

Hitachi-GE Nuclear Energy, Ltd.
UK ABWR GENERIC DESIGN ASSESSMENT
Resolution Plan for RO-ABWR-0006
Source Terms

RO TITLE:	Source Terms
REVISION :	<u>4</u>
Overall RO Closure Date (Planned):	30 th <u>March 2017</u>
REFERENCE DOCUMENTATION RELATED TO REGULATORY OBSERVATION	
Regulatory Queries	RQ-ABWR-0002
Linked ROs/RIs	RO-ABWR-0019, RO-ABWR-0022, RO-ABWR-0034, RO-ABWR-0035, RI-ABWR-0001
Other Documentation	GA91-9201-0003-00050

Scope of work :
<p>Hitachi-GE understands that this Regulatory Observation (RO) is associated with the definition of and evidence that will be necessary to justify the “Source Terms” for the UK ABWR design during “operational states” and “expected events”. “Operational States” includes “Normal Operations” and “Anticipated Operational Occurrences”. For a nuclear power plant, this includes start-up, power operation, shutdown, maintenance, testing, and refuelling. Also those events that are expected to occur over the lifetime of the plant, such as minor pin-hole leaks in fuel, are included within the scope of Normal Operations as an “Expected Events”.</p> <p>The responses to this RO will demonstrate that the source terms for UK ABWR during operational states have been reduced So Far As Is Reasonably Practicable (SFAIRP) and that Best Available Techniques (BAT) have been applied. These responses include the development, definition and justification of the source terms used.</p> <p>For the purpose of these RO responses, the “Source Term” is defined as:</p> <p style="padding-left: 40px;">“The types, quantities, and physical and chemical forms of the radionuclides present in a nuclear facility that have the potential to give rise to exposure to radiation, radioactive waste or discharges.”</p> <p>Once defined, the Source Terms are used as the basis of assessments to support the management and control of the reactor chemistry, radiation protection, radioactive waste management and decommissioning strategy development and fault studies areas. The objectives of this work are:</p> <p>(a) To ensure that the design is optimized such that the source terms are reduced SFAIRP. (b) To demonstrate that consequential hazards such as radiation doses, generation of radioactive waste and discharges are also reduced SFAIRP and apply BAT respectively. (c) To demonstrate that the design ensures that numerical targets and legal limits, including restrictions on doses, are met.</p> <p>Based on these objectives, Hitachi-GE defined the scope of work to be covered by the resolution plan [1] and provided the topic reports on definition and justification of source Terms [2, 3] in January 2015. However, these reports did not meet regulatory expectations and RI-ABWR-0001 was issued in June 2015, the main purpose of which is for Hitachi-GE to provide a suitable and sufficient definition justification for the radioactive source terms for UK ABWR during normal operations. The resolution plan for RI-ABWR-0001 [4] was agreed with regulators and published.</p>

In recognition of the RI for ST, a revised resolution plan for RO-ABWR-0006 has been developed to deliver the remaining responses for RO-ABWR-0006. The revised Resolution Plan for RO-ABWR-0006 defines what is covered in response to RO-ABWR-0006 and RI-ABWR-0001, as shown in Table 1.

In the plant design stage, Hitachi-GE will demonstrate that radioactivity in the UK ABWR design has been reduced SFAIRP based upon material selection, operational chemistry, and expected operational practices. The source terms of reactor water systems, miscellaneous sludge waste and laundry drain will also be defined and justified in documents related to RI-ABWR-0001. Fuel and activated structures will be discussed in other supporting documents.

The Source Terms of refuelling, turbine maintenance and decontamination of piping and equipment will also be defined and justified in documents related to RI-ABWR-0001. Design Basis Accident (DBA) source terms and Severe Accident (SA) Source Terms will be discussed in other topic reports. The source terms of the Interim Spent Fuel Storage (ISFS) will also be discussed in other documents. For the decommissioning phase of the project the Source Term of deposits on piping and equipment will be defined and justified in documents related to RI-ABWR-0001, however information on activated structures will be discussed in other supporting documentation.

