Hitachi-GE Nuclear Energy, Ltd.
UK ABWR GENERIC DESIGN ASSESSMENT
Resolution Plan for RO-ABWR-0073
(Robust demonstration that the design of the UK ABWR off-gas system reduces risks SFAIRP)

RO TITLE:	Robust demonstration that the design of the UK ABWR off-gas system reduces risks SFAIRP	
REVISION :	1	
Overall RO Closure Date (Planned):		28th April 2017
REFERENCE DOCUMENTATION RELATED TO REGULATORY OBSERVATION		
Regulatory Queries	RQ-ABWR-0083 (Trim Ref. 2014/118093); RQ-ABWR-0781 (Trim Ref. 2016/88145); RQ-ABWR-0782 (Trim Ref. 2016/88165); RQ-ABWR-0783 (Trim Ref. 2016/88184); RQ-ABWR-0784 (Trim Ref. 2016/88221); RQ-ABWR-0785 (Trim Ref. 2016/88247); RQ-ABWR-0786 (Trim Ref. 2016/88273); RQ-ABWR-0787 (Trim Ref. 2016/88303).	
Linked ROs	RO-ABWR-0016 RO-ABWR-0017 (Trim Ref. 2014/253119); RO-ABWR-0036 (Trim Ref. 2015/18292); RO-ABWR-0037 RO-ABWR-0044 (Trim Ref. 2015/59719); RO-ABWR-0054 RO-ABWR-0064 (Trim Ref. 2015/390811).	
Other Documentation	See Related Deliverables in 'Description of Work and References'	

Scope of work :

Background

RO-ABWR-0073 has been raised by the ONR with regard to providing a robust demonstration that the design of the UK ABWR off-gas system reduces risks So Far As is Reasonably Practicable (SFAIRP). This includes looking at specific aspects of the system and its design as it has evolved from early BWRs, considering how risks from these can be controlled SFAIRP, as well as considering the overall balance of risks. Aspects of the Off-Gas System are covered in a range of linked Regulatory Queries (RQs) and Regulatory Observations (ROs). These linked RQs and ROs will be considered in the response to this RO.

This Resolution Plan describes Hitachi-GE's current plan to address the RO. It contains the information to show how the RO will be resolved; this includes the planned activities, deliverables, milestones and timescales. This resolution plan is multidisciplinary as it relates to a number of technical areas, as outlined in the regulators RO.

Scope

The need for a robust ALARP demonstration is identified by this RO. As a result, the ALARP analysis must consider several aspects to justify the UK ABWR OG design. Additionally, the Off-Gas System must be consistent with all radiological, safety, conventional and environmental legislation including As Low As Reasonably Practicable (ALARP) and Best Available Techniques (BAT).

According to the general design approach [Ref-1][Ref-2][Ref-3], potential risks associated with the reference design will be identified. Hitachi-GE will implement a gap analysis to eliminate, reduce or mitigate these risks as far as is reasonably practicable whilst ensuring appropriate use of Best Available Techniques. The gap analysis will be based on options derived from RGP and worldwide OPEX and will be performed by, Hitachi-GE and UK Subject Matter Experts (SMEs).

This resolution plan shows the actions and milestones to show that the UK ABWR off- gas system has been designed to safely control and mitigate a number of hazards during normal operations (including start-up, operational and shutdown modes) and potential fault conditions, taking a precautionary approach where there are uncertainties and pursuing improvements unless the sacrifice in making improvements is grossly disproportionate to their safety benefit.

This RO heavily interacts with a number of other ROs, which are in the process of being answered by Hitachi-GE. Therefore this resolution plan is centred on an update and development of the previous Off-Gas ALARP Topic Report [Ref-4], recognising the potential interaction with other documents and work-streams (see Gantt chart attached for timescales).

Revision 1 of this document describes Hitachi-GE's updated plan to address RO-ABWR-0073 following feedback from the ONR during November 2016. Any additional developments to the approach being taken will be shared with the ONR as appropriate. In the updated plan, Hitachi-GE includes following works to enhance the ALARP demonstration for the design of the OG system;

- Further justification on safety categorisation and classification of the system. Particular attention will be given to the approach to hydrogen management, especially for the Recombiner and its supporting components.
- Further gap analysis/optioneering on the design of the charcoal delay beds, with particular consideration being given to a guard bed and the arrangement (series vs. parallel) of the beds.
- Further demonstration that the OG charcoal delay bad capacity is adequate and ALARP.

