Minimum dynamic level of 450MW
- Firm providers (red areas) were predominantly pumped storage and thermals
- Other firm providers included small diesel generators
- BM (or "Mandatory" Frequency Response) regularly accounted for between 40-60% of total requirements



Pumped storage (Firm)

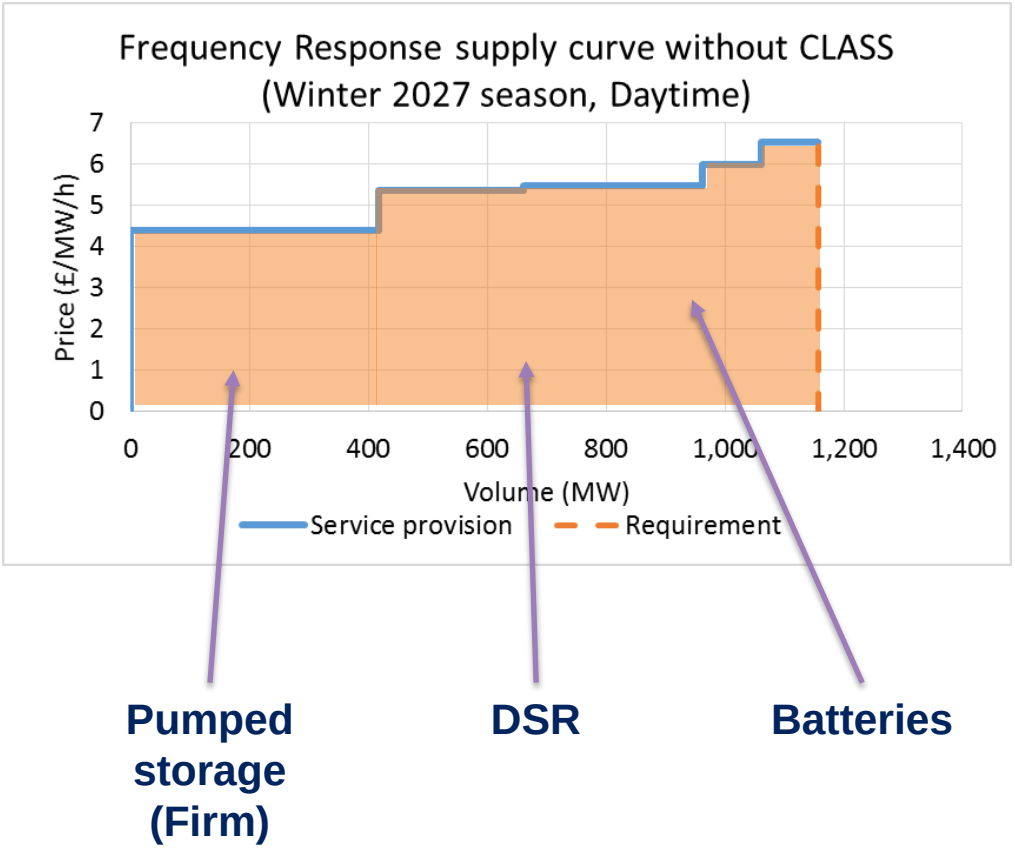
Thermal units (BM/Mandatory)

Thermal unit(s) (Firm)

Frequency Response baseline 2027

Supply of Frequency Response in 2027

- Secondary requirement is assumed to be binding
- 450 MW dynamic constraint
- All provision met by Firm providers
- Bottom-up cost-based bidding produces lower fees than in 2014/15 – reflects greater competition from increased diversity of new entrants
- New entrants are assumed to have a 20 year life, and to benefit from forecast CM revenues



Fast Reserve baseline 2014/15

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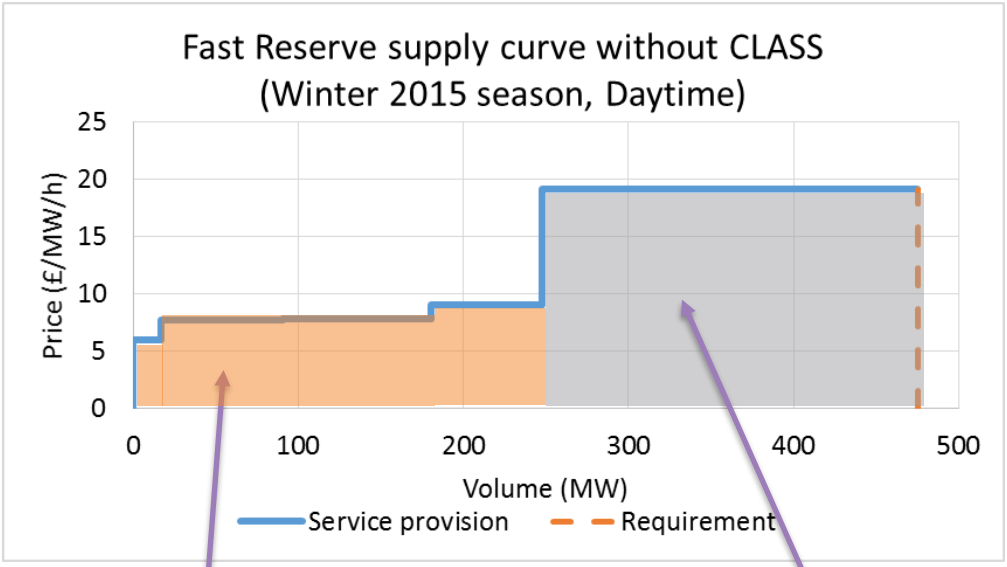
Supply of Fast Reserve in 2014/15

- The market is split into Firm (tendered) contracts, and Non-tendered contracts
- The 2014/15 Firm market was fully supplied by two pumped storage providers
- Non-tendered contracts are understood to also be mainly supplied by pumped storage, for a few hours per day



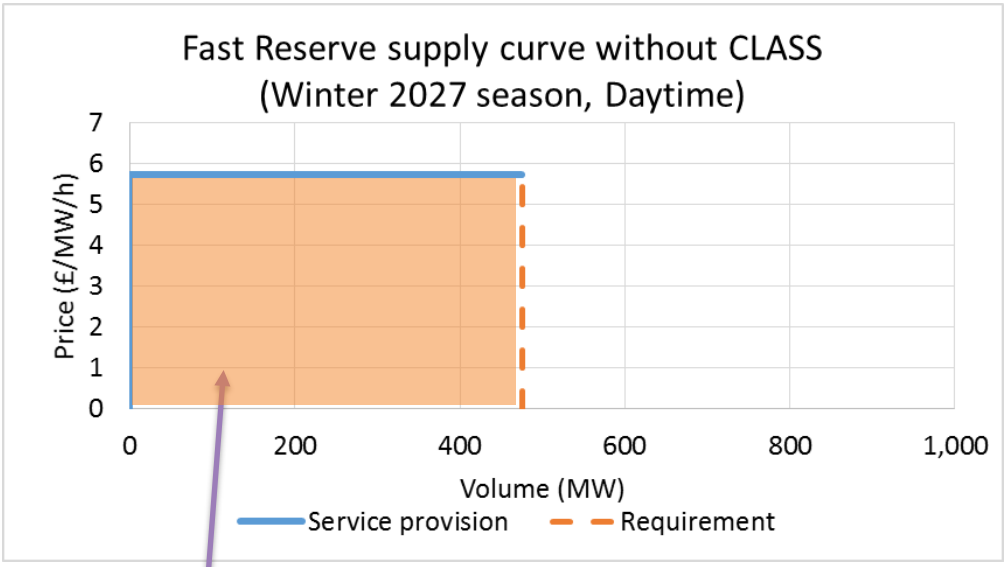
Pumped storage (Firm)

Non-tendered capacity

Fast Reserve baseline 2027

Supply of Fast Reserve in 2027

- Assumed that pumped storage is still competitive to provide Fast Reserve in 2027 by bidding down to opportunity cost
- Gas engines are out-of-merit owing to their LRMC-based bids being uncompetitive – though are assumed to provide any "shoulder" hours where pumped storage could otherwise be unavailable



Pumped storage (Firm)

STOR baseline 2014/15 and 2027

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2014/15 baseline

- Participant level data is not shared for STOR market
- However, previous reports have shown that BM providers make up approximately 40% on a capacity basis, but provide around 70% of the utilisation requirement
- Non-BM providers included engines, DSR, CHP and Hydro
- Our STOR stacks are based on the published average utilisation price curve across 2014/15

2027 baseline

- 2027 stack has been developed on the basis of:
  - Utilisation cost = Short Run Marginal Costs (of Electricity generation)
  - Availability cost = recovery mechanism for opportunity cost or LRMC
- We assume that the market is predominantly supplied by Non-BM plant, including DSR, Diesel, and Gas Engines.

