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Pre-Construction Environmental Report

Chapter 6

Quantification of Discharges and Limits

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6.1 List of Abbreviations and Acronyms

APG	Steam Generator Blowdown System [SGBS]
BAT	Best Available Technique
BFX	Fuel Building
BNX	Nuclear Auxiliary Building
BRX	Reactor Building
BWX	Radioactive Waste Treatment Building
CGN	China General Nuclear Power Corporation
CVI	Condenser Vacuum System [CVS]
DWK	Fuel Building Ventilation System [FBVS]
DWN	Nuclear Auxiliary Building Ventilation System [NABVS]
DWQ	Waste Treatment Building Ventilation System [WBVS]
EA	Environment Agency
EBA	Containment Sweeping and Blowdown Ventilation System [CSBVS]
EDE	Annulus Ventilation System [AVS]
HEPA	High Efficiency Particulate Air
HPR1000 (FCG3)	Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3
HVAC	Heating, Ventilation and Air Conditioning
NRC	Nuclear Regulatory Commission (US)
OPEX	Operating Experience
P&ID	Process and Information Document for Generic Assessment of Candidate Nuclear Power plant Designs
PCER	Pre-Construction Environmental Report
PCSR	Pre-Construction Safety Report
PSR	Preliminary Safety Report
PWR	Pressurised Water Reactor

RADD	European Commission Radioactive Discharges Database
RCV	Chemical and Volume Control System [CVCS]
REA	Reactor Boron and Water Makeup System [RBWMS]
REPs	Radioactive Substances Regulation - Environmental Principles
RPE	Nuclear Island Vent and Drain System [VDS]
SEK	Waste Fluid Collection System for Conventional Island [WFCSCI]
SEL	Conventional Island Liquid Waste Discharge System [LWDS (CI)]
SRE	Sewage Recovery System [SRS]
TEG	Gaseous Waste Treatment System [GWTS]
TEP	Coolant Storage and Treatment System [CSTS]
TER	Nuclear Island Liquid Waste Discharge System [NLWDS]
TEU	Liquid Waste Treatment System [LWTS]
UK HPR1000	UK version of the Hua-long Pressurised Reactor

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Steam Generator Blowdown System (APG [SGBS]).

6.2 Introduction

6.2.1 Objective

This chapter aims to present the information on the likely radioactive gaseous and liquid discharges to the environment of UK version of the Hua-long Pressurised Reactor (UK HPR1000) during normal operation. In this chapter, the UK HPR1000 radioactive gaseous and liquid effluent streams and discharge routes are presented, and the estimated discharges and proposed limits for significant radionuclides during normal operation are provided.

The content of this chapter is in line with the requirements on radioactive gaseous and liquid discharges and limits outlined in the *Process and Information Document for Generic Assessment of Candidate Nuclear Power plant Designs (P&ID)*, Reference [1], and the principles provided in the *Radioactive Substances Regulation - Environmental Principles (REPs)*, Reference [2].

6.2.2 Scope

A nuclear power plant produces by nature radioactive materials during its operation. These materials are treated by physical or chemical process, and discharged to the environment or disposed in three forms: gas, liquid, and solid.

This chapter focuses on quantification of UK HPR1000 radioactive gaseous and liquid discharges and limits. The quantification of radioactive solid waste is described in Pre-Construction Environmental Report (PCER) Chapter 4. The quantification of non-radioactive waste is described in PCER Chapter 8.

The demonstration of Best Available Technique (BAT) on how the radioactive effluents are reasonably managed and controlled to minimise the radioactive discharges and their impacts on environment during normal operation for UK HPR1000 is provided in PCER Chapter 3 for generation, treatment and management of radioactive effluents, and in PCER Chapter 5 for sampling and monitoring.

The interfaces with other chapters are presented in T-6.2-1.

