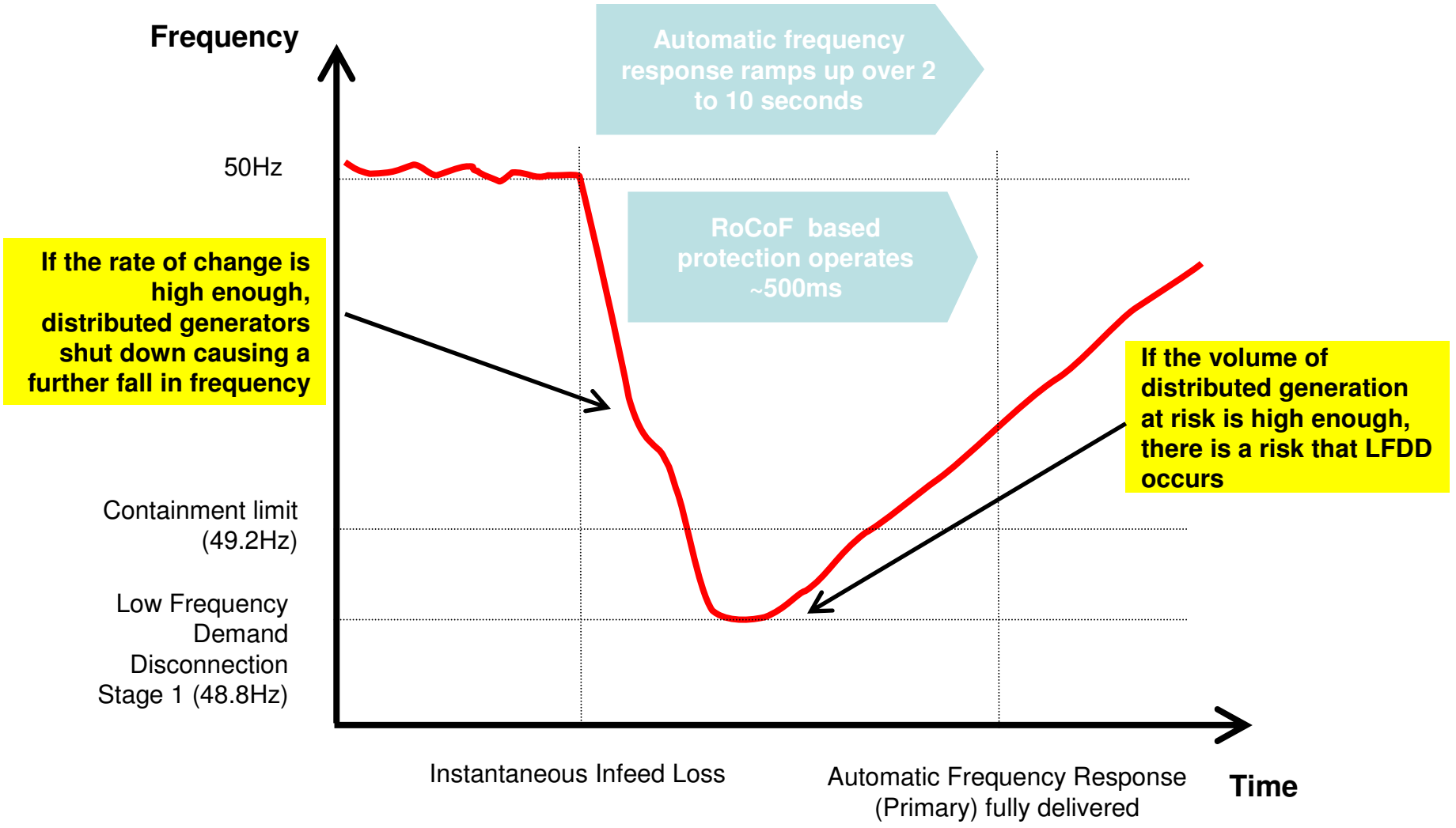
Frequency Changes Due to Large System Disturbances