Reactive Power

Reactive Power in 2014/15

- No market information on ERPS in 2014/15, as tenders have not been received since 2013
- Further, NGET did not require ERPS outside of the default payment mechanism (the mandatory service procured from generators)
- Furthermore, it is unclear whether all CLASS sites will be eligible as the requirement for the service is highly location-dependent

- Our approach: Average 2014/15 price paid for the Mandatory Service = **£2.53/MVArh** (supply stack assumed to be flat)

Reactive Power in 2027: Same assumptions used

Methodology for Impact Assessment

Impact assessment methodology

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Without CLASS

- Frequency Response
- Fast Reserve
- STOR
- *(Reactive Power)*

→ ~£400m NGET costs per year

Extrapolate to future year → Future NGET costs

CLASS

With CLASS

2014-15 costs incurred by NGET

Future costs incurred by NGET

→ Impact on displaced providers

→ DNO revenues and DUoS customer savings

→ BSUoS savings

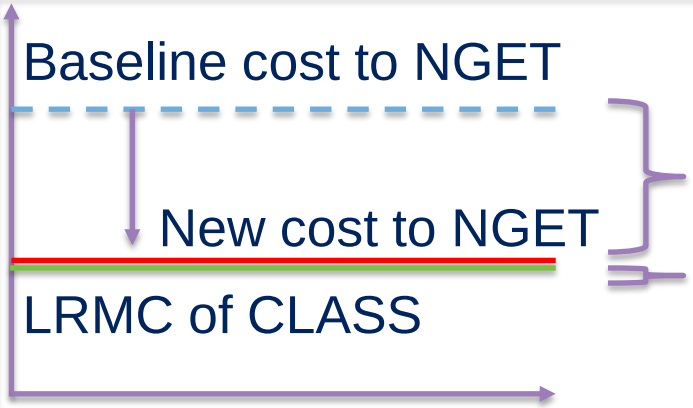
Consumer bill benefits

- BSUoS (Balancing Services Use of System) charges
  - Cost of NGET balancing actions are passed to consumers via BSUoS charges
  - If those costs can be reduced, majority of benefit passes to customers

- DUoS (Distribution Use of System) charges
  - All DNOs to treat CLASS costs and revenues as DRS8 as Directly Remunerated Service 8 DRS8, Valued Added Services
  - Net CLASS costs/revenues will be treated as Totex, being split between “fast” and “slow” money
  - Costs and revenues subject to each DNO’s sharing factor

CLASS pricing options

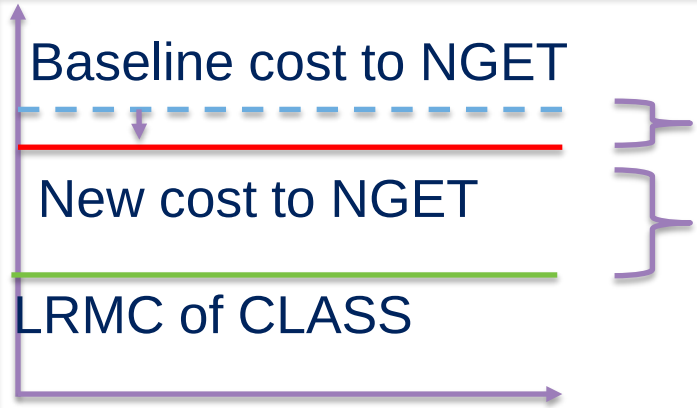
LRMC pricing



Customer benefit from BSUoS reduction

No net DUoS reduction

Shadow marginal pricing



Minimal savings in BSUoS

Net benefit above LRMC passed to consumers via DUoS under Totex treatment and sharing factors

Non-bill benefits

- Carbon emissions
  - Reduction in carbon emissions expected
    - Reduced part-loading of thermal generators
    - Reduced utilisation of more carbon-intensive providers
  - Depends on behaviour of displaced providers
- Security of Supply
  - Direct but small increase in risk of Customer Interruptions and Customer Minutes Lost (likely to be below regulatory threshold)
  - Less certain impact of displacing existing providers from balancing services
  - Uncertain interaction with OC6 requirement but likely to be neutral or possibly a positive impact

Results

Results

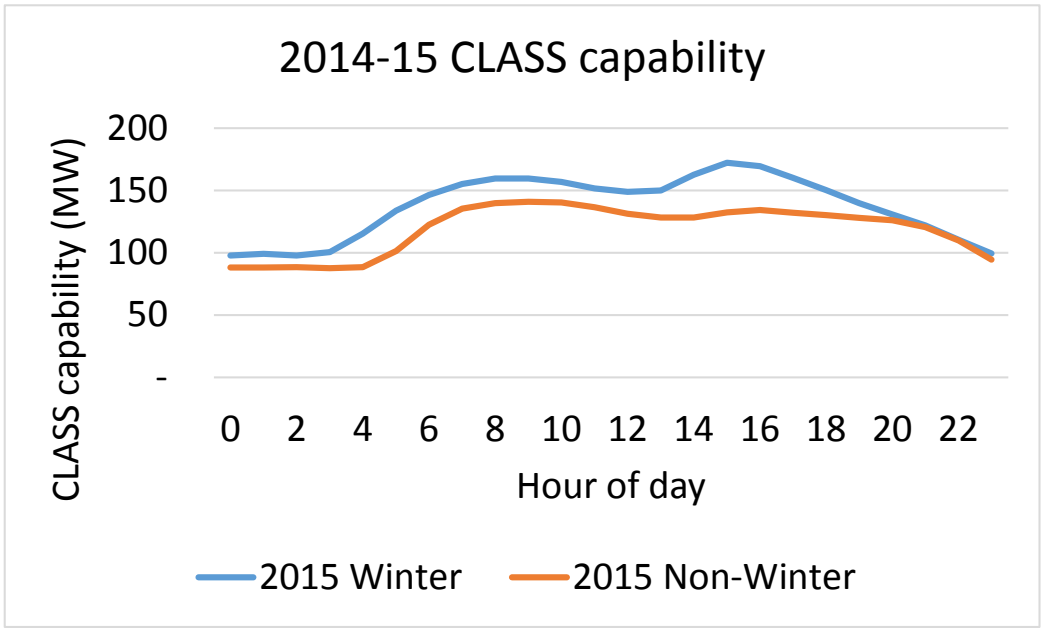
- Modelling results* are presented in the following sections:
  - Single-year snapshots
    - **2014-15 snapshot**, showing effect of deploying CLASS today
    - **2027 snapshot**, showing effect of CLASS in future market
      - **Variant 1: CLASS can provide dynamic and high** Frequency Response, so not limited by NGET minimum requirements
      - **Variant 2: CLASS unable to provide dynamic or high** Frequency Response, so can only displace plant if it does not breach minimum requirement
  - Multi-year Cost Benefit Analysis (CBA)
    - **CBA based on initial tranche** of CLASS investment, accounting for long-term totex treatment
    - **CBA based on projected deployment of CLASS**
      - **Variant 1: CLASS can provide dynamic high**
      - **Variant 2: CLASS unable to provide dynamic high**

*Note, results may be subject to small changes following final Quality Assurance exercise

Results

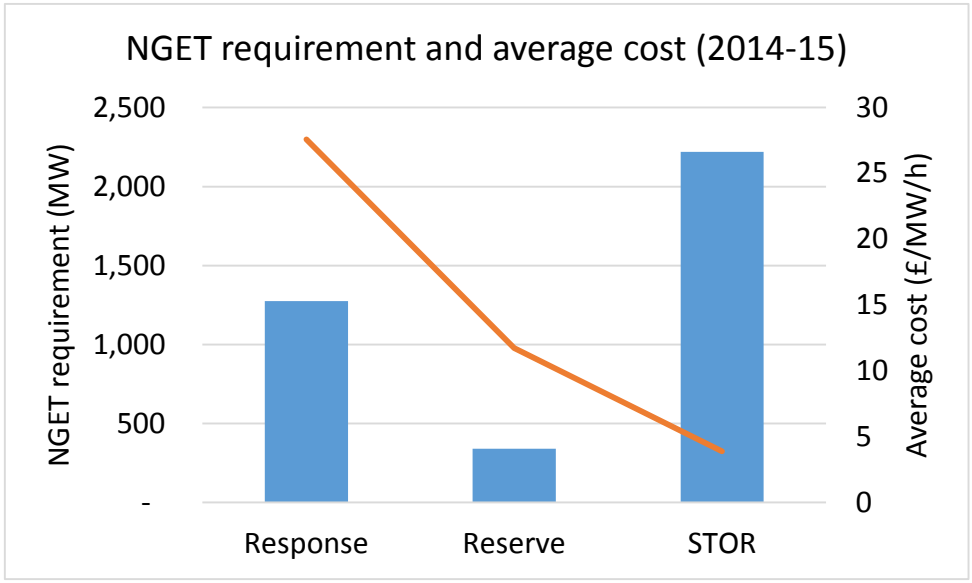
2014-15 snapshot

CLASS capability



- CLASS capability a function of underlying demand
  - Highest during winter evening peak
  - Lowest in non-winter overnight
- Converted to firm offer by taking minimum of:
  - Daytime & overnight
  - Winter & non-winter