T-6.2-1 Interfaces with Other Chapters

Chapters	Interface Relationships
PCER Chapter 1 Introduction	PCER Chapter 1 provides the summary of each PCER chapter and the P&ID route map.
PCER Chapter 3 Demonstration of BAT	PCER Chapter 3 provides the demonstration of BAT on generation, treatment and management of radioactive effluents for UK HPR1000 radioactive gaseous and liquid discharges.
PCER Chapter 4 Radioactive Waste Management Arrangement	PCER Chapter 4 provides information on UK HPR1000 radioactive waste management strategy and arrangement.
PCER Chapter 5 Approach to Sampling & Monitoring	PCER Chapter 5 provides information on UK HPR1000 sampling and monitoring related to gaseous and liquid discharges and its BAT demonstration. PCER Chapter 6 provides significant radionuclide list to support the selection of key radionuclides for monitoring.
PCER Chapter 7 Radiological Assessment	PCER Chapter 6 provides proposed annual limits and short term release as input for PCER 7 on radiological impact assessment. PCER Chapter 7 provides the radiological impact assessment results based on discharges and limits to support the selection of significant radionuclides.

6.3 Regulatory Context

6.3.1 P&ID Requirements

The requirements related to the quantification of radioactive gaseous and liquid discharges and limits provided in item 5 of Table 1 in P&ID, Reference [1], are as follows:

> ***Quantification of radioactive waste disposals***
>
> ***Provide quantitative estimates for normal operation of:***
>
> - *discharges of gaseous and aqueous radioactive wastes; 'Normal operation' includes the operational fluctuations, trends and events that are expected to occur over the lifetime of the facility, such as start-up, shutdown, maintenance, etc. It does not include increased discharges arising from other events, inconsistent with the use of BAT, such as accidents, inadequate maintenance, and inadequate operation.*
>
> *For gaseous and aqueous radioactive wastes, you should estimate your monthly discharges:*
>
> - *on an individual radionuclide basis for significant radionuclides;*
> - *on a group basis (for example 'total alpha' or 'total beta') for other radionuclides;*
> - *via each discharge point and discharge route.*
>
> *'Significant ' radionuclides are those which:*
>
> *- are significant in terms of radiological impact for people or non-human species;*
>
> *- are significant in terms of the quantity of radioactivity discharged (that is, numerically high);*
>
> *- have long half-lives, may persist and/or accumulate in the environment, and may contribute significantly to collective dose;*
>
> *- are significant indicators of facility performance and process control.*
>
> *Your radionuclide selection should be consistent with reference EU, 2004…*
>
> *…Your estimates of discharges and disposals should clearly show the contribution of each constituent aspect of normal operations, including:*
>
> - *routine operation (that is, typically, the design basis or "flowsheet design" and the minimum level of disposals);*
> - *start-up and shutdown;*
> - *maintenance and testing;*

- *infrequent but necessary aspects of operation, for example, plant wash-out; and the foreseeable, undesired deviations from planned operation (based on a fault analysis) consistent with the use of BAT, for example, occasional fuel pin failures.*

You should support your estimates with performance data from similar facilities and explain, where relevant, how changes in design or operation from those facilities affect the expected discharges and disposals. You should demonstrate that discharges and waste arising will not exceed those of comparable power stations across the world (as required by UK Government policy (GB Parliament, 2008)).

Provide your proposed limits for:

- *gaseous discharges;*
- *aqueous discharges;*

Provide your proposals for annual site limits (on a rolling twelve months basis) for gaseous and aqueous discharges.

6.3.2 Relevant REPs

The REPs, Reference [2], contain principles relevant to the quantification of radioactive gaseous and liquid discharges and limits, which are mentioned in Fundamental Principle E (Protecting Human Health and Environment) and Generic REP RSMDP12. All these principles have been considered in the analysis of UK HPR1000 radioactive gaseous and liquid discharges and limits, especially the following ones:

Limits and levels should be established on the quantities of radioactivity that can be discharged into the environment where these are necessary to secure proper protection of human health and the environment.