Table 1 Scope of work

Stage	Status	Category	Source Terms	Documents			
Plant Design	-	Source Terms Reduction SFAIRP	Material Selection	Reports in response to RO-ABWR-0006: see below			
			Operating Chemistry				
			Operational Practices				
Operation	<ul style="list-style-type: none"> - System Start-up - Power Operation - Normal Hot Stand-by - System Shutdown - Fuel Pin Failure 	Fuel	Fuel Spent Fuel Direct Radiation from Reactor Core	Further information will be provided in the UK ABWR PCSR support documents			
		Reactor Water Systems including piping and equipment	[Primary Source Terms] - Reactor Water - Reactor Steam	Defined in the resolution plan for RI-ABWR-0001			
			[Downstream Source Terms] - Mobile Source Terms (Radionuclides which move with water or steam) - Fixed Source Terms (Radionuclides which deposit on piping or equipment) e.g.				
			Reactor Water Clean-up System (CUW) Fuel Pool Cooling Clean-up System (FPC) Main Steam System (MS) Off Gas System (OG) Extraction Steam System (ES) Feed Water System (FDW) Circulating Water System (CW) Reactor Core Isolation Cooling System (RCIC) Suppression Pool Clean-up System (SPCU) Residual Heat Removal System (RHR) Radwaste Systems				
		Others	Activated Structure e.g. RPV Internals Concrete		Further information will be provided in the UK ABWR PCSR support documents		
			Miscellaneous Sludge Waste		Defined in the resolution plan for RI-ABWR-0001		
			Laundry Drain				
		Outage	Refuelling		-	Spent Fuel Pool	Defined in the resolution plan for RI-ABWR-0001
			Maintenance			Turbine Maintenance	
			Decontamination			Piping and Equipment	

Accident	Design Basis Accident	-	DBA Source Terms	Further information will be provided in the UK ABWR PCSR support documents
	Severe Accident		SA Source Terms	Further information will be provided in the UK ABWR PCSR support documents
Interim Spent Fuel Storage (IFSF)	Storage	-	Spent Fuel	Further information will be provided in the UK ABWR PCSR support documents Do we have a SFIS End user ST?
Decommissioning	Decontamination & Waste Management	-	Deposits on Piping and Equipment	Defined in the resolution plan for RI-ABWR-0001
			Decontamination of Piping and Equipment	
			Secondary Wastes during dormant period after operations and before decommissioning	
			Activated Structure	Further information will be provided in the UK ABWR PCSR support documents

This Resolution Plan describes Hitachi-GE's current plan to address the RO however as the work develops there may be a need to select alternative means to address the RO, through agreement with the regulators.

Description of work:

ACTION RO-ABWR-0006.1 – *Hitachi-GE are required to define the source term(s) for the UK ABWR design during operational states.*

This action was closed due to becoming part of RI-ABWR-0001.

Hitachi-GE provided a series of documents related to this action as a response to RI-ABWR-0001 by 31 Dec. 2015.

ACTION RO-ABWR-0006.2 – *Hitachi-GE are required to demonstrate the adequacy of the source term(s) used across the different technical areas.*

This action was closed due to becoming part of RI-ABWR-0001.

Hitachi-GE provided a series of documents related to this action as a response to RI-ABWR-0001 by 31 Dec. 2015.

ACTION RO-ABWR-0006.3 – *Hitachi-GE are required to demonstrate that the source term(s) have been used appropriately across the different technical areas.*

Hitachi-GE will describe how the source term is used to meet the requirements of the different technical areas, including:

- The management arrangements in place to control the source term information, at the time it was derived and should it need to be updated.
- Details of any assumptions which could significantly affect the source term.
- The assessments within the safety and environmental submissions where the source term is used, and how it is used.
- How the source term has been used consistently across the assessment areas.
- How the source term has been modified for use in each specific assessment area, particularly any additional assumptions.
- How changes to the source term are managed and cascaded to the different assessment areas

In response to Action 6.3,6.7 and 6.8, Hitachi-GE provided a Topic Report "Management of Source Term" which will show that the source term have been used appropriately across the different technical area by 30 Sep.2015.

