

**Hitachi-GE Nuclear Energy, Ltd.**  
**UK ABWR GENERIC DESIGN ASSESSMENT**  
**Resolution Plan for RI-ABWR-0001**  
**Definition and Justification for the Radioactive Source Terms**  
**in UK ABWR during Normal Operations**

<b>RI TITLE:</b>	Definition and Justification for the Radioactive Source Terms in UK ABWR during Normal Operations	
<b>REVISION :</b>	3	
<b>Overall RI Closure Date (Planned):</b>	30 <sup>th</sup> June 2016	
<b>REFERENCE DOCUMENTATION RELATED TO REGULATORY ISSUE</b>		
<b>Regulatory Queries</b>	-	
<b>Regulatory Observations</b>	RO-ABWR-0006	
<b>Linked RIs</b>	-	
<b>Other Documentation</b>	ONR letter dated 6 <sup>th</sup> March 2015 [REG-HGNE-077R]	

**1. Scope of work for this resolution plan:**

This Resolution Plan provides Hitachi-GE's response to RI-ABWR-0001: Definition and Justification for the Radioactive Source Terms in UK ABWR during Normal Operations.

The Japanese ABWR Reference Plant upon which the UK ABWR is based has been designed, constructed and operated in accordance with some of the highest safety and environmental standards. Worker dose and environmental discharges are amongst the lowest of any operational plant in the world. The plant is the culmination of some 50 years of continuous design-evolution in boiling water technology; and has a strong track record in safety and environmental protection, since the first plant began operation in 1996.

Hitachi-GE acknowledge that the 'calculation based approach' adopted in our responses to RO-ABWR-0006 Actions 1 and 2 and the use of two major Topic Reports submitted in January 2015 has not met UK Regulatory expectations. However, the design process used in the development of the Japanese Reference Plant is rigorous, and Hitachi-GE fully understands the level of hazard for which the plant must be designed.

We are therefore confident that whilst we may have interpreted differently what is required to define and justify the Source Term within the UK regulatory environment, our proposed ABWR generic design is safe and will meet appropriate UK environmental and safety standards.

In view of the challenges we have faced meeting the Regulator's expectations Hitachi-GE has proposed a staged delivery plan and a series of meetings to allow the regulators the opportunity to sample the work and provide feedback and advice to ensure alignment with regulatory expectations at appropriate points.

Hitachi-GE has reviewed the Regulatory Issue (RI-ABWR-0001) and the associated Regulatory Observation (RO-ABWR-0006) and has formulated an approach, scope and programme of work in response to this Regulatory Issue (RI) which it considers will enable the Regulators to close RI Actions 1

and 2.

RI-ABWR-0001.A1 – Hitachi-GE are required to provide a suitable and sufficient definition for the radioactive source terms for UK ABWR during normal operations.

Hitachi-GE will produce a suite of documents that describe the strategy, the methodology and define and justify the Radioactive Source Term(s) for the generic design of the UK ABWR in line with Regulatory expectations and relevant good practice. Hitachi-GE has developed a document structure which enables the Source Term to be defined and justified in accordance with the methodology, presented in a suitable format for end-users and referenced to appropriate supporting information. In particular our approach will :-

- Link our work to the end-use of the Source Term and the safety and environmental cases.
- Provide an appropriate balance between calculation and Operational Experience (OPEX) approach.
- Identify and justify assumptions and test these through suitable sensitivity studies.
- Ensure the documentation used to present the Source Term is user friendly and Source Term values are appropriate for their end-use.
- Ensure Source Terms are appropriately incorporated into the generic safety and environmental cases for the UK ABWR.

RI-ABWR-0001.A2 – Hitachi-GE are required to provide a suitable and sufficient justification for the radioactive source terms for UK ABWR during normal operations.