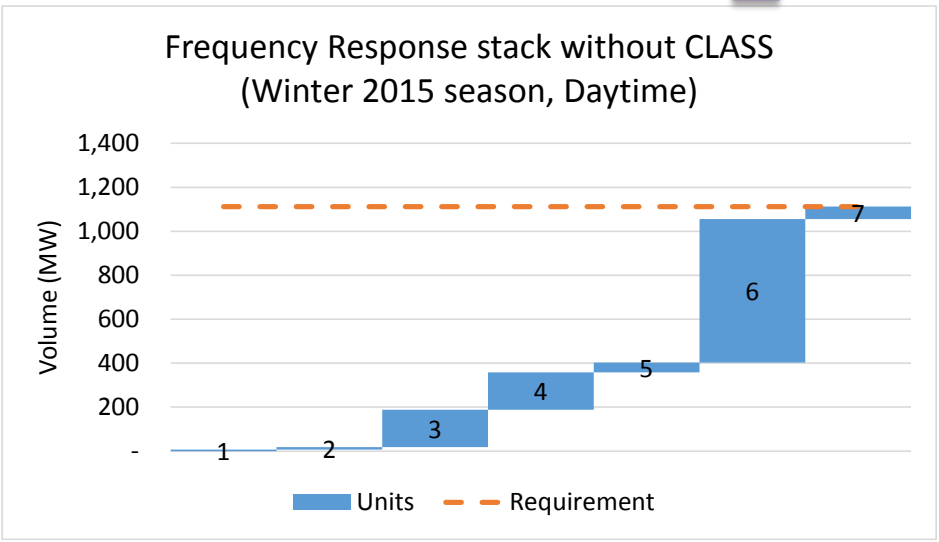
Choosing a Balancing Service market



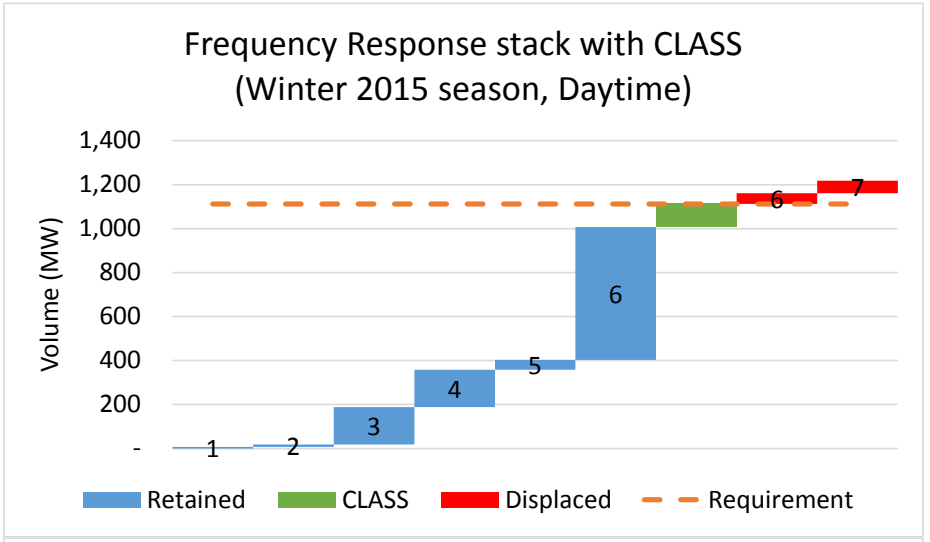
- Assume that CLASS is targeted at the most valuable service for which it is eligible
- Need to consider total market size
  - Also, the effect of any minimum requirements that CLASS cannot meet
- Small volumes assumed to target Frequency Response
  - Note there are strict technical standards required to participate

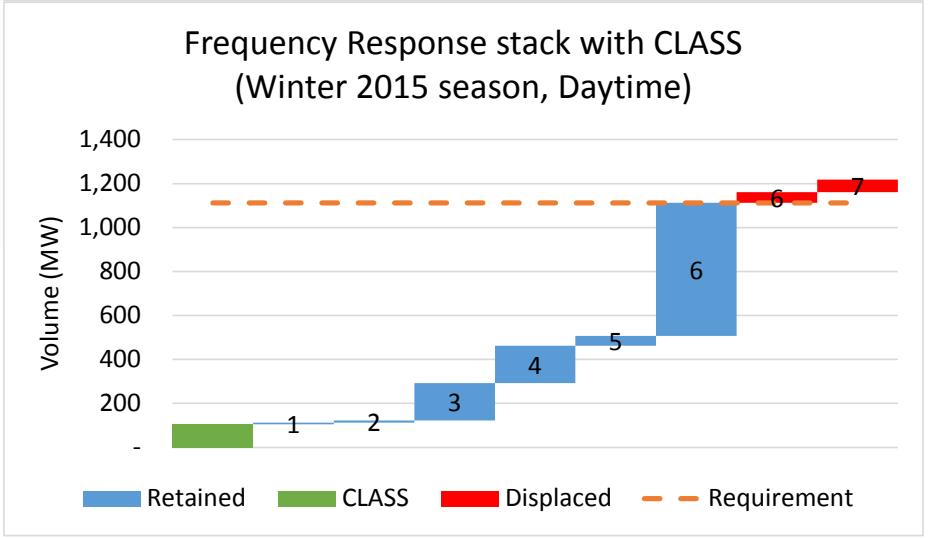
2014-15 CLASS impact – stack

Marginal



LRMC





2014-15 CLASS impact – supply curve

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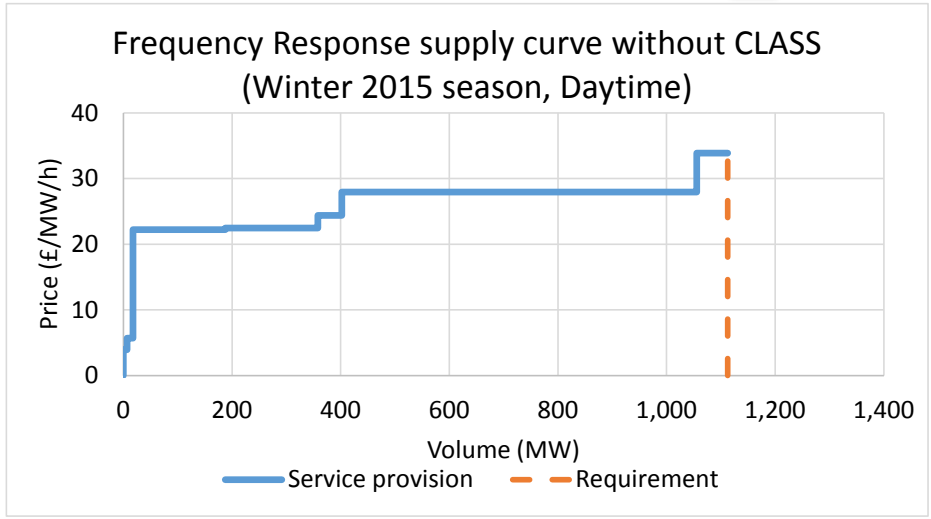
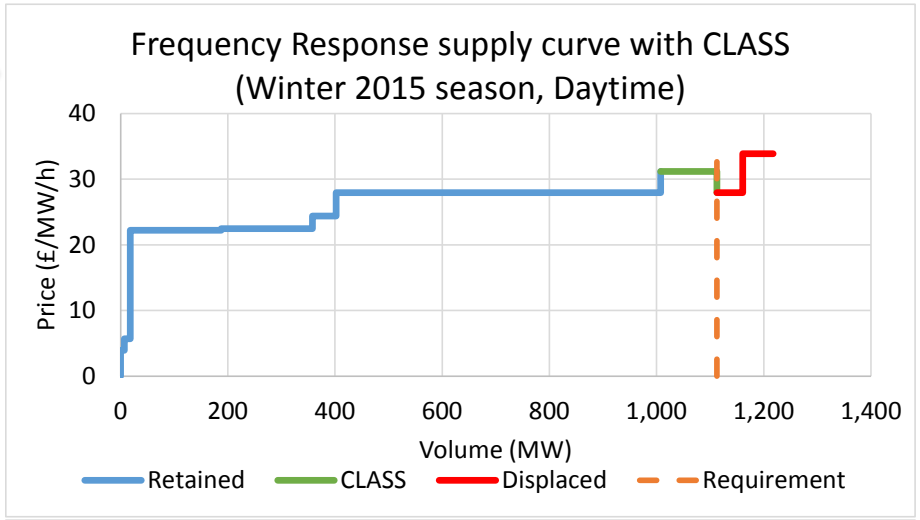
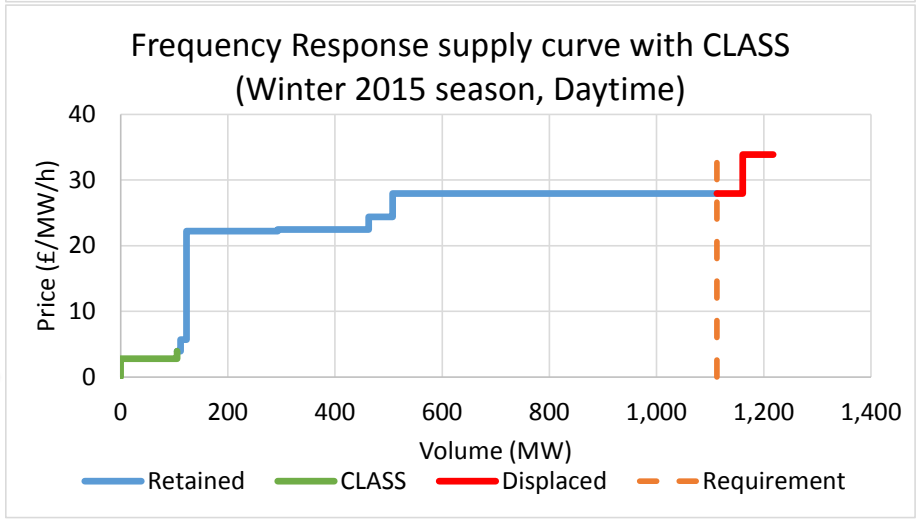