Workgroup Report and Next Steps

Presentation Outline

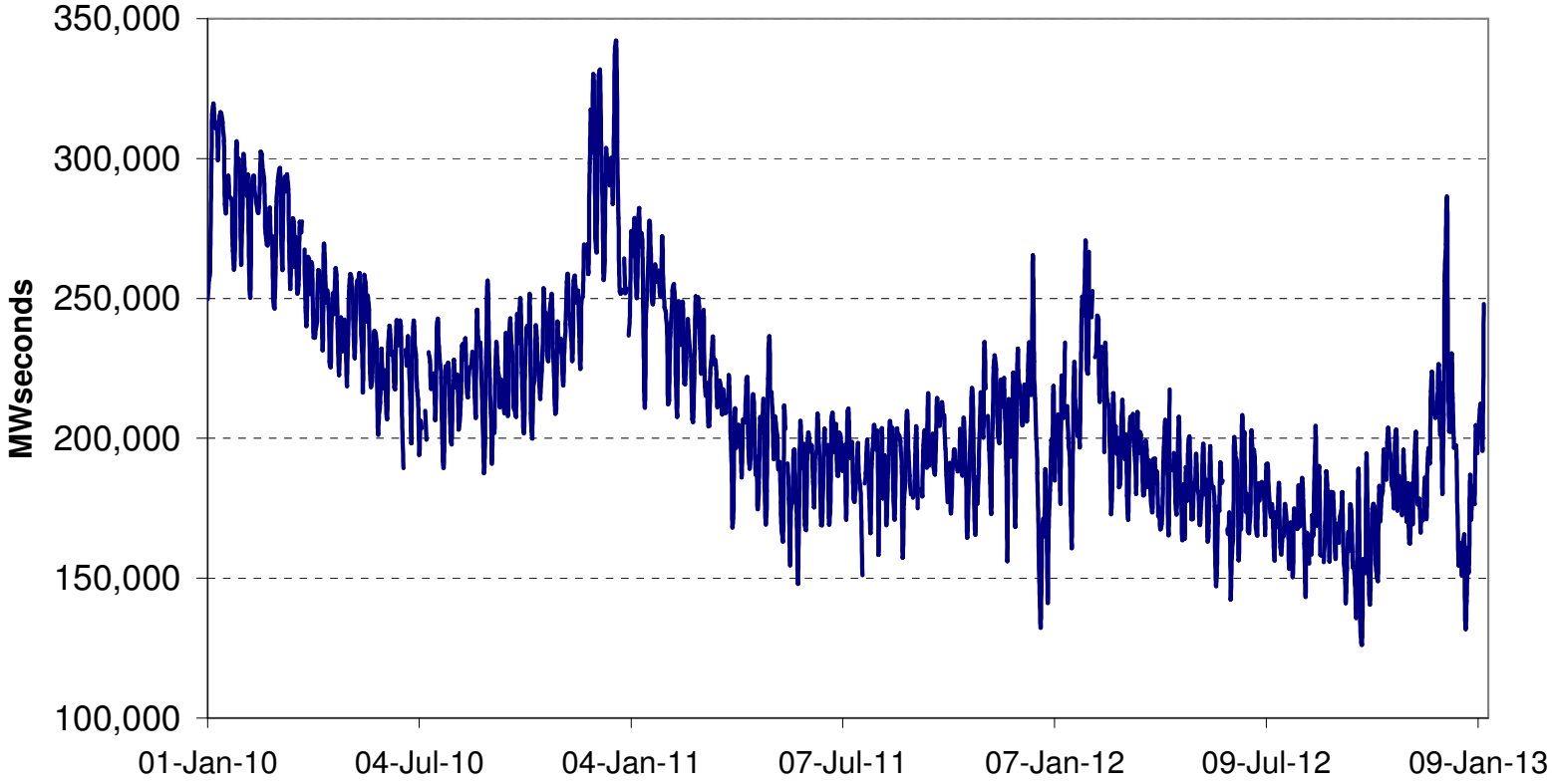
- Background
- Workgroup recommendations for a change to the Distribution Code
- Costs and Benefits
- Next Phase of Work