The Source Term(s) defined under RI-ABWR-0001.A1 will be justified to demonstrate that they are suitable and appropriate for the UK ABWR generic design and for the particular application/assessment area in which they are being applied. This work will be described in detail in the supporting reference documents for the Source Term Manual (described in more detail in Section 3) and in particular will:

- Extend coverage of operational feedback to BWRs worldwide, EPRI data and other data sources.
- Through screening and treatment of data will ensure appropriate use of calculation and OPEX data to derive and justify the Source term.
- Ensure specific and robust justification of Source Terms for those nuclides significant from the standpoints of the safety and environmental cases.

When the work outlined in the Resolution Plan is completed suitable and sufficient Source Term values required to support the UK ABWR generic safety and environmental cases will have been defined and justified. It is noted that the Source Term is managed throughout the plant lifecycle. Therefore, Hitachi-GE will compile a Source Term Manual based on the work undertaken in the Generic Design Assessment (GDA) and hand this on to the Site Licensee.

Hitachi-GE consider that the planned scope of work in response to RI-ABWR-0001 will address and enable the Regulators to close out a number of other actions from RO-ABWR-0006 whilst some actions will be addressed through the delivery of the Resolution Plan specific to RO-ABWR-0006. Once the RI-ABWR-0001 Resolution Plan has been accepted by the Regulators, Hitachi-GE will, as an early activity, review and re-submit the RO-ABWR-0006 Resolution Plan and programme to ensure an integrated approach to the overall work-scope.

## **2. Background:**

The Japanese ABWR Reference Plant upon which the UK ABWR is based has been designed, constructed and operated in accordance with some of the highest safety and environmental standards in the world.

Worker dose and environmental discharges are amongst the lowest of any operational plant. The plant is the culmination of some 50 years of continuous design-evolution in boiling water technology and has a

strong track record in safety and environmental performance since the first plant began operation in 1996.

For the purposes of the Generic Design Assessment of the UK ABWR, a Source Term strategy needs to be developed that satisfies UK Regulatory expectations. To date, this has not been achieved and the purpose of this Resolution Plan is for Hitachi-GE to outline how it intends to fully meet these expectations.

Hitachi-GE welcome the close engagement and efforts made by the Regulators to ensure the reasons why the response did not meet expectations has been understood and to ensure that Hitachi-GE have a good understanding of relevant good practice for the UK with respect to Source Terms.

Whilst the initial approach to development of the Source Term for the UK ABWR has not met Regulatory expectations, Hitachi-GE is clear that the design process used in the development of the Japanese Reference Plant is rigorous, and that Hitachi-GE fully understands the level of hazard for which the plant must be designed. Whilst there is a need to review the approach to presenting the Source Term in the UK regulatory context, Hitachi-GE remain confident that the basic design of the UK ABWR is safe and appropriate, with regard to environmental and safety standards.

Following the submission of the Source Term reports in January 2015 Hitachi-GE has met with the Regulators on a number of occasions and presented our revised approach to the definition and justification of the UK ABWR Source Term within the UK Regulatory environment. Steps taken include:

- **A revised approach:** *Hitachi-GE has undertaken a thorough review of the approach. This includes taking external advice from UK Consultants and has resulted in a revised approach which is presented in summary in this Resolution Plan.*
- **Increased Team Capability:** *Hitachi-GE has significantly enhanced its team in the UK and in Japan. The team now includes external contractor appointments. Members of the team have now been re-located to the UK.*
- **Availability of OPEX data:** *The need for relevant OPEX data was highlighted by the Regulators – Hitachi-GE has secured relevant available OPEX data and has access to the relevant EPRI database via Horizon Nuclear Power.*

Following confirmation from the Regulators that the revised approach set out in this Resolution Plan is credible, Hitachi-GE will have submitted the following key documents to the Regulators by the end of GDA Step 3:

- The Source Term Strategy
- The Primary Source Term Methodology Report (a key part of the Source Term Manual)

As the first documents to be submitted as part of the staged delivery, they will provide the Regulators with a comprehensive understanding of the revised approach to defining and justifying the Source Term, with a full description of the methodology being used for the Primary Source Term. This should provide the Regulators with confidence that the revised approach is appropriate to meet UK Regulatory requirements and that the work programmed for completion in Step 4 GDA (to take the safety and environmental documentation to completion) will meet their expectations.