Considerations:

a) *Limits and levels should be established on those radionuclides and/or groups of radionuclides which:*

   1) *Are of significance in terms of radiological impact for humans and non-human species, including those which may be taken up in food;*

   2) *Are of significance in terms of the quantity of radioactivity discharged;*

   3) *Have long half-lives and which may persist and/or accumulate in the environment, and may contribute significantly to collective dose;*

   4) *Are significant indicators of facility performance and process control; or*

   5) *Provide for effective regulatory control and enforcement.*

b) *The time periods on which limits and levels should be based should be consistent* *with the intent of the limits or levels. Such periods include annual, quarterly, monthly, weekly and daily. The periods may be calendar or rolling;*

c) *Limits should be set such that there is minimum headroom between actual levels of discharge expected during normal operation and the discharge limit. "Operation" relates to the current activities at a site including commissioning, operations and decommissioning. "Normal" operation includes maintenance and relevant operational fluctuations, trends and events that are expected to occur over the likely lifetime of the facility.*

6.3.3 Discharge Requirements Related to Dose Limitation

The Environmental Permitting (England and Wales) Regulations 2016 (as amended), Reference [3], set the limits and constraints on the annual radiation exposures of members of the public. It is required to ensure that:

All exposures to ionising radiation of any member of the public and of the population as a whole resulting from the disposal of radioactive waste are kept as low as reasonably achievable, taking into account economic and social factors;

The sum of the doses arising from such exposures does not exceed the individual public dose limit of 1mSv per year;

The individual dose received from any new discharge source since 13th May 2000 does not exceed 0.3mSv per year;

The individual dose received from any single site does not exceed 0.5mSv per year.

The Statutory Guidance to the Environment Agency Concerning the Regulation of Radioactive Discharges to the Environment, Reference [4], provides a lower bound of exposure of 10μSv per year for the most exposed group of members of the public. Below this bound, the Environment Agency (EA) will not require further reduction in the discharge limits if the requesting party applies and continues to apply BAT.

6.4 Discharge Routes

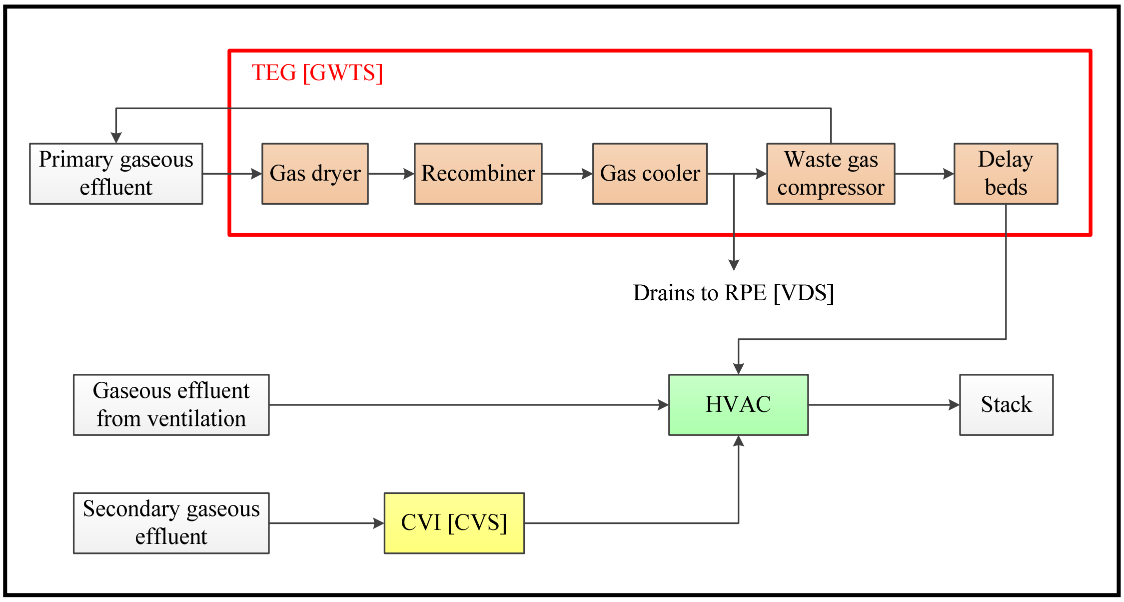
The radioactive gaseous and liquid effluents of UK HPR1000 are managed and treated by abatement systems, sampled in key locations for analysis, and monitored in real time by monitoring systems, to ensure that the discharges to environment are reasonable and acceptable.