Background

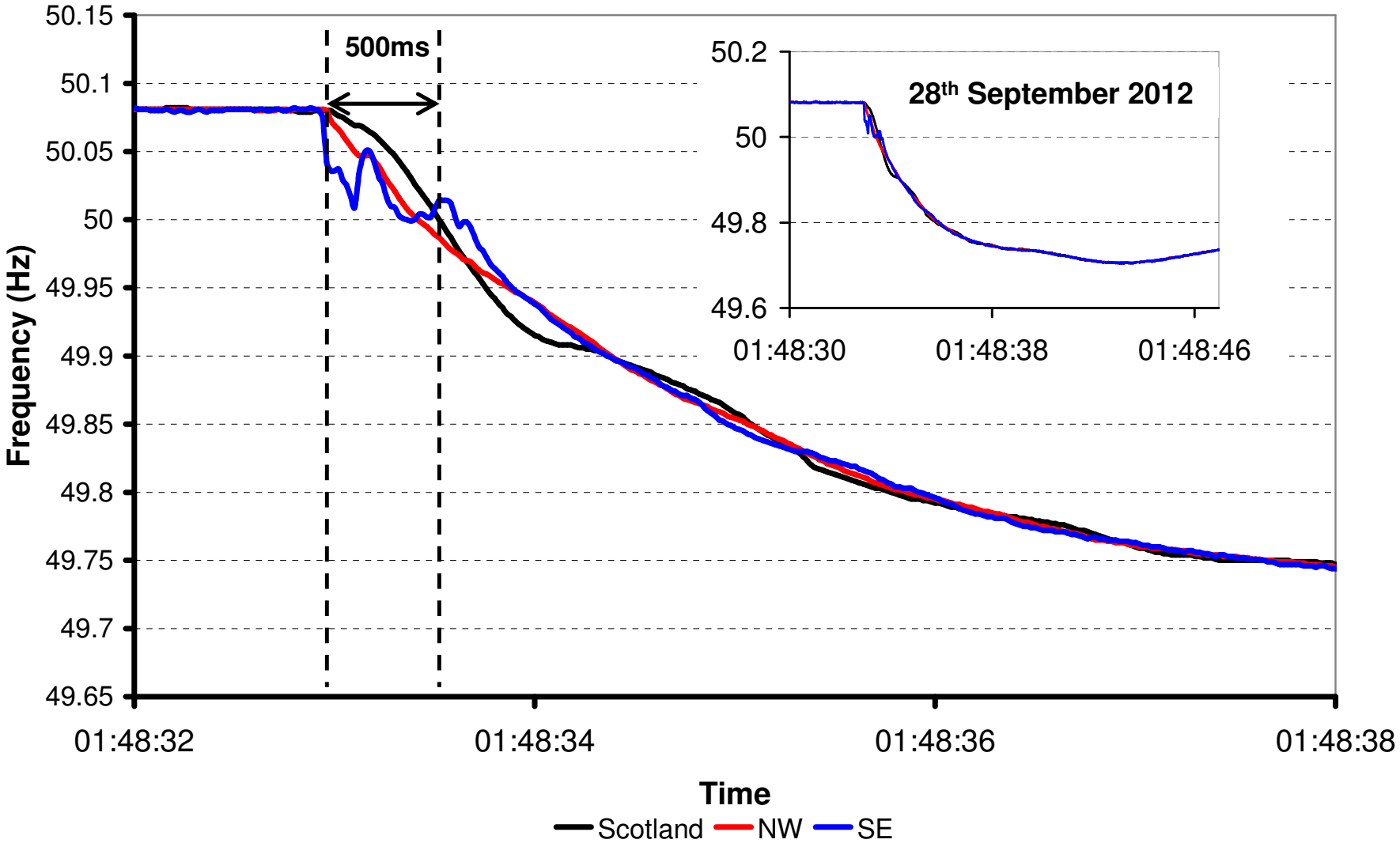

Frequency
Automatic frequency response ramps up over 2 to 10 seconds
50Hz
RoCoF based protection operates ~500ms
If the rate of change is high enough, distributed generators shut down causing a further fall in frequency
If the volume of distributed generation at risk is high enough, there is a risk that LFDD occurs
Containment limit (49.2Hz)
Low Frequency Demand Disconnection Stage 1 (48.8Hz)
Instantaneous Infeed Loss
Automatic Frequency Response (Primary) fully delivered
Time

System Requirement

Stored Energy in Transmission Contracted Synchronised Generation for the 1B Cardinal Point (overnight minimum demand period)