Marginal



LRMC



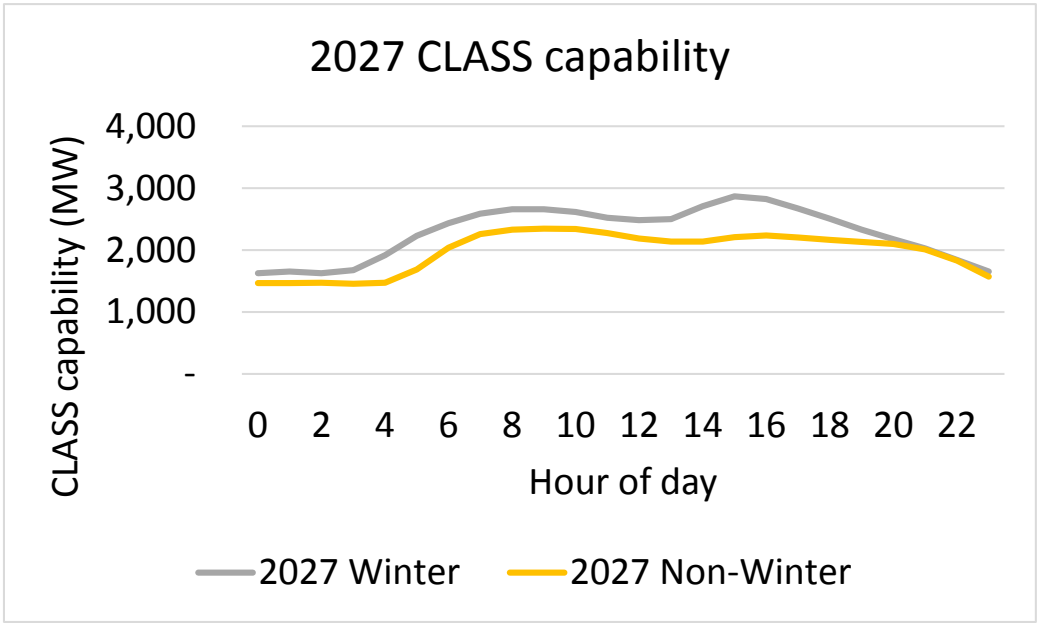
2014-15 impact

2015 (~180MW CLASS)	LRMC pricing £m (real 2015)	Marginal pricing £m (real 2015)
Cost to DNO of providing CLASS	2.4	2.4
Cost to NGET of CLASS	2.4	29.9
Displaced cost to NGET	32.2	32.2
Net NGET cost reduction	**29.8**	**2.3**

- Other quantified benefits:
  - Carbon: £82k benefit based on reduced part loading of thermals
  - CI/CML: Negligible cost (£82) since risk of fault and time to recover post-fault are both low

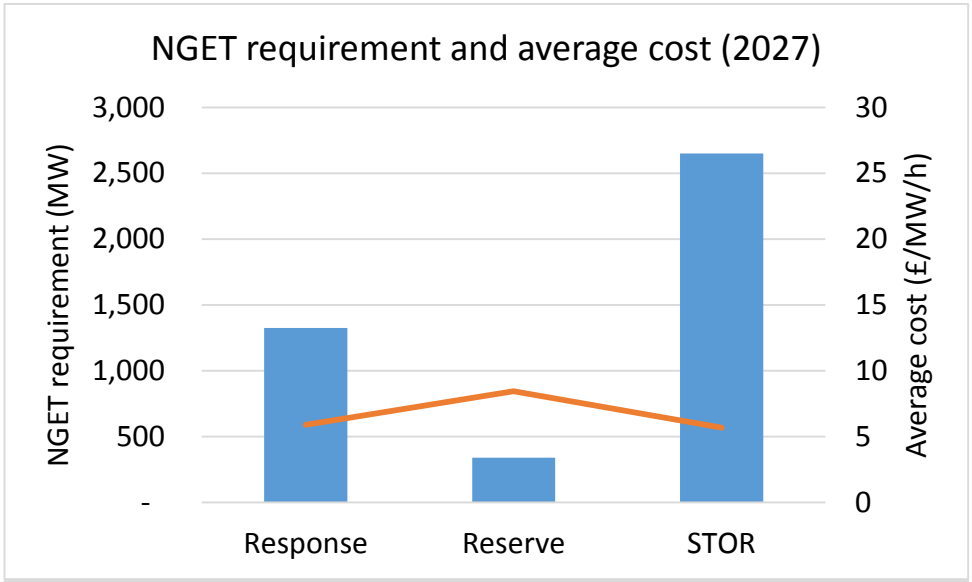
Results
2027 snapshot

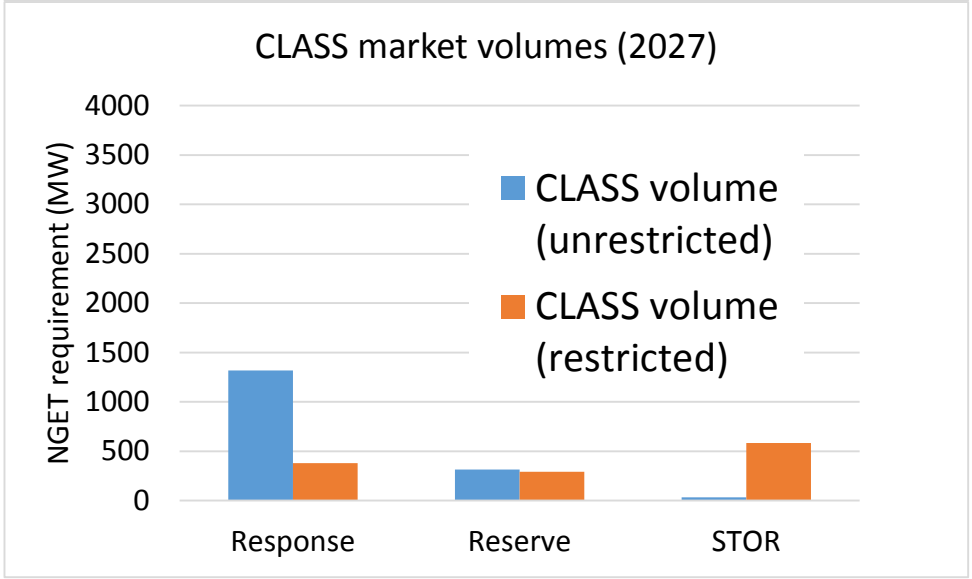
CLASS capability



- CLASS capability projected to peak at 3GW
  - Compares to 180MW in initial tranche
- True uptake very uncertain at this stage

Choosing a Balancing Service market





- Prices lower given completion from batteries and DSR
- Volume requirements slightly higher, but less than projected CLASS volumes
- Also, CLASS may be restricted in response market if it cannot provide:
  - Dynamic response
  - "High" response
- Effective STOR price for CLASS is lower than shown because of derating
  - LRMC ≈ shadow marginal price, so may not be worth participating

2027 CLASS impact – Frequency Response (unrestricted case)

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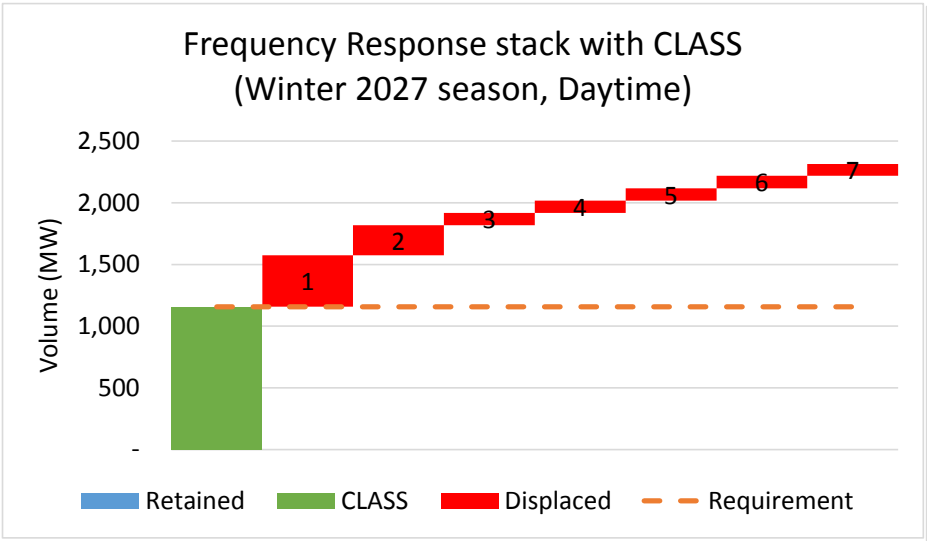