The discharges from waste incineration are not considered since onsite waste incineration technology is not adopted for UK HPR1000.

The radioactive gaseous and liquid effluent streams and discharge routes have been identified based on the UK HPR1000 process and system designs, described in Pre-Construction Safety Report (PCSR) system chapters, Reference [5], [6], [7], [8], [9] and [10], and the radioactive waste management strategy and arrangement, described in PCER Chapter 4.

6.4.1 Gaseous Effluent Discharge Routes

The UK HPR1000 radioactive gaseous effluents are collected and treated by three systems: Gaseous Waste Treatment System (TEG [GWTS]), Heating, Ventilation and Air Conditioning (HVAC) system, and Condenser Vacuum System (CVI [CVS]). The HVAC system consists of several subsystems in different radioactive buildings, such as Containment Sweeping and Blowdown Ventilation System (EBA [CSBVS]) and Annulus Ventilation System (EDE [AVS]) in Reactor Building (BRX), Nuclear Auxiliary Building Ventilation System (DWN [NABVS]) in Nuclear Auxiliary Building (BNX), Fuel Building Ventilation System (DWK [FBVS]) in Fuel Building (BFX), and Waste Treatment Building Ventilation System (DWQ [WBVS]) in Radioactive Waste Treatment Building (BWX), etc. After the abatement process, all gaseous effluents are finally discharged through the HVAC system via the main stack. The summary schematic of UK HPR1000 radioactive gaseous effluent streams is as shown in F-6.4-1.



F-6.4-1 Radioactive Gaseous Effluent Streams

The radioactive gaseous effluents can be divided into three categories:

a) Primary gaseous effluent. This gaseous effluent mainly comes from the degassing and head spaces of the vessels containing primary coolant or primary effluent. It is collected and processed by TEG [GWTS] before being discharged. During steady-state operation, TEG [GWTS] operates continuously as a closed circuit and the flushing gas is reused and decays in the closed circuit. Only a little quantity of gas goes to the delay beds, where it is delayed for decay. During shutdown and start-up transients, a large quantity of gas goes to the delay beds for decay before discharge.

After passing through the delay beds, the gas goes to DWN [NABVS] for final abatement and discharge. The High Efficiency Particulate Air (HEPA) filters, iodine traps (if necessary) and their pre-filters within DWN [NABVS] can further reduce the radioactivity of the gaseous effluent before the release into the environment via the main stack.

b) Gaseous effluent from ventilation. This gaseous effluent results mainly from possible leakage of radioactive components inside buildings and from evaporation of open water (for example, the water in spent fuel pool). It is collected by HVAC system and treated by HEPA filters, iodine traps (if necessary) and their pre-filters inside the radioactive buildings, like BRX, BNX, BFX, and BWX. It is finally discharged via the main stack.

c) Secondary gaseous effluent. This gaseous effluent is normally not radioactive except in the case of leakage from the primary circuit to the secondary circuit. It is collected by CVI and sent to DWN [NABVS], treated by HEPA filters, iodine traps (if necessary) and their pre-filters within DWN [NABVS], and finally routed to the main stack for discharge.

During normal operation, all the radioactive gaseous effluents are treated and discharged as described above. At the final gaseous discharge point, sampling and online monitoring of radioactivity are provided to continuously obtain information on gaseous discharges. Further information on sampling and monitoring of discharges is presented in PCER Chapter 5.