System Requirement



System Requirement

Predicted Average System RoCoF (Hz/s)

Year	Demand	1320 MW loss		1800 MW loss	
		100ms	500ms	100ms	500ms
2014	20 GW	-0.24	-0.24	-0.34	-0.33
	35 GW	-0.13	-0.13	-0.18	-0.17
2016	20 GW	-0.25	-0.24	-0.35	-0.34
	35 GW	-0.13	-0.13	-0.19	-0.18
2018	20 GW	-0.30	-0.29	-0.43	-0.42
	35 GW	-0.16	-0.16	-0.23	-0.22
2020	20 GW	-0.36	-0.35	-0.50	-0.49
	35 GW	-0.19	-0.19	-0.27	-0.26

Table 1: Predicted Average System RoCoF (High Wind Conditions)

Year	Demand	1320 MW loss		1800 MW loss	
		100ms	500ms	100ms	500ms
2014	20 GW	-0.26	-0.26	-0.36	-0.36
	35 GW	-0.14	-0.13	-0.19	-0.18
2016	20 GW	-0.27	-0.27	-0.38	-0.37
	35 GW	-0.14	-0.14	-0.20	-0.19
2018	20 GW	-0.33	-0.32	-0.47	-0.45
	35 GW	-0.17	-0.17	-0.24	-0.24
2020	20 GW	-0.42	-0.40	-0.57	-0.56
	35 GW	-0.21	-0.20	-0.29	-0.28

Table 2: Predicted Average System RoCoF (High Wind, High Imports)

Hazard Assessment

Protection Setting Options assessed:

Setting Option	RoCoF (Hzs^{-1})	Measurement Period	Deadband Applied
1	0.5	0	No
2	0.5	0.5	No
3	1	0	No
4	1	0.5	No
5	0.5	0	Yes
6	0.5	0.5	Yes
7	1	0	Yes
8	1	0.5	Yes
9	0.12	0	No
10	0.13	0	No
11	0.2	0	No

Results based on the current population of synchronous generators where RoCoF is used

Key results for Individual Risk from Network:

Setting Option	IR_E (P-V control mode)	IR_E (P-pf control mode)
2	$1.13x10^{-9}$	$1.43x10^{-13}$
4	$2.37x10^{-9}$	$1.57x10^{-12}$

Key results for Out of phase re-closure probabilities:

Setting Option	N_{OA} (P-V control mode)	N_{OA} (P-pf control mode)
2	$2.98x10^{-1}$	$4.56x10^{-4}$
4	$1.42x10^{-1}$	$8.26x10^{-5}$

Workgroup Recommendations

- The Workgroup recommends:
  - Proposals for a change to RoCoF settings on loss of mains protection for existing and new distributed generators within stations of registered capacity of 5MW and above to 1Hzs^{-1} measured over half a second (Option 4) are taken forward to consultation with views sought on
    - the findings of the group's probability and risk assessment relating to the risk to individuals and the risk to equipment
    - the acceptability of an increase in islanding risk in the context of existing network related risks
    - the assessment and mitigation measures that would be appropriate for synchronous generators to take to reduce the risk of out-of-synchronism re-closures that could otherwise present a hazard
    - The costs and benefits that the group have considered in determining the value of proceeding with a change
  - Completion of information gathering for distributed generation at stations of registered capacity of 5MW and larger
  - Implementation of protection setting changes within 18 months
  - Further, a site specific safety risk assessment in respect of distributed synchronous generators at stations of registered capacity of 5MW and larger prior to implementation of a protection setting change
  - To proceed with the further work required to develop proposals for all distributed generation of less than 5MW in capacity and to develop proposals for a RoCoF withstand capability

Costs of Implementing Proposals

- Making a protection setting change
  - Estimated at £10k or less per site
  - Total maximum cost is ~£1.5m assuming less than half the ~300 sites have used RoCoF for Loss of Mains purposes
- Out of phase re-closure risk for synchronous generators
  - Assessment costs of ~£25k per site
  - Assuming 50% of the 183 synchronous generators have used RoCoF for Loss of Mains, total cost is £2.3m
  - Mitigation costs where necessary of £100k per site add up to £3.8m assuming 20% of sites require action