### 3. Description of work:

In order to derive and justify a suitable and sufficient Source Term for the UK ABWR, Hitachi-GE, through discussion with the Regulators and review of relevant good practice, have developed a revised technical approach. Hitachi-GE will produce a suite of documents that sets the strategy and methodology for defining and justifying the Source Terms for the UK ABWR. A new document structure has been introduced to provide a clearer understanding of how the Source Term will be used and effectively integrated into the UK ABWR safety and environmental cases. The documentation that will be produced according to a clear hierarchy (four levels) is as follows:

1. **Strategy document:** which presents the purpose and scope of the Source Term work and provides an overview of the key technical areas affected by the Source Term.
2. **Source Term Manual:** which will be a set of documents describing the methodology for defining and justifying the Source Terms. These documents will clearly describe the methodology for deriving the Source Terms that have been defined and how to use them consistently and appropriately in the safety and environmental cases for the UK ABWR. This will form an important document as the UK ABWR design is progressed through the GDA process into site specific and operational safety and environmental cases as it will inform future users on how to use the Source Terms in the correct way at all levels.
3. **Source Term Values:** which will be the documents that contain the derived Source Terms in the systems and areas defined (i.e. values/data sets).
4. **Supporting Source Term Manual References:** which will form the bulk of the documentation for the Source Term work and provides all of the key under-pinning operational experience data used, justification and assumptions required to demonstrate that the Source Terms derived and used in the UK ABWR design are appropriate and correctly applied.

More detail on how Hitachi-GE will deliver the Source Term work for the UK ABWR design in line with the levels identified above is given below.

#### **Strategy Document:**

The aim of the Strategy Document is to establish the purpose and scope of the Source Term for the generic design of the UK ABWR, and to explain how the suite of documents created to define and justify the Source Term will be used to inform each technical area within the generic safety and environmental cases.. The Strategy Document will state the scope of the Source Term, detail what is covered in its definition, and will provide an overview of each of the technical areas impacted by Source Term. Hitachi-GE recognise that the Source Term for the UK ABWR must be developed with a good understanding of what it will be used for in the safety and environmental cases for the UK ABWR design. It is fundamental to understand the purpose and use of the Source Term to ensure that it is appropriately developed based on its significance within the safety and environmental cases (i.e. to confirm that appropriate conservatism has been used including consideration of operational phases and events that affect design basis and operation). The radioactive sources (nuclide inventory) vary depending on plant operational phases (system start-up, power operation, normal hot stand-by, system shutdown and outages) and between different systems. Selection and justification of the nuclide inventory used to calculate the Source Term is of key importance and requires detailed knowledge and understanding of the nuclide types and their impact on radioactivity levels. Guidance and relevant good practice on the selection of radionuclides for Source Term will be used by Hitachi-GE to ensure this is used in the selection and justification of radionuclides used to develop the Source Term for the generic design of the UK ABWR.

In addition, decisions made for areas such as material selection, operational chemistry and plant operation will affect the Source Term for the UK ABWR. The effects of these decisions on the Source Term need to be understood to allow effective demonstration that reasonably practicable measures have been taken to ensure the risk associated with the Source Term is reduced so far as is reasonably practicable (SFAIRP).

To ensure these elements are effectively addressed, Hitachi-GE will conduct a review of the safety and environmental cases to identify the links, requirements and constraints for the Source Term work. Hitachi-GE will demonstrate how links will be incorporated and, based on relevant good practice, identify the boundaries and limits for the Source Term used in particular areas (for example, to confirm in the area of radiation protection, very conservative levels based on peak activity have been used to ensure reduction of operator dose). Hitachi-GE will also identify the key radionuclides selected and demonstrate a robust selection and justification process using its expertise of the ABWR design and UK Source Term relevant good practice.