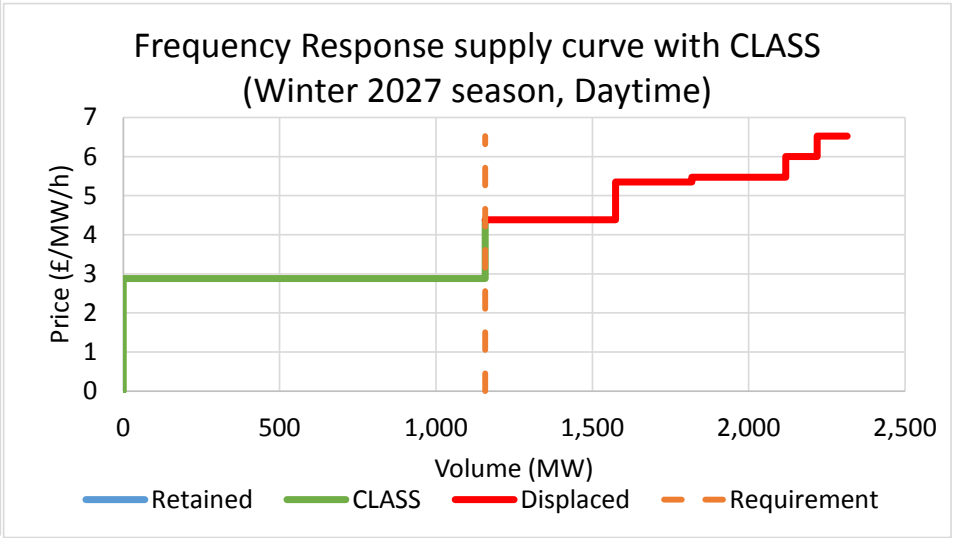

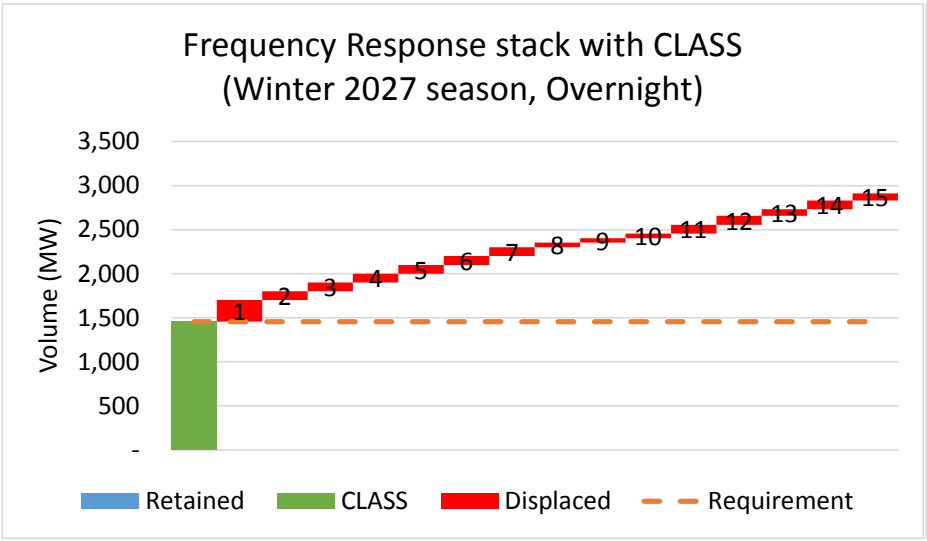

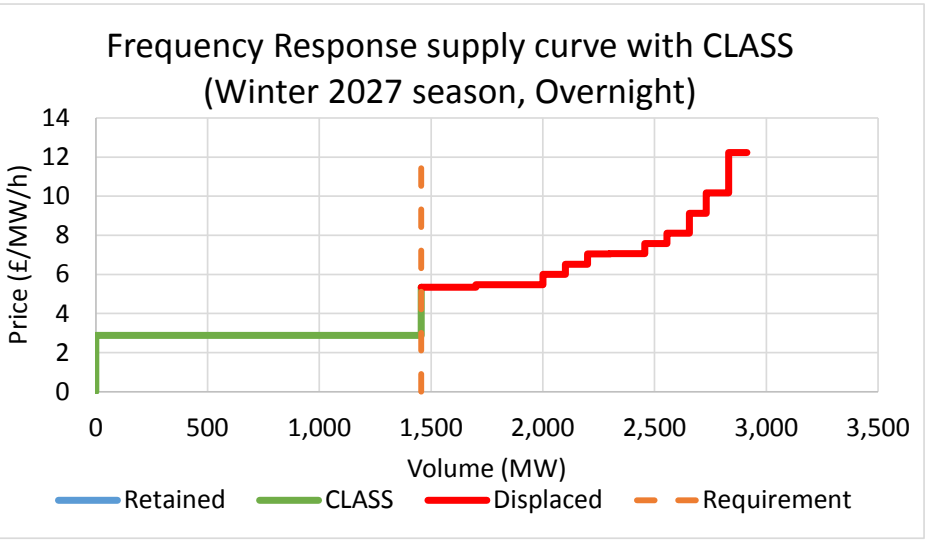

2027 CLASS impact – Frequency Response (restricted case)

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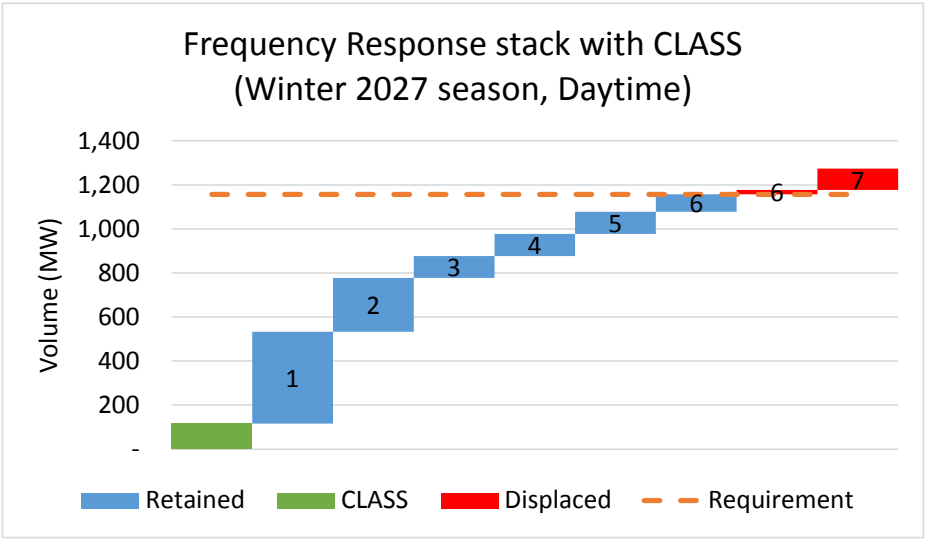

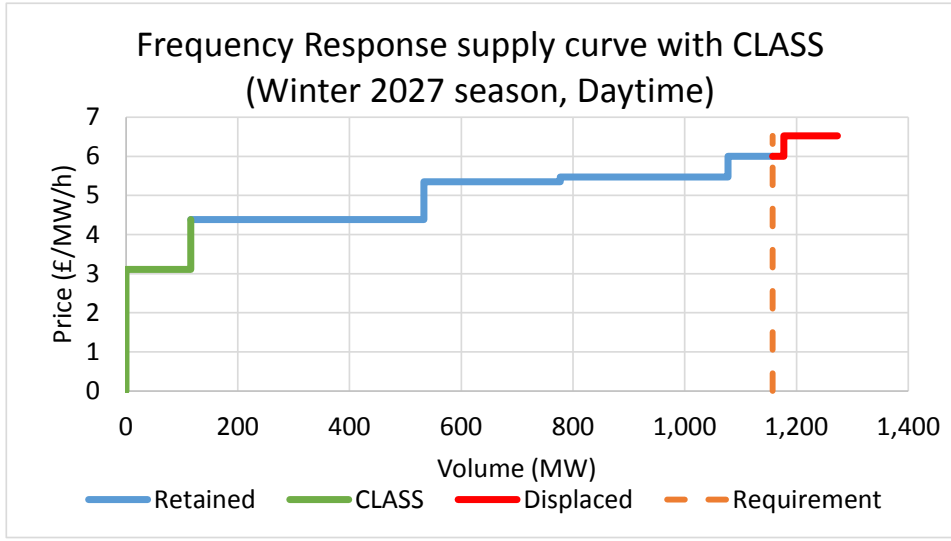

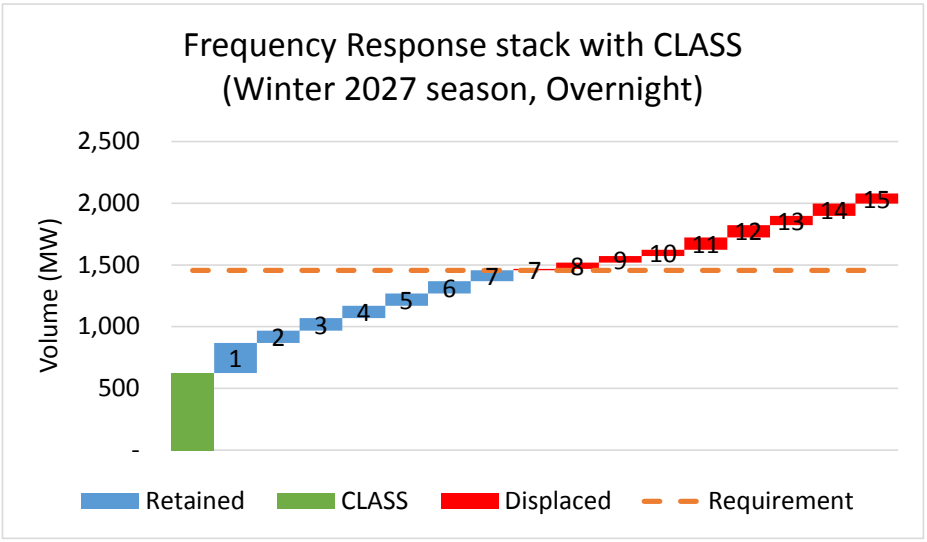

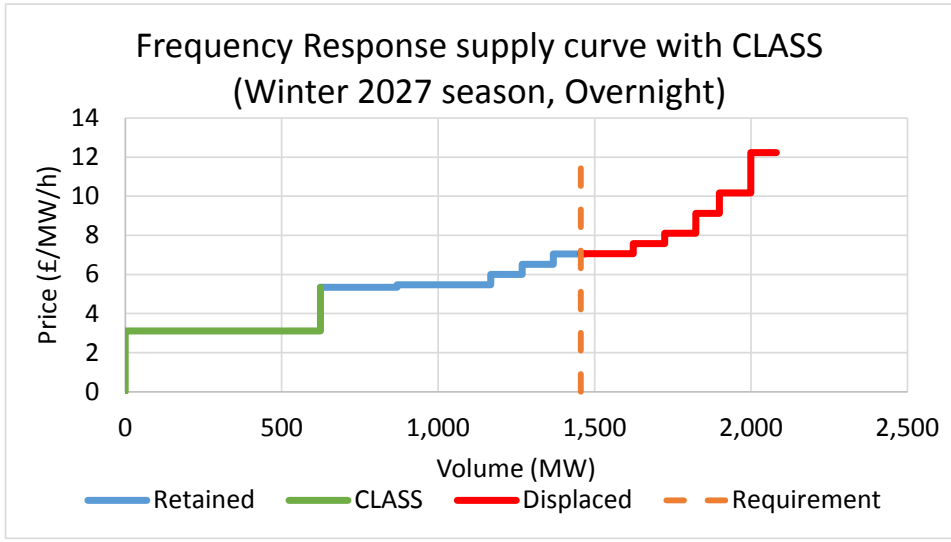

2027 CLASS impact – Fast Reserve

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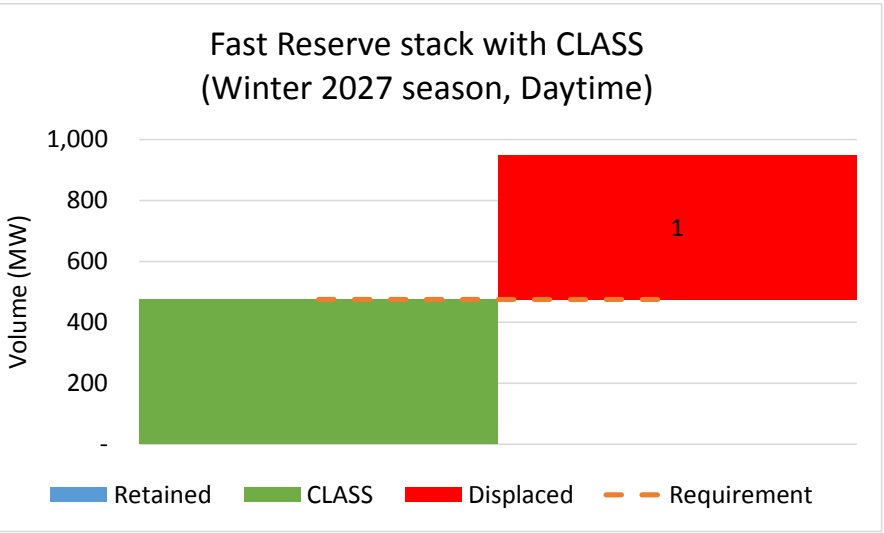