These aspects of the work are not new technical areas, but will provide more detailed demonstration of ALARP. Therefore the section entitled "description of work" is not changed. The related additional actions are described in the detailed Gantt Chart [Ref-7] to show the approach for the RO closure. As part of this revised approach, Hitachi-GE has updated the Resolution Plan to reflect an extension to the submission date of the revised OG ALARP report [Ref-4].

Description of work:

As described above, the RO is linked to several other ROs and RQs. It highlights the requirement for some high level responses, such as hazard identification and risk assessment for the Off-Gas System, as well as in the areas of moisture ingress, radioactivity build up, hydrogen management, effects of temperature and the design of the beds. There are strong interactions between Actions A1, A2 and A3. As a result the list of activities to resolve the RO has been included in the response to A1 while recognising that they also respond to actions A2 and A3. For transparency, after discussion under A1, short sections follow giving key activities addressing the other actions.

The current UK ABWR design is based on an operational ABWR design. There are many variants of BWRs / Off-Gas systems worldwide. There are also other potential sources of RGP. The RO asks for clarification around hazard identification and risk control measures associated with the RGP design for the UK ABWR to address these points, and show robust control of safety and environmental aspects, several strands of information and activities are required. They are addressed through a number of tasks; their role in addressing this RO is shown schematically in Figure 1 below. Descriptions of tasks are below the diagram; as noted, these are listed under Action 1.