6.4.2 Liquid Effluent Discharge Routes

The UK HPR1000 radioactive liquid effluents are collected, stored and treated by Chemical and Volume Control System (RCV [CVCS]), Coolant Storage and Treatment System (TEP [CSTS]), Reactor Boron and Water Makeup System (REA [RBWMS]), Nuclear Island Vent and Drain System (RPE [VDS]), Sewage Recovery System (SRE [SRS]), Liquid Waste Treatment System (TEU [LWTS]), Nuclear Island Liquid Waste Discharge System (TER [NLWDS]), Steam Generator Blowdown System (APG [SGBS]), Conventional Island Liquid Waste Discharge System (SEL [LWDS (CI)]) and Waste Fluid Collection System for Conventional Island (SEK [WFCSCI]). After being treated, the liquid radioactive effluents can be discharged if they meet the discharge requirements. The summary of UK HPR1000 radioactive liquid effluent streams is as shown in F-6.4-2.

The radioactive liquid effluents are divided into three categories:

a) Reactor coolant effluent. This category is from letdown of primary coolant by RCV [CVCS] and drainage or leakage collected by RPE [VDS]. The recyclable part of this effluent is sent to TEP [CSTS] for decontamination, boron concentration and water separation. The decontaminated and separated boric acid and distillate are then sent to REA [RBWMS] for reuse. In the case of high tritium concentration or other chemical contamination, the distillates cannot practically be treated further and thus are routed to the TER [NLWDS] for discharge. The unrecyclable part is sent to TEU [LWTS] for abatement as liquid waste.

b) Liquid waste. It includes:

1) The unrecyclable part of reactor coolant effluent, collected by RPE [VDS]; and,

2) The effluent from waste management and radioactive area decontamination, collected by the (SRE [SRS]).

It can be divided into four types:

1) The process drains, coming from flushing or leakage of the tanks or pipelines with reactor coolant;

2) The chemical drains, coming from the radioactive experiments and the relevant decontamination;

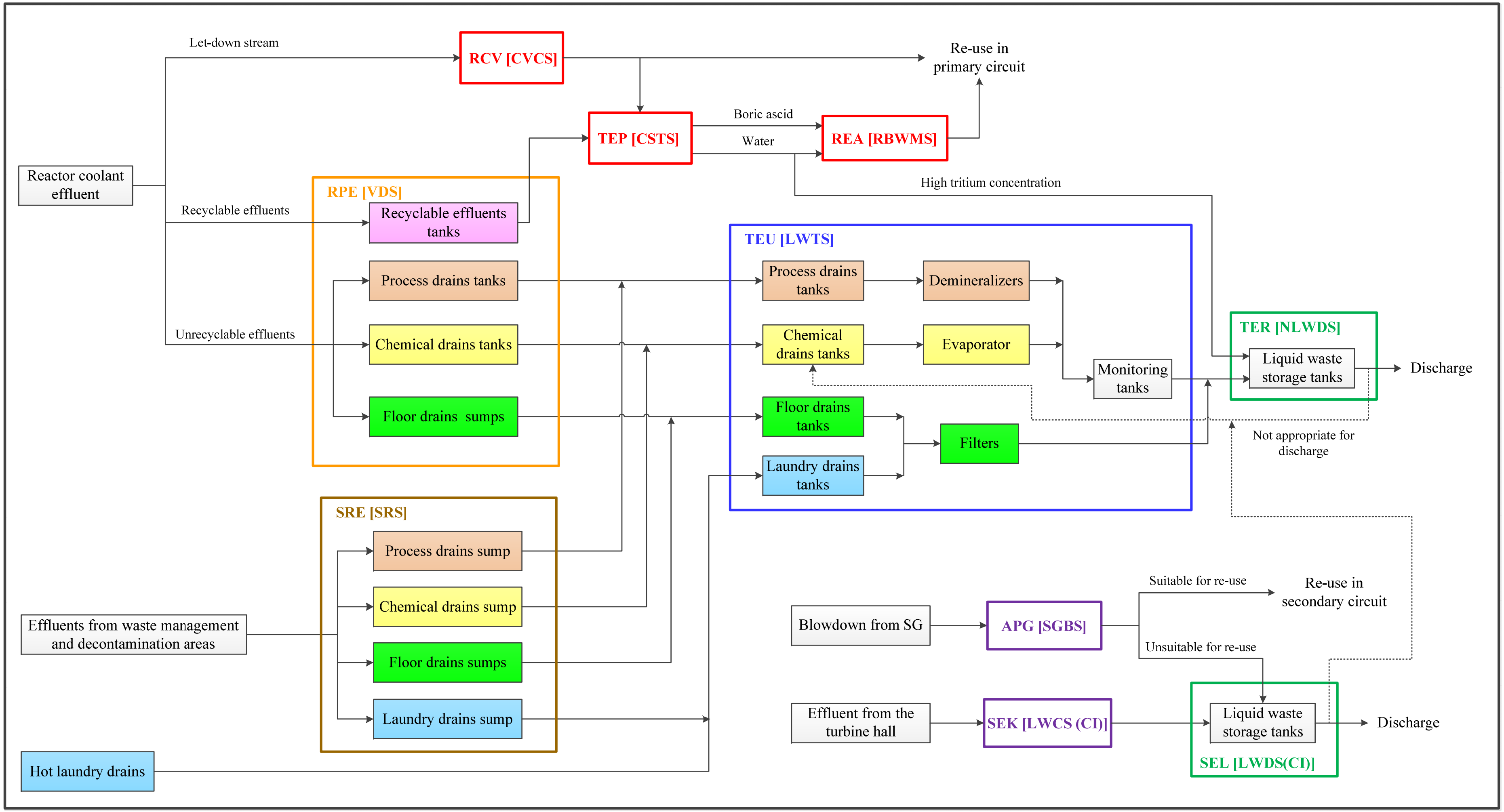
3) The floor drains, coming from leakage of components or washing of the floors in controlled area;