ACTION RO-ABWR-0006.4 – *Hitachi-GE are required to demonstrate that radioactivity in the UK ABWR design has been reduced SFAIRP during operational states, based upon the material choices.*

The reduction of radioactivity within the UK ABWR is important to reduce potential doses to workers and can be affected by a number of parameters, such as material choices and operating chemistry. Other factors will also have a bearing on the final decision on material selection such as material degradation, manufacturability and structural integrity and will be considered as part of the demonstration of ALARP. The ALARP justification for material selection for particular SSCs is demonstrated in the Material Selection Report as a response to RO-ABWR-0035. The response to RO-ABWR-0035 will therefore addresses certain aspects of RO-ABWR-0006.4.

In summary, Hitachi-GE will address this ROA as follows;

- Key components for the reduction of radioactivity are identified in a new Topic Report on Reduction of Source Terms by Material Selection.
- The ALARP justification of material selection for particular SSCs is demonstrated in Material Selection Report (as a response to RO-ABWR-0035) in consideration of manufacturability, material degradations, radioactivity, etc. The reduction of radioactivity due to material selection and control or reduction of the trace element content in materials selected are also described in the Material Selection Report. A summary of the Material Selection Report related to Source Term is described in the new Topic Report on Reduction of Source Terms by Material Selection.

The new Topic Report on Reduction of Source Terms by Material Selection will include.

- Historical evolution of material change to reduce radioactivity for BWRs and ABWRs;
- Optimization of manufacturing process and treatment to minimize the generation of corrosion product and/or mitigate the accumulation of radioactive deposits with evidence.

The Topic Report on Reduction of Source Terms by Material Selection will be updated as required according to the outcome of the ALARP justification of material selection in Material Selection Report as this will continue to be developed throughout GDA as a living document..

The Topic Report on Reduction of Source Terms by Material Selection submitted by 31 May 2016.

Material Selection Report Revision 1 was submitted at the end of April 2015. Revisions 2, 3, 4 and 5 will be submitted at the end of December 2015, the end of March 2016, the end of July 2016 and the end of December 2016, respectively. The reduction in use of materials (including easily activated elements such as Co) is described in the Topic Report on Reduction of Source Terms by Material Selection with supporting evidence. For particular components, an ALARP justification of material selection is provided in the Material Selection Report.

As stated above, the Topic Report on Reduction of Source Terms by Material Selection will be updated as required.

ACTION RO-ABWR-0006.5 – *Hitachi-GE are required to demonstrate that radioactivity in the UK ABWR design has been reduced SFAIRP during operational states, based upon the operating chemistry.*

Hitachi-GE understands the importance of operating chemistry to reducing Source Term. Operating chemistry (including that used during commissioning and hot functional testing) effects corrosion behaviour of materials, corrosion products release from and deposition on structural material surfaces and chemical form of some kinds of elements.

Hitachi-GE will demonstrate that the adopted operating chemistry corresponds to relevant good practice and that Source Term reduction has been achieved SFAIRP. This will be through the following studies and evaluations based on the operating chemistry in this ROA under the determined material choices and expected operational practices for UK ABWR.

- Historical evolution of Source Term reduction by changing operating chemistry used in BWRs and ABWRs
- Identification of key element and parameter for Source Term reduction
- Quantification of water chemistry control effect on Source Term
- Applicability of existing countermeasures to reduce Source Term such as zinc injection and optimum iron concentration control in FW
- Gathering new water chemistry control information applicable to Source Term reduction
- Research and development of new water chemistry control applicable to Source Term reduction
- Making a judgement as to whether additional measures are reasonably practicable as the basis of this decision.
- Evaluation of the impact water quality control has on the integrity of nuclear fuel.

Each study or evaluation will consider the effect of water chemistry control on benefit, disadvantage, cost and so on with comparison to previously operating BWRs and ABWRs. The water chemistry selected for UK ABWR will be demonstrated to reduce radioactivity SFAIRP in the report on reduction of Source Terms.