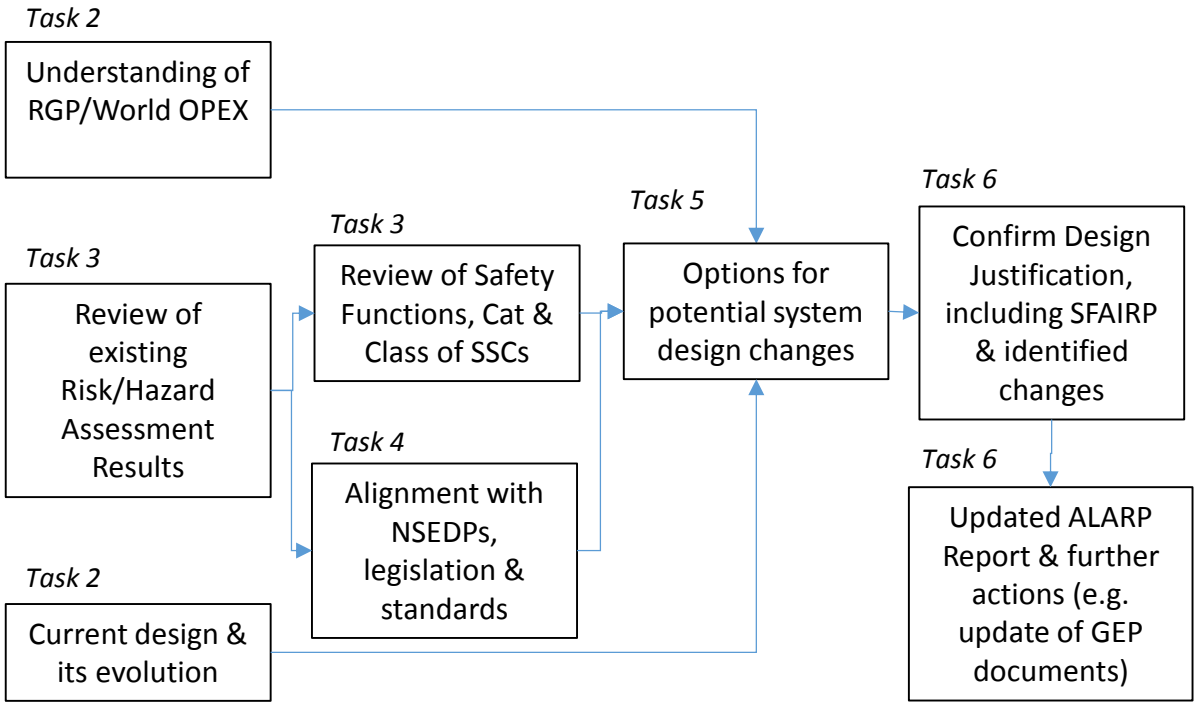


Figure 1 Schematic of workflows of the RO Response

ACTION 1: Hitachi-GE to provide a robust demonstration to show that the design of the UK ABWR off-gas system reduces relevant risks SFAIRP, taking due account of actions under this and related ROs.

Hitachi-GE's scope:

Hitachi-GE will update and develop the "Topic Report on ALARP Assessment for Off-Gas System [Ref-4]" (hereinafter referred to as "ALARP report") according to following approach:

Task 1. Development of the "route-map" for ALARP demonstration

The previous ALARP report focused on specific technical areas as opposed to providing a holistic system overview; it is now recognised that there is a need to present an overview of the ALARP case for the OG system as a whole. Therefore, Hitachi-GE will develop a "route-map" for the ALARP demonstration to show the holistic design approach for the OG. This route-map will follow the engineering design approach which relates to mechanical engineering, RO-ABWR-0016 and chemical/process engineering, RO-ABWR-0054, and Hitachi-GE will develop the Table of contents (ToC) structure of the updated ALARP report according to this route-map. Therefore the updated report will follow the UK ABWR general design approach, including consideration of Hitachi-GE's Nuclear Safety and Environmental Design Principles (NSEDPs) and thus it will also satisfy the corresponding regulatory requirements (e.g. in respect of SAPs and use of BAT), complying with the following processes:

- Safety Case Development Manual [Ref-1]
- GDA ALARP Methodology [Ref-2]
- General Design Process Approach for Mechanical Engineering SSCs [Ref-3]

Task 2. Understanding of RGP and worldwide OPEX

Good practice and OPEX relevant to the off-gas system will be reviewed by Hitachi-GE and assessed against the design features of the UK ABWR that support safety and environmental performance in normal operations, and that prevent or mitigate potential fault conditions. This review will seek additional worldwide sources of good practice and OPEX to those already used in order to ensure that the UK ABWR has incorporated any improvements and learning from past operational practices. A review of the Light Water reactors around the world will be completed, as these reactors have comparable off gas streams which require abatement. A review of other reactors with similar gas stream compositions will also be included. Available information from these alternate systems will be summarised to allow a comparison of designs and approaches used for gas systems on other reactors e.g. hydrogen management systems, use of delay bed in parallel or series, use of guard beds.

The totality of the good practice and worldwide OPEXs will be used to identify any gaps against the current off-gas baseline design or highlight areas where further consideration may be required e.g. based on past incidents in BWR off-gas systems identified through review of OPEX. This will form the answer to RO-ABWR-0073.A2

Task 3. Review of existing risk/hazard assessment results

Risk identification is a first step of the design approach. Possible risks on the OG have been identified by the FMEA [Ref-5] relating to RO-ABWR-0036, and the hazard and operability study (HAZOP) relating to RO-ABWR-0017 and RO-ABWR-0054. Since the issue of the latest version of the ALARP report, a number of actions identified during the HAZOP have been progressed as more information has become available to fully respond to actions from the HAZOP and the previous version of the ALARP report. This will be incorporated into completion of this task along with the work that has been completed with respect to

- Human error as an initiating factor and human reliability is referred in the Basis of Safety Cases on OG [Ref-6].
- Non-reactor fault scenarios as covered in "Topic Report on Fault Assessment [Ref-5]".

It is recognised that hydrogen management is a key issue, and this topic will be addressed in the response to the RO (noting links to work carried out in other Tasks, notably Tasks 2 and 5). Similarly, moisture ingress into beds is recognised as an area which will need to be considered.