#### **Source Term Manual:**

The aim of the Source Term Manual is to provide a robust description of the methodology used to derive the Source Terms for the UK ABWR and provide guidance on how the future Operator should manage this. Hitachi-GE will use the methodology to quantify the radioactive Source Terms for the UK ABWR in a clear hierarchical sequence as follows:

- **Primary Source Term:** which will quantify the amount of radioactivity in the reactor water and reactor steam based on factors such as the nuclear fission process and the number of contaminant species present that could become radioactive as they pass through the core.
- **Process Source Term:** which will quantify the amount of radioactivity that is present and mobile in all systems that could contain radioactivity. The Process Source Term is calculated from the Primary Source Term.
- **Deposit Source Term:** which will quantify the amount of radioactivity that becomes fixed within the different systems of the UK ABWR design. As radionuclides are transported through the systems (Process Source Term) some are deposited on pipework and equipment.
- **End Use Source Terms:** which will quantify the final amount of radioactivity that needs to be considered for a particular application within a technical area (e.g. shielding design for radiation protection).

Changes in the amount of radioactivity identified above will occur throughout a normal operational cycle and due to events that could occur in the normal day to day operation of the plant. Hitachi-GE will base its work on UK relevant good practice to ensure the scope, definition and application of Source Term is appropriate and in line with expectation for the UK regulatory environment. Each section of the Source Term Manual will:

- Identify the conditions which will affect the magnitude of the amount of radioactivity in each of the UK ABWR systems.
- Describe the approach used to define an appropriate level of Source Term to be used for the UK ABWR GDA.
- Identify all of the key radionuclide groups that contribute to the size of the Source Term, the most significant of these groups (i.e. the radionuclides that have the biggest impact on Source Term) and the key factors that affect the amounts of radionuclides in these groups (such as fuel design, material selection and reactor chemistry regime).

Hitachi-GE will then consider how the amounts of the radionuclides vary at all stages of the operational cycle (system start-up, power operation, normal hot stand-by, system shutdown and outages) and show how this impacts the Source Term present in the plant (for example peaks of transients or steady state operation). For the Source Terms defined above, Hitachi-GE will determine two levels of Source Term values:

- **Best Estimate Value:** which gives an overall average of the Source Term expected in the UK ABWR over a defined period of time. This will be a representative condition that is realistic and reasonable so as not to result in over-specification of plant systems. The Best Estimate Source Term can be used for areas such as Disposability Assessments and routine discharges.
- **Design Basis Value:** which gives a conservative maximum value for the Source Term which can be considered a bounding limit for the plant design (i.e. it is expected that this level would not be exceeded during operation, including for expected events). This Source Term is important for key safety related applications such as shielding calculations to ensure that doses to the operators and public are minimised.

The application of these levels of Source Term to particular uses (such as shielding calculations or routine discharges) as part of demonstrating that the design of the generic UK ABWR reduces risks are SFAIRP, will be carefully considered and justified by Hitachi-GE to demonstrate that they are appropriate and in line with relevant good practice.

Hitachi-GE have developed a logical and structured approach to determine the Source Term for the UK ABWR design based on the different Source Terms identified above. The structured and staged approach to the derivation and justification of each of the Source Terms allows the methodology to be discussed with the Regulators and to ensure that the approach remains aligned with expectations as the work progresses.

The revised methodology for the derivation and justification of the Primary Source Term for the UK ABWR developed by Hitachi-GE uses a balanced approach of operational experience from numerous operating BWR (including ABWR) plants around the world, and calculation to determine numerical values. The use of operating experience will take careful consideration of the relevant good practice and expectations detailed by the Regulators. Hitachi-GE will provide a clear explanation of how operating experience has been selected, how statistical analysis techniques have been applied, and ultimately show why it is relevant for use in the derivation or justification of the Source Term for the UK ABWR.