Hitachi-GE provided a Topic Report “Reduction of Source Terms by Operating Chemistry” which will also describe the radioactivity reduction by the operating chemistry by 31 May 2016.

ACTION RO-ABWR-0006.6 – *Hitachi-GE are required to demonstrate that radioactivity in the UK ABWR design has been reduced SFAIRP during operational states, based upon the expected operational practices.*

Hitachi-GE understands that operational practices are also important to reduce the Source Term.

Hitachi-GE will demonstrate operational practices adopt relevant good practice and that Source Term reduction has been achieved SFAIRP. This will be through the following studies and evaluations based on the expected operational practices in this ROA under the determined material choices and operating chemistry for UK ABWR.

- Historical operational practices to reduce Source Term reduction used in BWRs and ABWRs
- Identification of key practices for Source Term reduction
- Quantification of operational practices effect on Source Term
- Applicability of existing operational practices to reduce Source Term such as low temperature shutdown cooling system in-service
- Gathering new operational practices information applicable to Source Term reduction
- Research and development of new expected operational practices applicable to Source Term reduction
- Making a judgement as to whether additional measures are reasonably practicable as the basis of this decision.

Each study or evaluation will consider the effect of operational practices on benefit, disadvantage, cost and so on with comparison to previously operating BWRs and ABWRs. The expected operational practices for UK ABWR will be demonstrated to reduce radioactivity SFAIRP in the report on reduction of Source Terms.

Hitachi-GE will provide a Topic Report “Reduction of Source Terms by Operating Practices” which will also describe the radioactivity reduction through expected operational practices by 29 April 2016.

ACTION RO-ABWR-0006.7 – *Hitachi-GE are required to demonstrate that the response(s) to this RO will be adequately captured within the safety and environmental cases for UK ABWR design.*

In response to Action 7, Hitachi-GE will provide a related document list which the source term will be adequately captured within safety and environment cases. These documents list will be added to a Topic Report “Management of Source Term” by 30 June 2016.

ACTION RO-ABWR-0006.8 – *Hitachi-GE are required to include any accident source terms derived from the Action 1 responses as part of their response to Actions 3 and 7.*

Hitachi-GE will capture any accident source terms derived from the RI-ABWR-0001 responses as part of our response to Actions 3 and 7. This was described into a Topic Report “Management of Source Term” by 30 June 2015.

ACTION RO-ABWR-0006.9 – Hitachi-GE are required to provide a description of the expected behavior of radioactivity within UK ABWR.

Hitachi-GE has provided 3 Topic Reports on Source Term Reduction and relevant supporting documents (topic reports) in order to resolve ROA.4 to ROA.6. These reports state the measures taken to reduce Source Terms ALARP, however, Hitachi-GE understand that the linkage of these measures to the safety case is not clear. Therefore Hitachi-GE will provide a Topic Report “TR on Radioactivity Behaviour in UK ABWR” to make it clear. This Topic Report will:

Describe the overall description of radioactivity (radioactivity behaviour of CP, AP and FP) in the UK ABWR,

Describe the fundamental principles of radioactivity control, considering oxide form on the fuel and oxide layer form on the components and piping,

Describe the important factors in controlling radioactivity based on OPEX and semi-quantify their effects with model calculation, and

Link to the relevant evidence (in other submissions), the safety claims and specific conditions.

Hitachi-GE will provide the TR on Radioactivity Behaviour in UK ABWR by 27 Dec 2016.