4) Laundry drains, coming from laundry of clothes or gloves.

This liquid effluent is sent to TEU [LWTS] for abatement. The TEU [LWTS] abatement process consists of demineralisation, evaporation and filtration. After the abatement, this effluent is sent to TER [NLWDS] for discharge.

c) Secondary circuit effluent. This liquid effluent is normally not radioactive except in case of leakage from the primary circuit to the secondary circuit. It comes from periodic blowdown of steam generator and secondary drainage. The former part is treated by APG [SGBS] in the turbine building and then sent to the main turbine condenser for recycling or to SEL [LWDS (CI)] for discharge; while the latter part is collected by SEK [WFCSCI] and then sent to SEL [LWDS (CI)] for discharge.

During normal operation, all the radioactive liquid effluents are treated and discharged as described above. Sampling and monitoring are set throughout the liquid effluent streams to check whether the abated liquid effluents are acceptable and whether the systems are working as anticipated. Further information on sampling and monitoring is presented in PCER Chapter 5.



F-6.4-2 Radioactive Liquid Effluent Streams

6.5 Methodology for Quantification of Discharges and Limits

6.5.1 General Methodology

In the Preliminary Safety Report (PSR), the radioactive gaseous and liquid discharges of Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)) meeting Chinese regulations and requirements were provided. These values were obtained by pure theoretical calculation based on conservative assumptions.

In order to be consistent with UK context and to obtain more realistic radioactive gaseous and liquid discharges and limits for UK HPR1000, a new methodology mainly based on Operating Experience (OPEX) data has been developed. The main process of quantification of radioactive gaseous and liquid discharges and limits for UK HPR1000 is as follows:

a) Collection of OPEX data

The OPEX data for discharges can be divided into the following two categories:

1) Basic OPEX data

The basic OPEX data serve as the basis underpinning the quantification of discharges and limits for UK HPR1000. The OPEX data of China General Nuclear Power Corporation (CGN) fleet, up to 66 reactor-years of data, have been collected, and almost 52 reactor-years data have been selected as the basic data following the OPEX data selection criteria.