Hitachi-GE will invite an independent desktop review all of the previous FMEA and HAZOP documentation, utilising the enhanced good practice and OPEX gathered as part of Task 2. The review will be carried out by a third-party team of experts, with a lead safety case specialist drawing on the rest of the team for support as appropriate, including specialists in process engineering, chemistry, hydrogen management, dose assessment and ALARP. This will further be assured by staff with recent direct experience of UK nuclear safety regulation. The review will be used in the development of the ALARP arguments and to demonstrate the connection between identified risks and Safety Function Claims (SFCs) more clearly, revising the SFCs, their category and the classification of associated structures, systems and components as appropriate, which includes consideration of how the hazards and risks have been evaluated. As the design process has progressed, more information has become available (as well as the options which were still being evaluated under the ALARP report optioneering); this information will be taken into account.

The task will cover the following specific actions identified in this RO:

- Identify and describe what the risks are that are being eliminated, or mitigated, including likelihood and consequences [A1.(1)]
- Describe how the potential for human error, against normal and fault conditions in all operational modes, to give rise to a leakage or escape, has been minimised, SFAIRP [A3.(4)]
- Consider all 'non-reactor' fault scenarios which may give rise to a leakage or escape. This should include adequate consideration of both acute and chronic scenarios [A3.(5)]

Task 4. Alignment with relevant UK legal requirements

As a key part of good engineering design the UK ABWR aligns with the appropriate legislative, regulatory and guidance requirements. Compliance with legal limits and cognisance of the ONR SAPs (and other guidance) is an important input to derive functional requirements. Therefore Hitachi-GE will confirm that the OG aligns with these requirements, with the principle route being through consideration of the NSEDPs, which have been derived to be consistent with relevant guidance and requirements. Relevant legal limits, consistency with the SAPs (and other relevant guidance) will be identified and will be utilised when conducting a gap analysis between the reference off-gas design and the enhanced good practice and OPEX. Whilst noting the importance of numerical targets (including legal limits), there are deterministic requirements and a broader need to satisfy ALARP, and responding to these aspects will form the main thrust of the response.

Task 5. Gap analysis of baseline Off-Gas system design against Relevant Good Practice

Tasks 2-4 will be used as an input into a gap analysis of the baseline Off-gas design against relevant good practice (including relevant standards as guidance, as per Task 4). As noted, in addition to identifying potential differences from RGP, which will need to be considered, the review of RGP and OPEX will be used to identify areas where incidents and issues have arisen in existing BWRs, and provide a focus for further consideration of options. Key areas identified are:

- Charcoal bed design (guard bed, arrangement of charcoal bed, operating temperature and holdup time within charcoal bed, etc.);
- Containment function including leak detection and monitoring;
- Hydrogen management.

Task 6. Revised ALARP demonstration

Having established through the above tasks any gaps between relevant good practice and the current baseline off-gas design Hitachi-GE will then consider what more can be done to reduce risks further whilst ensuring that any additional modifications are not grossly disproportionate to the safety benefit. The emphasis will be on identifying potential further options, and considering their merits taking account of hierarchies of measures (e.g. ERICPD, waste hierarchy) and other safety and environmental requirements, rather than on quantitative and cost-benefit approaches against departures from the current design, although such methods will be adopted where it is believed they add value e.g. contentious or particularly challenging decisions. This activity will be used to demonstrate the design of the UK ABWR off-gas system reduces risks SFAIRP.

Hitachi-GE will develop further design justification using the approach and this will be captured in the updated ALARP report.

This task will cover following specific actions required in this RO:

- What measures are in place to eliminate, reduce or mitigate these risks, including the adoption of relevant good practice measures [A1.(2)]
- Identify what options, or range of options, could be applied to further mitigate these risks [A1.(3)]
- A demonstration of whether these options are reasonably practicable to implement or not, supported by robust arguments and suitable and sufficient evidence [A1.(4)]
- Consideration of any residual detriment and a demonstration the overall design of the off-gas system reduces relevant risks SFAIRP [A1.(5)]
- Identify and describe the measures in place to eliminate, or prevent, leakage or escape from the off-gas system containment boundaries [A3.(1)]
- Identify and describe any systems designed to detect, locate, quantify and monitor any leakage or escape that may occur from the off-gas system containment boundaries [A3.(2)]

ACTION 2: Hitachi-GE to provide an evaluation of the off-gas system design for UK ABWR against RGP and the hazards defined under Action 1, to identify whether any reasonably practicable improvements can be made to reduce risks SFAIRP

Hitachi-GE's scope:

As noted in the RO, this work is an important input under Action 1, and has been covered by Tasks 1-6 for Action 1, with Tasks 2 and 5 as the most directly relevant. Hitachi-GE will include more information about good practice and OPEX in the updated ALARP report, and support justification of, or reasonably practicable improvements to, the current design.