Summary of impact on GDA submissions:

The following planned submissions are considered those most likely to be impacted by the Source Term work:

GDA Submission Documents	C/U	Related GDA RO Action(s)	Submission Date to ONR/EA
PCSR Ch18: Radioactive Waste Management * 18.1 : Source Terms (GA91-9101-0101-18001) 18.2 : Liquid Radioactive Waste Management System (GA91-9101-0101-18002) 18.3 : Off-Gas Radioactive Waste Management System (GA91-9101-0101-18003) 18.4 : Solid Radioactive Waste Management System (GA91-9101-0101-18004)	U	A1, A7	<u>Mar.</u> 2017
PCSR Ch20: Radiation Protection * 20.1 : Introduction (GA91-9101-0101-20001) 20.2 : Definition of Radioactive Sources (GA91-9101-	U	A1, A7	<u>Mar.</u> 2017

0101-20002)			
20.3 : Strategy to Ensure that the Exposure is ALARP (GA91-9101-0101-20003)			
20.4 : Protection and Provisions against Direct Radiation (GA91-9101-0101-20004)			
20.5 : Protection and Provisions against Radioactive Contamination (TBD)			
20.6 : Radiation and Contamination Monitoring of Occupational Exposure (GA91-9101-0101-20006)			
20.7 : Dose Assessment for Public from Direct Radiation (GA91-9101-0101-20007)			
20.8 : Post Accident Accessibility (GA91-9101-0101- 20008)			
PCSR Ch24: Design Basis Analysis * (GA91-9101-0101- 24000)	U	A1, A7, A8	<u>Mar.</u> 2017
PCSR Ch25: Probabilistic Safety Assessment * (GA91- 9101-0101-25000)	U	A1	<u>Mar.</u> 2017
PCSR Ch31: Decommissioning * (GA91-9101-0101- 31000)	U	A1, A7	<u>Mar.</u> 2017
GEP E4: Radioactive Waste Management Arrangements * (GA91-9901-0022-00001)	U	A1, A7	Feb. 2016
GEP E5: Demonstration of BAT * (GA91-9901-0023- 00001)	U	A1, A7	Feb. 2016
GEP E7: Quantification of Discharges and Limits * (GA91- 9901-0025-00001)	U	A1, A7	Feb. 2016
GEP E8: Prospective Dose Modelling * (GA91-9901-0026- 00001)	U	A1, A7	Feb. 2016
Impact Assessment Report (<u>GA91-9201-0003-00820</u>)	<u>U</u>	A3, A7	<u>Jul.</u> 2015
Source Term Strategy Report (GA91-9201-0003-00864)	<u>U</u>	A1, A2	<u>Sep.</u> 2015
Primary Source Term Methodology Report (GA91-9201- 0003-00863)	<u>U</u>	A1, A2	<u>Jul.</u> 2016
Process Source Term Methodology Report (GA91-9201- 0003-00946)	<u>U</u>	A1, A2	<u>Jul.</u> 2016
Deposit Source Term Methodology Report (<u>GA91-9201- 0003-00960</u>)	<u>U</u>	A1, A2	<u>Jul.</u> 2016
End User Source Term Methodology Report (<u>GA91-9201- 0003-00976</u>)	<u>U</u>	A1, A2	<u>Jul.</u> 2016
Source Term Manual General Report (GA91-9201-0003- 00942)	<u>U</u>	A1, A2, A3	<u>Nov.</u> 2015
Calculation of Primary Source Term Value (GA91-9201- 0003-00928)	<u>U</u>	A1	<u>Jun.</u> 2016
Calculation of Process Source Term Value (GA91-9201- 0003-00944)	<u>U</u>	A1	<u>Jun.</u> 2016
Calculation of Deposit Source Term Value (<u>GA91-9201- 0003-00961</u>)	<u>U</u>	A1	<u>Jun.</u> 2016
<u>Calculation of Radioactive Waste End User Source Term Value (GA91-9201-0003-01083)</u>	<u>U</u>	<u>A1</u>	<u>Jul.</u> 2016
<u>End User Source Term Value for Decommissioning (Contamination Source Term) (GA91-9201-0003-01093)</u>	<u>U</u>	<u>A1</u>	<u>Jun.</u> 2016
<u>End User Source Term Value for Radiation Protection</u>	<u>U</u>	<u>A1</u>	<u>Sep.</u> 2016
Primary Source Term Supporting Report (GA91-9201- 0003-00929)	<u>U</u>	A1, A2	<u>Jul.</u> 2016
Process Source Term Supporting Report (GA91-9201- 0003-00945)	<u>U</u>	A1, A2	<u>Jul.</u> 2016
Deposit Source Term Supporting Report (<u>GA91-9201- 0003-00959</u>)	<u>U</u>	A1, A2	<u>Jul.</u> 2016
Management of Source Term (GA91-9210-0003-00931)	<u>U</u>	A3, A7, A8	<u>Aug.</u> 2016