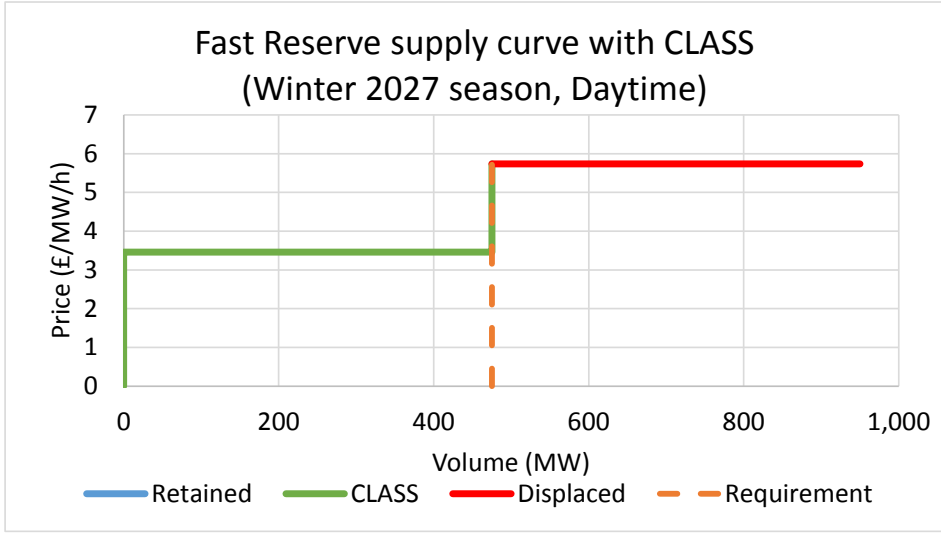

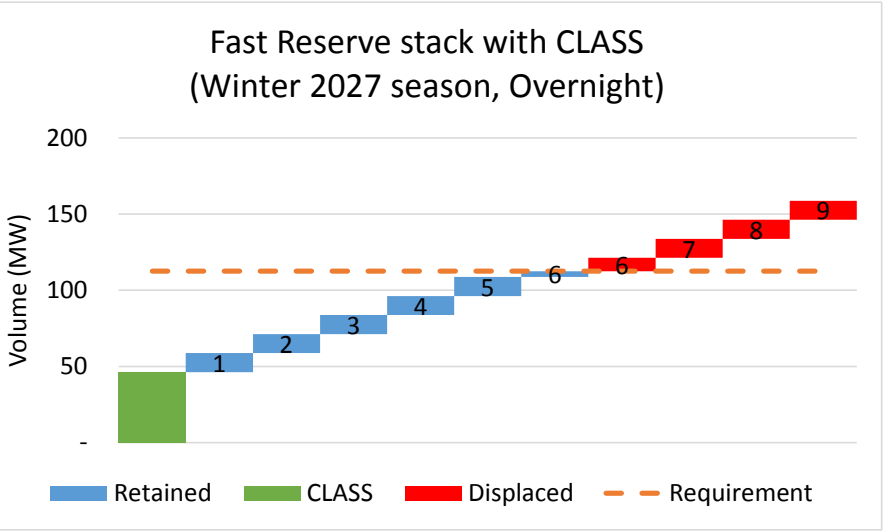

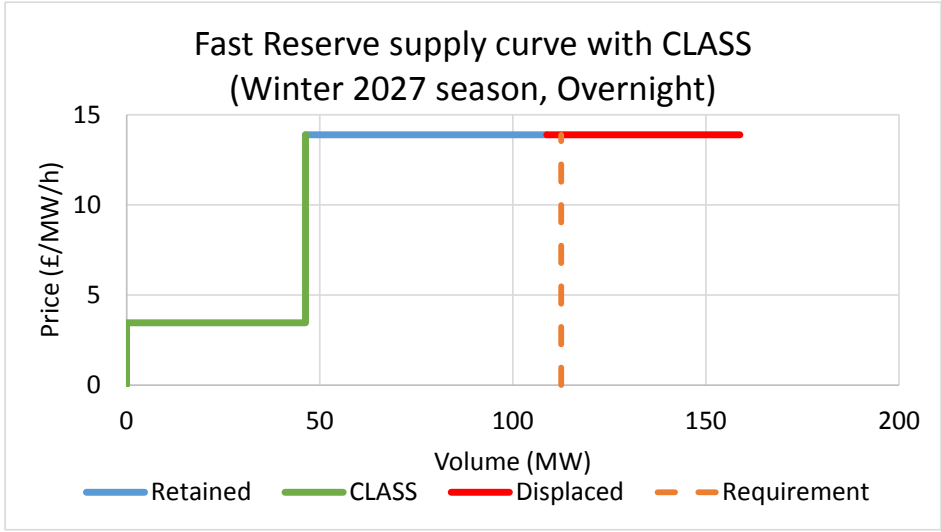

2027 STOR

- De-rating has been applied to STOR
  - Reduces the value of each MW of CLASS
  - Also, no value overnight
- Chosen strategy is to offer a low utilisation fee and recover LRMC through availability bid
  - Modelling suggests that CLASS at LRMC exceeds what NGET is willing to pay
  - Sensitive to modelling assumptions, but assume CLASS does not participate

2027 impact summary

2027 unrestricted case (~3GW CLASS)	LRMC pricing £m (real 2015)	Marginal pricing £m (real 2015)
Cost to DNO of providing CLASS	40.5	40.5
Cost to NGET of CLASS	40.9	80.9
Displaced cost to NGET	81.6	81.6
Net NGET cost reduction	**40.8**	**0.7**

2027 restricted case (~1GW CLASS)	LRMC pricing £m (real 2015)	Marginal pricing £m (real 2015)
Cost to DNO of providing CLASS	13.7	13.7
Cost to NGET of CLASS	13.6	29.8
Displaced cost to NGET	29.9	29.8
Net NGET cost reduction	**16.2**	**0.0**