ACTION 3: Hitachi-GE to provide a robust demonstration to show the design of the UK ABWR off-gas system provides adequate containment of radioactive materials and radioactive wastes, SFAIRP.

Hitachi-GE's scope:

Hitachi-GE will update the ALARP report including the justification of the containment function and reduction of radioactive wastes. This work is also an important input under Action 1, and has been covered in tasks 1-6 for Action 1; Task 3 will provide an important role in addressing this Action.

ACTION 4: Hitachi-GE are required to appropriately describe and document, in all relevant UK ABWR Generic Environmental Permitting (GEP) documentation, any further reasonably practicable measures, that should be implemented for the off-gas system.

Hitachi-GE's scope:

Hitachi-GE recognises the importance of presenting a complete view of the OG in matters relating to impact and risk on and off-site. Noting this aim and to show that, overall, the system is optimised, Hitachi-GE will fully include consideration of discharges and environmental factors under Action 1 as appropriate, including appropriate liaison with other areas. Any consequential changes from this work will be included in GEP documentation as necessary.

Deliverables for all Actions:

1) Final Resolution Plan:
2) Topic Report on ALARP Assessment of Off-Gas System:

Summary of impact on GDA submissions:

The GDA submissions that will be affected by the actions to resolve this RO are summarised below. These documents will be originated and/or revised in accordance with the corresponding actions as necessary.

GDA Submission Document		Planned Submission Date to ONR
Topic Report on ALARP Assessment for Off-Gas System	GA91-9201-0001-00125 (GE-GD-0035)	31st January 2017

This RO is an overarching RO and includes inputs and outputs from other ROs as well as a range of RQs. Hitachi-GE will provide a separate reference document which will allow the ONR to track changes as a result of this RO (and related RQs) into the various GDA submissions.

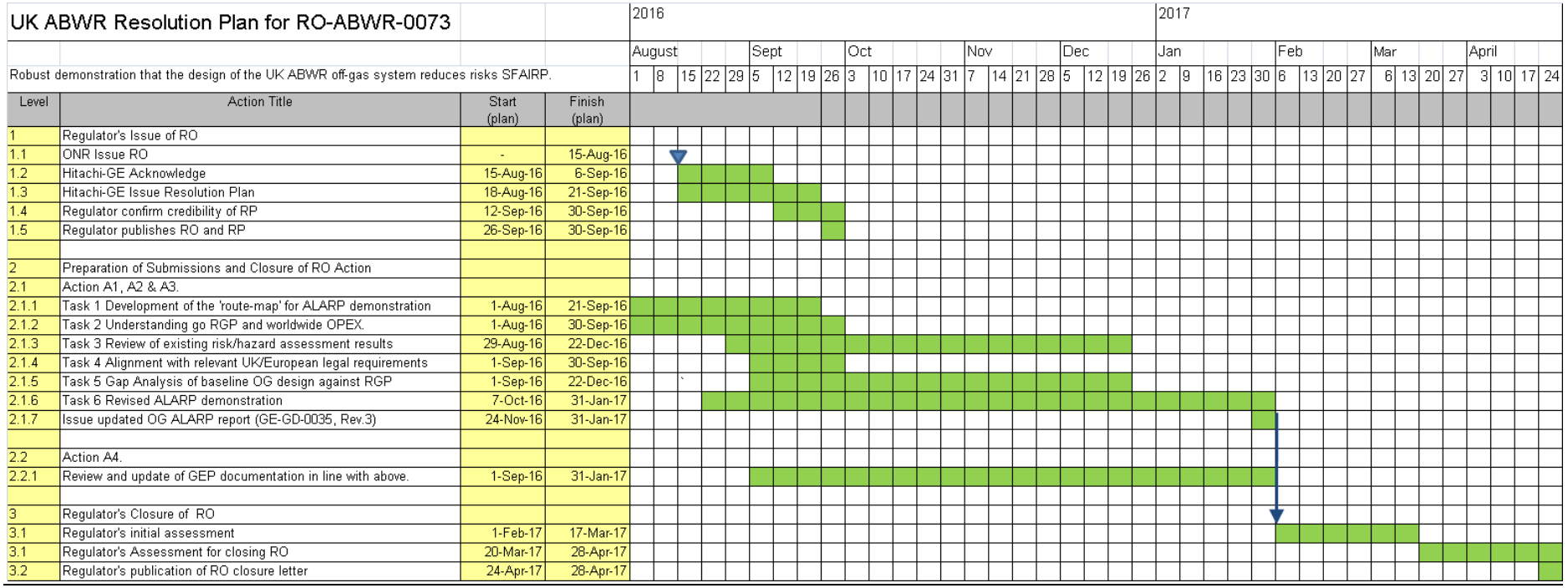
Programme Milestones/ Schedule:

Refer to the attached Gantt-chart for the programmed activities and the schedule for the resolution of the RO. Detail Gantt-Chart is shown in [Ref-7].

Reference:

Ref.	Document Title	Document ID	Rev.
1	GDA Safety Case Development Manual	GA10-0511-0006-00001 (XD-GD-0036)	1
2	GDA ALARP Methodology	GA10-0511-0004-00001 (XE-GD-0037)	1
3	General Design Process Approach for Mechanical Engineering SSCs	GA91-9201-0003-00854 (SE-GD-0297)	0
4	Topic Report on ALARP Assessment for Off-Gas System	GA91-9201-0001-00125 (GE-GD-0035)	2
5	Topic report on Fault Assessment	GA91-9201-0001-00022 (UE-GD-0071)	4
6	Off-Gas System Basis of Safety Case	GA91-9201-0002-00054 (GE-GD-0009)	3
7	Detailed Gantt Chart for UK ABWR Resolution Plan (Corresponding to RO-ABWR-0073)	GA91-9201-0005-00073 (GE-GD-0054)	0

Table 1 RO-ABWR-0073 Gantt Chart



Level	Action Title	Start (plan)	Finish (plan)
1	Regulator's Issue of RO		
1.1	ONR Issue RO	-	15-Aug-16
1.2	Hitachi-GE Acknowledge	15-Aug-16	6-Sep-16
1.3	Hitachi-GE Issue Resolution Plan	18-Aug-16	21-Sep-16
1.4	Regulator confirm credibility of RP	12-Sep-16	30-Sep-16
1.5	Regulator publishes RO and RP	26-Sep-16	30-Sep-16
2	Preparation of Submissions and Closure of RO Action		
2.1	Action A1, A2 & A3.		
2.1.1	Task 1 Development of the 'route-map' for ALARP demonstration	1-Aug-16	21-Sep-16
2.1.2	Task 2 Understanding go RGP and worldwide OPEX.	1-Aug-16	30-Sep-16
2.1.3	Task 3 Review of existing risk/hazard assessment results	29-Aug-16	22-Dec-16
2.1.4	Task 4 Alignment with relevant UK/European legal requirements	1-Sep-16	30-Sep-16
2.1.5	Task 5 Gap Analysis of baseline OG design against RGP	1-Sep-16	22-Dec-16
2.1.6	Task 6 Revised ALARP demonstration	7-Oct-16	31-Jan-17
2.1.7	Issue updated OG ALARP report (GE-GD-0035, Rev.3)	24-Nov-16	31-Jan-17
2.2	Action A4.		
2.2.1	Review and update of GEP documentation in line with above.	1-Sep-16	31-Jan-17
3	Regulator's Closure of RO		
3.1	Regulator's initial assessment	1-Feb-17	17-Mar-17
3.1	Regulator's Assessment for closing RO	20-Mar-17	28-Apr-17
3.2	Regulator's publication of RO closure letter	24-Apr-17	28-Apr-17