Reduction of Source Terms by Material Selection (<u>GA91-9201-0001-00202</u>)	<u>U</u>	A4	<u>Dec. 2016</u>
Reduction of Source Terms by Operational chemistry (<u>GA91-9201-0001-00166</u>)	<u>U</u>	A5	<u>Dec. 2016</u>
Reduction of Source Terms by Operational practices (<u>GA91-9201-0001-00165</u>)	<u>U</u>	A6	<u>Dec. 2016</u>
Material Selection Report (GA11-1001-0002-00001)	<u>U</u>	A4	<u>Dec. 2016</u>
<u>Topic Report on Material Degradation Mechanisms - Flow-Accelerated Corrosion and Erosion-Corrosion (GA91-9201-0001-00212)</u>	<u>U</u>	<u>A4</u>	<u>Nov. 2016</u>
<u>Radioactivity Behaviour in UK ABWR (TBD)</u>	<u>C</u>	<u>A9</u>	<u>Dec. 2016</u>
<u>Fe concentration control in feedwater (GA91-9201-0001-00156)</u>	<u>U</u>	<u>A9</u>	<u>Apr. 2016</u>
ALARP Assessment on the Water Chemistry Regime (<u>GA91-9201-0001-00163</u>)	<u>U</u>	A5	<u>Nov. 2016</u>

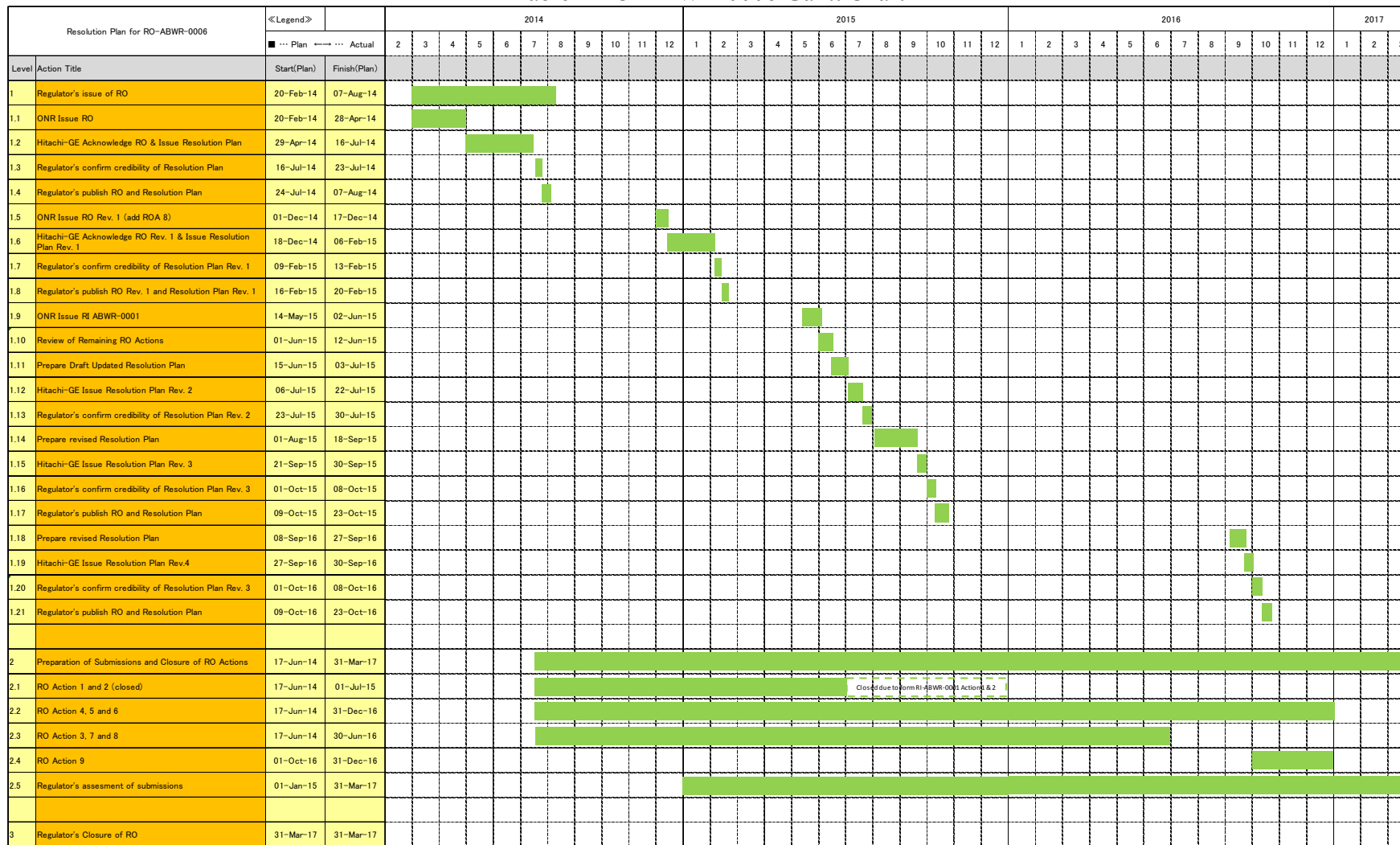
Programme Milestones/ Schedule:

See attached Gantt Chart (Table 2)

Reference:

- [1] Resolution Plan for RO-ABWR-0006: Source Terms, GA91-9201-0004-00012, WPE-GD-0059, Revision 0, 10 July 2014
- [2] Topic Report 1: Definition of the UK ABWR Design Source Term, GA91-9201-0001-00107, HE-GD-5088, Revision 0, 15 January 2015
- [3] Topic Report 2: Demonstration and Justification of the Source Term for the UK ABWR, GA91-9201-0001-00108, HE-GD-5089, Revision 0, 15 January 2015
- [4] Resolution Plan for RI-ABWR-0001: Definition and Justification for Radioactive Source Terms in UK ABWR during Normal Operations, GA91-9201-0004-10001, WPE-GD-0167, Revision 1, 18 June 2015

Table 2 RO-ABWR-0006 Gantt Chart



Glossary

Glossary follows definition of this RO.

AP – *Activation Product*

BAT – *Best Available Techniques*

BWR – *Boiling Water Reactor*

CP – *Corrosion Product*

CRUD – *Chalk River Unidentified Deposit*

Expected event – *events that are expected to occur over the lifetime of the plant. This does not include events that are inconsistent with the use of BAT such as accidents, inadequate maintenance and inadequate operation.*

FP – *Fission Product*

GEP – *Generic Environmental Permit*

Operational States – *Including “normal operations” and “anticipated operational occurrences”. For a nuclear power plant, this includes start-up, power operation, shutting down, shutdown, maintenance, testing and refuelling.*

ORE – *Operational Radiation Exposure*

PCSR – *Pre-construction Safety Report*

RO – *Regulatory Observation*

ROA – *Regulatory Observation Action*

RPV – *Reactor Pressure Vessel*

Severe accident - *As defined in the SAPs. A fault sequence which leads either to consequences exceeding the highest radiological doses given in the BSLs of Target 4, or to a substantial unintended relocation of radioactive material within the facility which places a demand on the integrity of the remaining physical barriers*

SFAIRP – *So Far as is Reasonably Practicable*

Source term – *The types, quantities, and physical and chemical forms of the radionuclides present in a nuclear facility that have the potential to give rise to exposure to radiation, radioactive waste or discharges*

UK ABWR – *UK Advanced Boiling Water Reactor*