Results

Multi-year Cost Benefit Analysis

CLASS CBA – initial capex tranche

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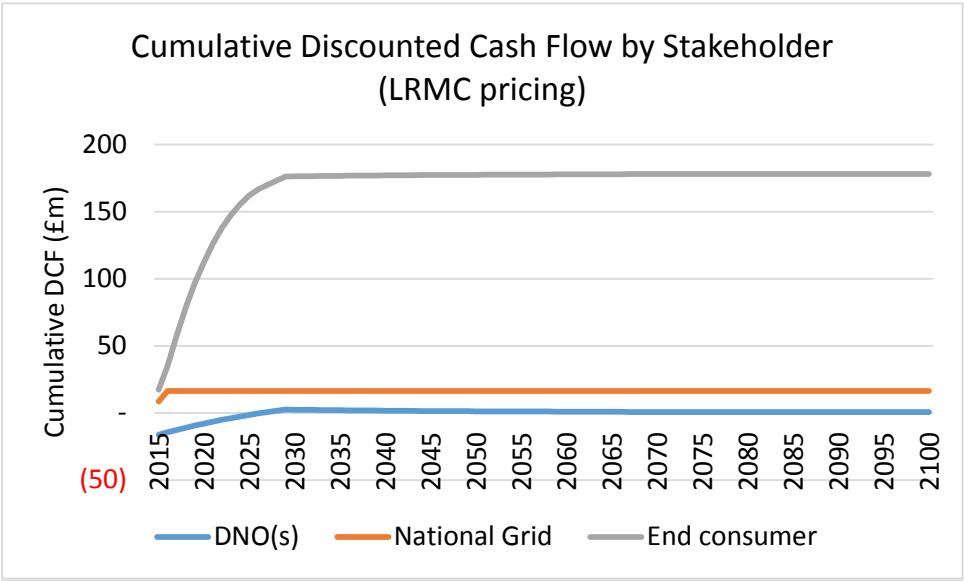
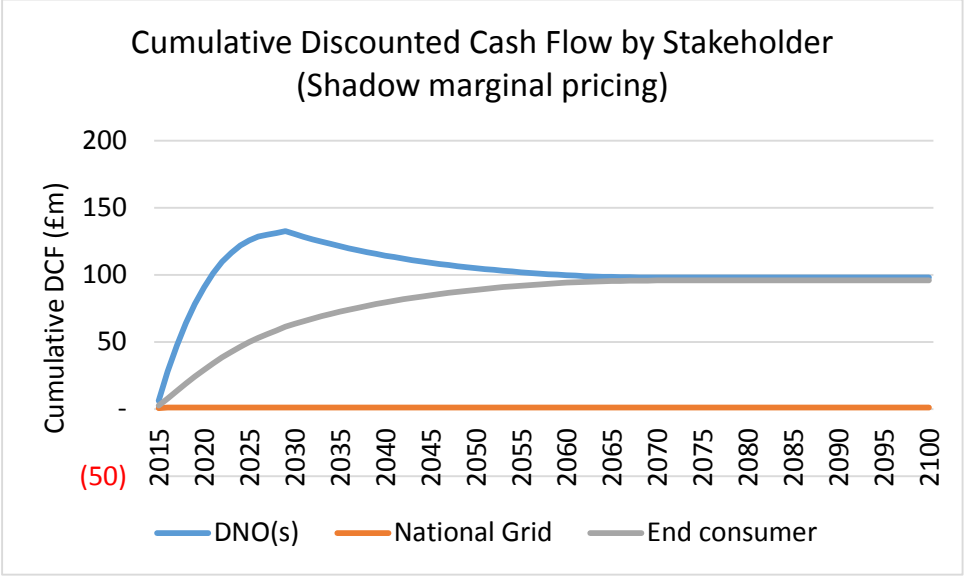
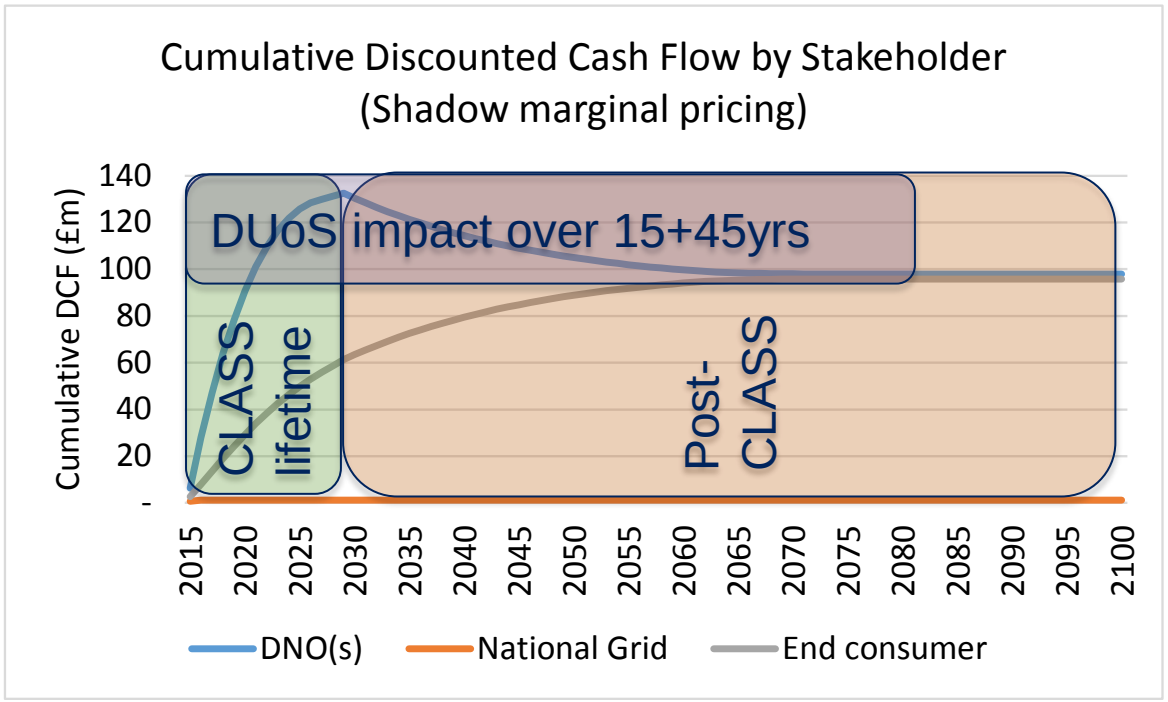




- Initial tranche only
- Cost Benefit Analysis expressed as Discounted Cash Flow
  - 3.5% discount rate
- Relative benefits depend on CLASS pricing strategy
  - Long Run Marginal Cost: DNO breaks even
  - Shadow marginal pricing has minimum BSUoS benefit but customers benefit through DUoS

Stakeholder	LRMC NPV	Marginal NPV
DNO(s)	£0.7m	£98.0m
NGET	£16.4m	£1.3m
Consumers	£178.0m	£95.8m
Total	**£195.1m**	**£195.1m**

NPV effect of Totex



- CLASS assumed to have 15yr lifetime
- DUoS impact continues long after initial tranche of capex
- Totex treatment means that all costs and revenues affect Regulated Asset Value (RAV)

CLASS CBA – projected deployment (unrestricted response provision)

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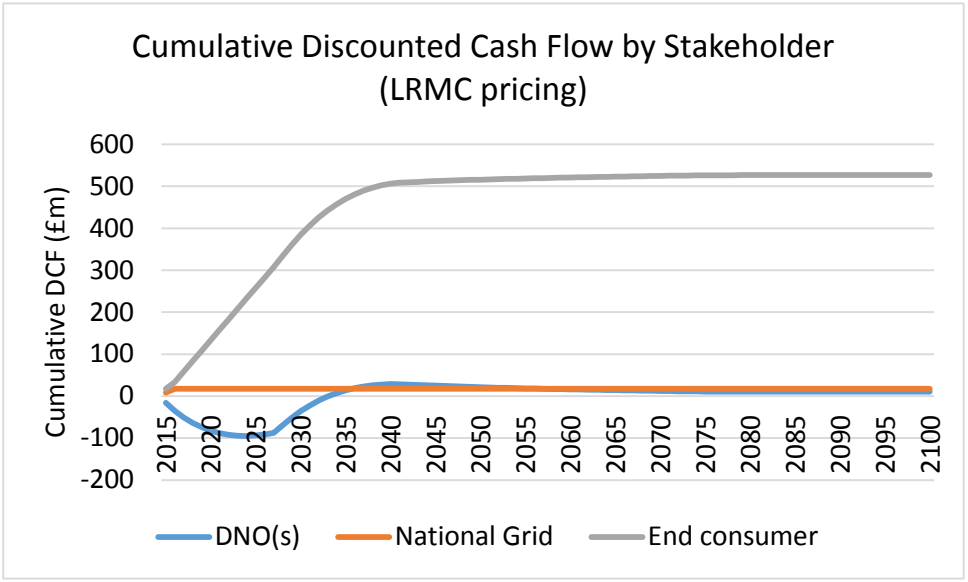
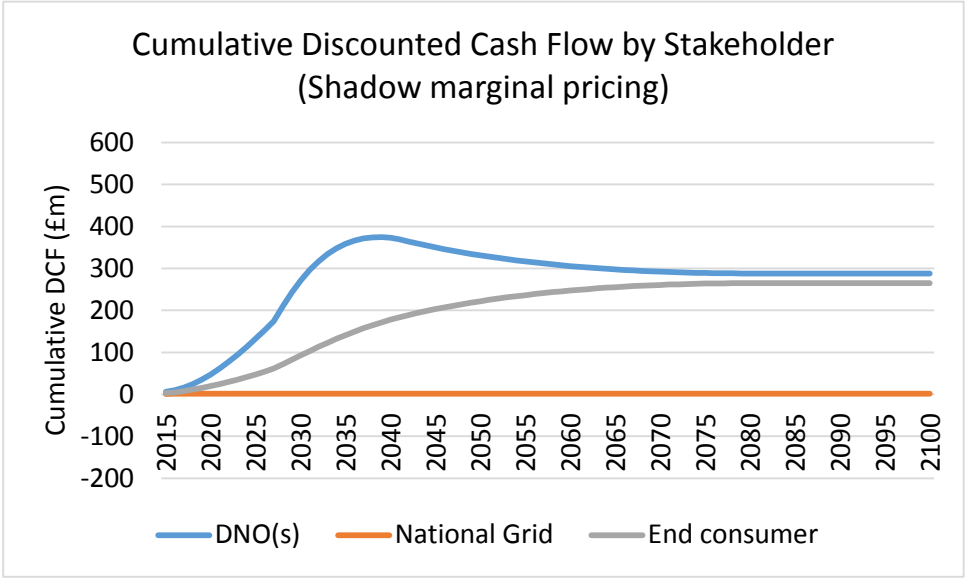
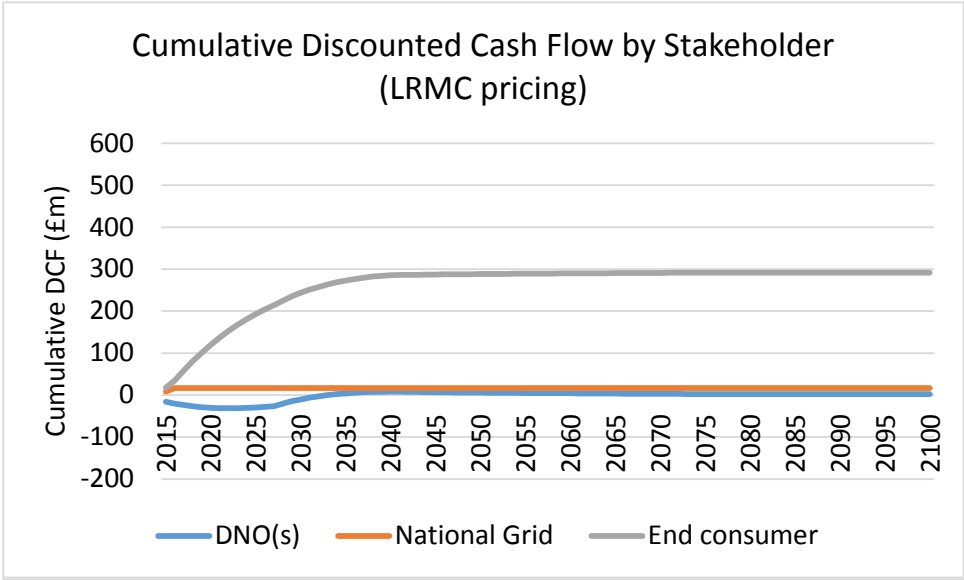