The Primary Source Term will then be used to calculate the Process Source Term. For the Process Source Term, all key assumptions (e.g. flow rates, decontamination factors and radioactive decay) for the different systems will be clearly identified and justified as these form the basis for the derivation of the Process Source Term. The Process Source Term will quantify the amount of radioactivity that is present and mobile in all the systems and equipment (for example suppression pool and Condensate Storage Tank) that could contain radioactivity. The Process Source Term is essentially a mass/activity balance for all systems which contain radioactivity in the plant for the radioactive nuclides that make up the Source Term. Development of the Process Source Term in this way provides a good baseline for future development of the UK ABWR Source Term for the remainder of GDA and for future operators.

The Deposit Source Term is calculated from the Process Source Term using a deposition model. This model is an empirical model derived from measured nuclide deposition from Japanese OPEX data and is location specific as the deposition rates vary with material and physical conditions. This OPEX data is limited to Japanese BWR plants as it requires both deposition measurements and reactor water product concentration. The empirical model has deposition rates for fission products, insoluble and soluble corrosion products, with a correction factor derived from worldwide OPEX applied to account for the different water chemistry regime. The Deposition Source Term will be justified using independent Japanese OPEX data. Fuel crud deposition will be derived and justified using worldwide and Japanese OPEX data.

The final stage in the development of the Source Term Manuals for the UK ABWR is the production of the End Use Source Terms. These give the amount of radioactivity for a specific application and so their derivation is highly dependent on their application. Key to this is the selection of the appropriate level of Source Term to be used (e.g. Best Estimate or Design Basis). Hitachi-GE will present a methodology and guidance for developing the End Use Source Term for each application. This will be important in maintaining consistency for the End Use Source Terms and ensuring that the Source Terms are appropriately used in the safety and environmental case for the UK ABWR.

#### **Source Term Values:**

The output values from each of the source term methodologies will be reported following each methodology description. Best Estimate Values and Design Basis Values will be derived as part of the Source Term methodologies, and as such, two Source Term values will be reported for each radionuclide. These values collectively act as the inventory from which radionuclide activities are taken in order to inform the safety and environmental case for the UK ABWR design. Source Term values are used in conjunction with the End User Source Term methodology to develop the specific Source Term for a technical area as required. The Source Terms Values will be split into the following documents by considering UK ABWR hierarchical sequences:

- Calculation of Primary Source Term Value
- Calculation of Process Source Term Value
- Calculation of Deposit Source Term Value
- End User Source Terms

#### **Supporting Source Term Manual References:**

In addition to the key Source Term methodology documents detailed above, a number of supporting documents will be produced in order to both inform the methodology for defining the Source Term, and to provide a robust justification for the Source Term derived for the UK ABWR at the same time as submission of the source term documents. Supporting documents will be produced for each area of the Source Term Manual and will cover key areas such as the OPEX selection methodology, key assumptions made in the derivation of the Source Terms and an overall justification for the Source Term.

The OPEX selection methodology will be used in the definition of the Source Term for the UK ABWR. It will describe how OPEX is taken from the existing ABWR and worldwide BWR fleet, screened and rationalised for use in the definition of the Source Term. This will be outlined mainly for the Primary Source Term and system specific Source Terms where appropriate. Thus, the methodology for reducing the worldwide OPEX data set to a data set that is applicable to the UK ABWR for use in the definition of the Source Term will be outlined. This document will clearly outline the screening criteria and assumptions made to decide which OPEX data is relevant for use in the definition or justification of the Source Term for the UK ABWR.

The Source Term justification aims to demonstrate that the Source Term presented within the suite of documents is relevant and appropriate for the UK ABWR. OPEX will primarily be sought for justification of the Source Term, and will be supplemented with calculations where necessary to ensure the Source Term is robust. The Data will be managed in such a manner that any data used in the derivation of the Source Term category is excluded from the justification data set, thus ensuring independence between the data sets.