Benefits of Implementing Proposals

- Implementation of the recommended protection settings change will
  - Significantly reduce the risk of involuntary demand control through operation of RoCoF protection
  - Take the first necessary step to eliminating Balancing Services expenditure on RoCoF Risk Management
    - Forecast up to 2016
      - Central forecast of £10m pa
      - Upper bound of £100m pa
- Full delivery of these benefits is dependent on completion of the next workgroup phase

Benefits of Implementing Proposals

- Further Information on Balancing Services Costs
  - National Grid's forecast costs for this year as of January were £11m
    - A forecast based on average summer and winter wind output and a range of interconnector position scenarios
  - Costs for the first 2 months of the year are £1m
    - These were the costs of reducing the maximum infeed loss by forward trading 12GWh of energy
  - Alternative action (synchronising additional units) would have been
    - 240GWh* of energy at a price of £150/MWh (£95/MWh bid + £55/MWh offer) which extrapolates to £100m per year
  - The central forecast for the year is that there will be a few occasions where energy trading alone does not or cannot meet requirements, meaning the higher cost alternative route of synchronising additional units
  - The full annual cost will include the costs of managing specific contingencies
    - Infeed risk arising as a result of planned work
    - These will average up to £5m pa

* For a RoCoF of 0.125Hzs-1, 100MW of infeed loss requires ~ 2,000MW of generation output (~3,500MW capacity) to contain it. ie there is a 1:20 relationship. For $1Hzs^{-1}$ this relationship is approximately 1:2½. The ratio reduces as the inertia per MW on synchronous generation increases.

Benefits of Implementing Proposals

- Further Information on Balancing Services Costs
  - Year to date costs have been suppressed by
    - Higher than average demands at the beginning of the year
    - Lack of coincidence of windy periods with low demands
    - A need to manage other issues (eg downward regulation and voltage)
  - National Grid's view of the biggest risk to costs at the moment is the ability to trade, either through a lack of available options for counter-parties or through new regulatory arrangements
  - For future years, the upward pressure on costs increases as new non synchronous technology connects to the networks
    - In the near future, larger instantaneous infeed losses will be the biggest single risk to costs (by which we mean anything above 800MW)
    - Central forecast and upper bound increase by a factor of 3 at least post 2017

Programme of further work

Research the characteristics (numbers/types etc) of embedded generation of less than 5MW registered capacity including likely RoCoF withstand capabilities;

Review DNO information and survey additional sources as necessary;

Investigating the characteristics of popular/likely inverter technology deployed, particularly in relation to RoCoF withstand capability and island stability;

Survey manufacturers and installers and survey additional sources as necessary;

Assess the requirement to test equipment to verify its characteristics;

Development of RoCoF withstand criteria for use in GB (as will be required by RfG 8.1(b));

Workgroup members to develop a view of generation technologies' inherent withstand capability;

Review the final proposals (post consultation) from the July 2013 recommendations in respect of protection settings and the Total System requirement;

Identify and asses any gaps in withstand capability;

Assess the costs, benefits and risks of setting withstand capability requirements for future generators;

Assess the costs, benefits and risks of setting withstand capability requirements for existing generators;

Programme of further work

Assessing or modelling the interaction of multiple generators in a DNO power island;

Review existing approaches to multi-machine dynamic simulation;

Develop new approaches if required;

Investigating and quantifying the risks to DNO networks and Users of desensitising RoCoF based protection on embedded generators of rated capacity of less than 5MW;

Assess the costs, benefits and risks of requirements to de-sensitise RoCOF settings for future generators of registered capacity of less than 5MW;

Analyse the merit of retrospective application of RoCoF criteria to existing embedded generation of less than 5MW (including comparison with similar programmes in Europe);

Review international experience of large retrospective change programmes;

Assess the costs, benefits and risks of requirements to de-sensitise RoCoF settings for existing generators of registered capacity of less than 5MW;

Consideration of issues relating to the continuing use of Vector Shift techniques;

Review the likely exposure of distributed generation to vector shifts in excess of recommended settings during system disturbances.

Next Steps

- The Panel is asked to
  - Note the workgroup's recommendations for a change to the Distribution Code
  - Provide comments and feedback on the workgroup's recommendations for inclusion in the consultation process
  - Invite the workgroup to complete its programme of further work