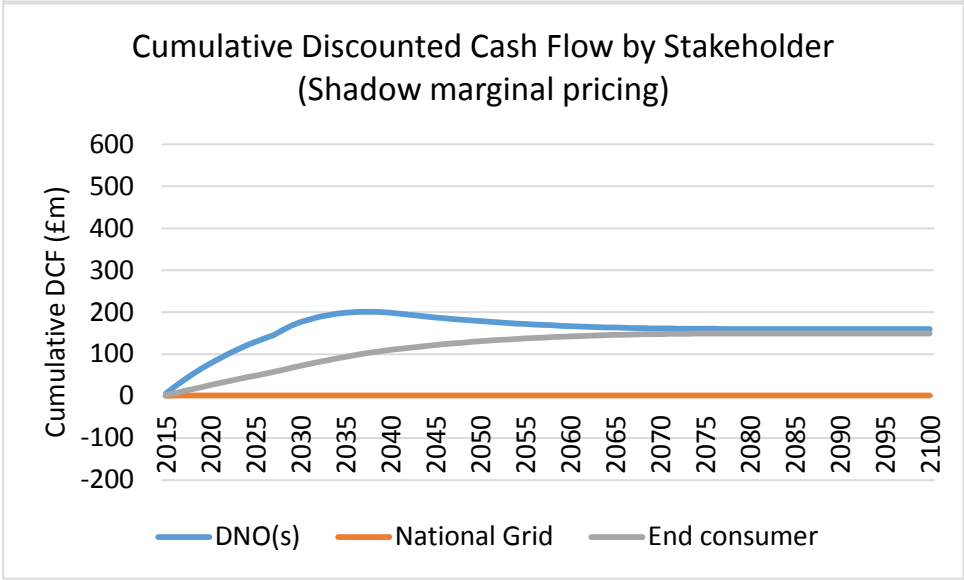


- CLASS deployment
  - 354 substations (180MW) 2014-15
  - 5,900 substations (3GW) 2027
  - Linear growth between
- DNOs incurring capex until 2027
- Totex capitalisation means net revenues are shared over 45 years
- DNOs under LRMC break even in long run but not until 2035

Stakeholder	LRMC NPV	Marginal NPV
DNO(s)	£10.3m	£287.8m
NGET	£17.2m	£1.3m
Consumers	£526.8m	£265.2m
Total	**£554.3m**	**£554.3m**

CLASS CBA – projected deployment (restricted response provision)





- If CLASS cannot provide dynamic and “high” response the potential market is severely restricted
- No value in deploying at more than 2,000 substations (1GW) (vs 5,900 projected) including initial 354

Stakeholder	LRMC NPV	Marginal NPV
DNO(s)	£2.3m	£160.0m
NGET	£16.6m	£1.3m
Consumers	£291.8m	£149.5m
Total	**£310.8m**	**£310.8m**

Quantitative conclusions

- There is significant scope for CLASS to reduce consumer costs
  - Most valuable if CLASS treated as capable of providing dynamic and high response
  - If not, deployment of CLASS will be constrained by 2027, reducing its potential to benefit consumers
- The DUoS sharing factor allows consumers to benefit under a range of pricing strategies
  - More consumer benefit if CLASS is priced at cost, manifesting as reduced BSUoS
  - Under shadow marginal price, all revenues, costs and risks shared between DNO and consumers
  - Note that CLASS deployment levels could vary as a function of pricing rules
- Future benefits and revenues from CLASS less certain
  - NPV horizon does not necessarily reflect DNO business decision-making
  - Competitive technologies expected to drive prices down
  - Growth in market requirement not enough to offset this

Non-quantified impacts

Qualitative impact assessment (1)

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Behaviour of displaced parties

- The direct effect of CLASS is for existing providers to lose a revenue stream
- To understand true cost, need to consider the spread that they were achieving
- Also, need to know what their resulting strategy is, e.g.
  - Retire the plant
  - Change CM bidding strategy (as missing money is higher)
  - Participate in alternative Balancing Services
  - Participate in the wholesale market

Qualitative impact assessment (2)

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Security of Supply (margin) impacts

- Direct effects
  - It is not planned to offer CLASS into the Capacity Market
  - It could be considered as reducing the CM requirement, since it can reduce maximum demand
  - However, some of CLASS capability already there under OC6 requirement
    - Intention is to ensure that CLASS is always additional to OC6 requirement
    - Likely that OC6 response could be enhanced by installing CLASS capability

- Effect of displacing balancing participants
  - By displacing existing participants, there may be an effect on SoS. This depends on participant behaviour:
    - Stay open, and move volumes to other Balancing Services or Wholesale markets, then the impact may be negligible
    - Stay open, but aim to recover missing money through other means (CM or new, bespoke Balancing Service contract) – negligible impact on SoS, but cost of maintaining SoS could increase
    - Exit market – SoS may decline

Qualitative impact assessment (3)

Other impacts

- Quality of service impacts (from voltage control actions)
  - Trials indicated that customers did not notice the action of CLASS
- Cash-out impact on suppliers
  - Impact on supplier balance likely to be small, but this is a real effect
  - However, not limited to CLASS, and is an issue for all DSR
- Network reinforcement cost impact
  - CLASS is not being targeted at Triad periods
  - No reason to think that it will have a systematic reduction on transmission reinforcement

Next steps and questions

Next steps

- Finalise Peer Review process
- Publication of tool and final report by end-May

Questions?

Tony McEntee

CLASS Implementation Manager

Next steps

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Next steps

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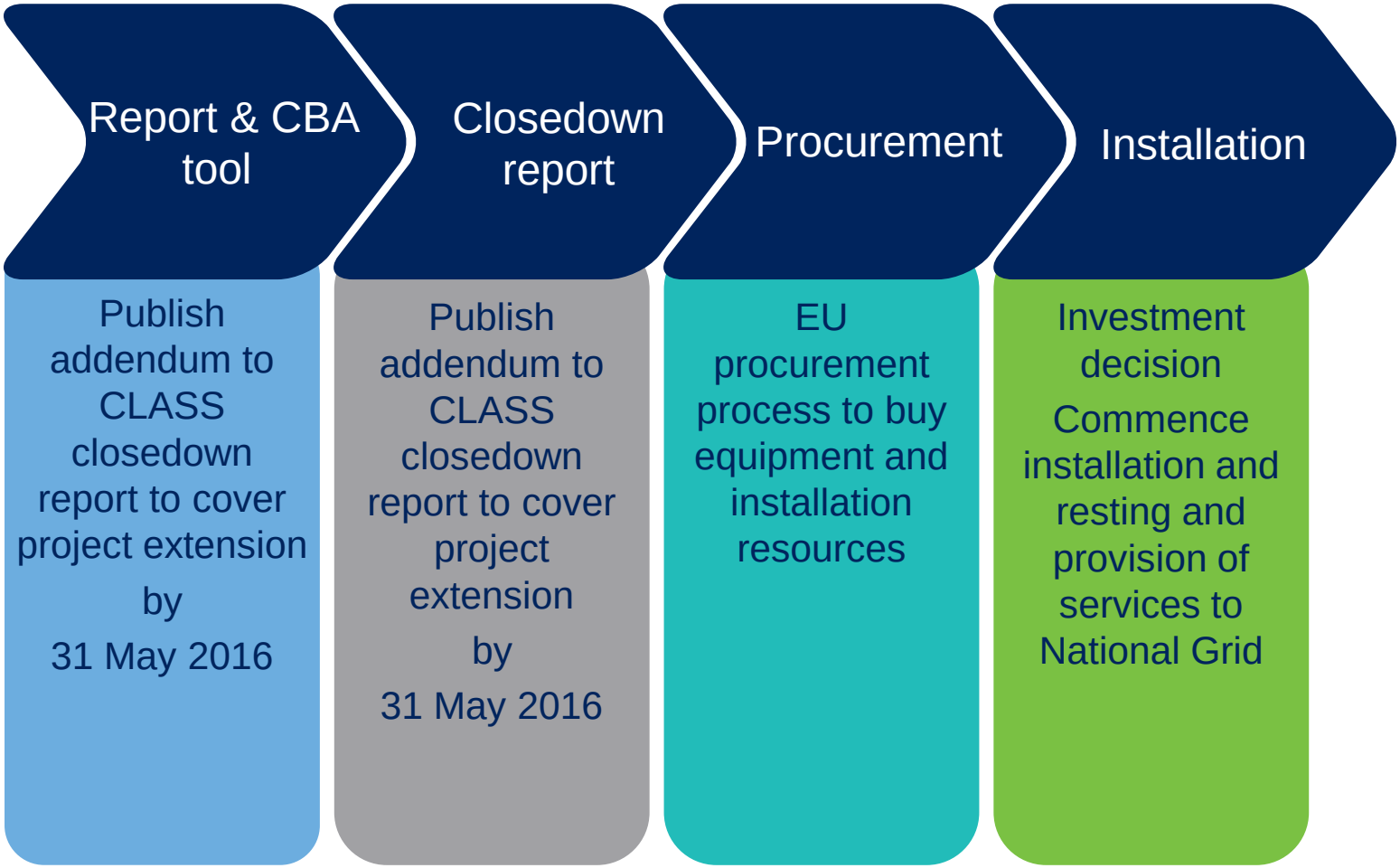

QUESTIONS & ANSWERS

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