#### 4. 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 RI Action(s)	Submission Date to ONR/EA
PCSR Ch18: Radioactive Waste Management *	U	A1	Mar.2017
PCSR Ch20: Radiation Protection *	U	A1	Mar.2017
PCSR Ch24: Design Basis Analysis *	U	A1	Mar.2017
PCSR Ch25: Probabilistic Safety Assessment *	U	A1	Mar.2017
PCSR Ch31: Decommissioning *	U	A1	Mar.2017
GEP E4: Radioactive Waste Management Arrangements *	U	A1	Feb.2016
GEP E5: Demonstration of BAT *	U	A1	Feb.2016
GEP E7: Quantification of Discharges and Limits *	U	A1	Feb.2016
GEP E8: Prospective Dose Modelling *	U	A1	Feb.2016
Impact Assessment Report	C	A1, A2	Jul. 2015
Source Term Strategy (R0)	C	A1, A2	Aug. 2015
Primary Source Term Methodology Report (R0)	C	A1, A2	Aug. 2015
Process Source Term Methodology Report (R0)	C	A1, A2	Oct. 2015
Deposit Source Term Methodology Report (R0)	C	A1, A2	Oct. 2015
End User Source Term Methodology Report (R0)	C	A1, A2	Nov. 2015
Source Term Manual General Report (R0)	C	A1, A2	Sep. 2015
Calculation of PST Value (R0)	C	A1	Sep. 2015
Calculation of Process ST Value (R0)	C	A1	Oct. 2015
Calculation of Deposit ST Value (R0)	C	A1	Nov. 2015
Reports of End User Source Term value	C	A1	Nov. - Dec. 2015
Supporting documents	C	A1, A2	Sep. - Nov. 2015
Compile Final Source Term Manua(R0)	C	A1, A2	Jun. 2016

U = Update    C = Create    \* = Not required for closure of RI Action 1 and 2

#### 5. Programme Milestone/Schedule:

Please refer to the attached Resolution Plan Programme

Key Planning Assumptions:

- To ensure the Source Term work produces an acceptable output to meet regulatory requirements, Hitachi-GE have proposed a staged delivery plan to ensure the core methodology and approach remains aligned with Regulator expectations.
- In order to help ensure Hitachi-GE's submissions meet the Regulator's expectations, Hitachi-GE request the Regulators sample through the resolution process and provide feedback and advice to

ensure alignment with regulatory expectations at appropriate points through written responses to submissions and regular communications via Level 4 Technical Meetings (in the UK and Japan).

- An initial Impact Assessment has been carried out to inform this Resolution Plan and Resolution Plan Programme.
- Hitachi-GE will continue this Impact Assessment and discuss it with the Regulators at an early stage in the delivery of this Resolution Plan (in particular those aspects where one Regulator relies on the output of the assessment from the other) with the aim of confirming its planning assumptions by mid-July. The output from this exercise may result in changes to the overall Resolution Plan timeframes.

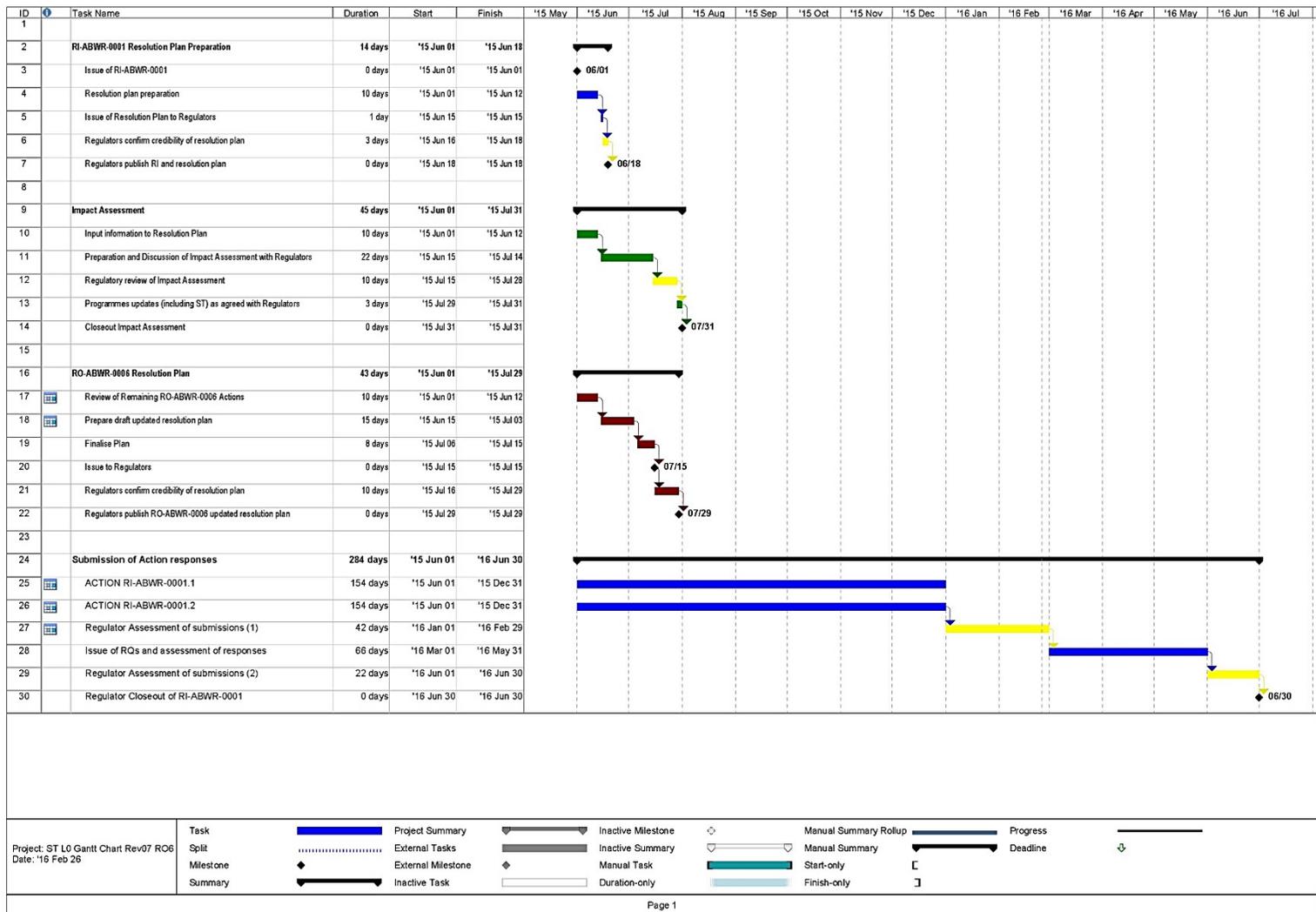
## 6. References:

RO-ABWR-0006 Regulatory Observation

RO-ABWR-0006 Resolution Plan

ONR letter dated 6th March 2015 [REG-HGNE-077R]

Figure 1 – Resolution Plan Programme for RI-ABWR-0001



## Glossary

ABWR – *Advanced Boiling Water Reactor*

BAT – *Best Available Techniques*

BWR – *Boiling Water Reactor*

EA – *Environment Agency*

EPRI – *Electric Power Research Institute*

GDA – *Generic Design Assessment*

GEP – *Generic Environmental Permit*

Normal Operation s – *Includes all five operational phases associated with the ABWR. This includes system start-up, hot standby, power operation, system shutdown and refuelling outage.*

ONR – *Office for Nuclear Regulation*

OPEX – *Operating Experience data from operational plants worldwide.*

PCSR – *Pre-construction Safety Report*

Radwaste – *Radioactive Waste*

RI – *Regulatory Issue*

RIA – *Regulatory Issue Action*

RO – *Regulatory Observation*

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*

TR – *Topic Report*

UK ABWR – *UK Advanced Boiling Water Reactor*