2) Comparison OPEX data

The Comparison OPEX data are used to compare with the UK HPR1000 discharges to check at which level the UK HPR1000 discharges locate. The OPEX data from other representative international Pressurised Water Reactor (PWR)s, including UK fleet, French fleet, German fleet and American fleet, have been collected from relevant websites and selected as the comparison data.

More detailed information on OPEX data, including the scope, selection and validity of OPEX data, and the discharges of OPEX data, is provided in the supporting document *OPEX Data Selected for Quantification of Discharges and Limits for UK HPR1000*, Reference [11].

b) Identification of discharge routes and effluent streams

Based on the UK HPR1000 radioactive waste management strategy and arrangement, and the process and system design, the radioactive gaseous and liquid discharge routes and effluent streams have been identified, as shown in Sub-chapter 6.4.

c) Establishment of expected event list

The expected events refer to those events which are infrequent but can have influences on discharges and are consistent with the use of BAT. They do not include accidents, inadequate maintenance and inadequate operation.

The establishment of expected event list is divided into the following two steps:

1) Establishment of the preliminary expected event list by systematic analysis along the effluent streams; and,

2) Finalisation of the expected event list by verification and analysis based on OPEX, expertise and theoretical evaluation.

The operating conditions considered in quantification of radioactive gaseous and liquid discharges and limits, including expected events, are described in Sub-chapter 6.5.2. More detailed information on expected events, including the definition, the assumption, the method and the preliminary list of expected events, are provided in the supporting document *Expected Event List for UK HPR1000*, Reference [12].

d) Estimation of discharges and limits

The estimation of discharges and limits consist of the following two steps:

1) Estimation of discharges and limits based on the basic OPEX data

When estimating the discharges and limits, the correction factors and headroom factors are defined to reasonably modify the basic OPEX data to obtain the estimated discharges and limits for UK HPR1000: The former ones are defined to quantify the changes on discharges resulted from the differences in design schemes between UK HPR1000 and OPEX units[1]; the latter ones are defined to provide adequate margins to cover all the operating conditions of normal operation.

The definition and consideration of correction factors and headroom factors are described respectively in Sub-chapter 6.5.4 and 6.5.5.

2) Estimation of discharges and limits for those radionuclides without OPEX data

It has been identified that there are a number of radionuclides existing in discharges but without OPEX data. This is because their discharges are below the detection limits or they are not required to be measured in the country.

For these radionuclides without OPEX data, the radionuclides with OPEX data which have similar physical and chemical characteristics and share the same effluent streams and discharge routes with them are selected as indicators. Theoretical analysis is applied based on the similar behaviours between these radionuclides and their indicators, and also the primary source term provided in

1 "OPEX units" means the units from which the OPEX data have been selected.

PCSR Chapter 22, Reference [13], to complement the discharges of the radionuclides without OPEX data but probably existing in discharges.

More detailed information on estimation of discharges and limits, including the considerations of key factors (correction factors and headroom factors) and the estimation of discharges and limits, is provided in the supporting document *Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000*, Reference [14].

The estimated discharges and limits based on current basic OPEX data (CGN OPEX data) are provided in Sub-chapter 6.6.

e) Comparison with other plants around the world

The estimated UK HPR1000 radioactive gaseous and liquid discharges are then compared with the comparison OPEX data (representative international OPEX data) to check at which level they locate, as described in Sub-chapter 6.7.

f) Update of the discharges and limits by operators

Since the OPEX data of UK HPR1000 will not be available during GDA process, the estimated discharges and limits of UK HPR1000 are based on the basic OPEX data from similar units.

Once the OPEX data of UK HPR1000 itself are available for a sufficient operation period, the discharges and limits will be verified and updated based on its own OPEX data.

6.5.2 Operating Conditions

The operating conditions considered in the quantification of discharges and limits are normal operation, which includes mainly routine operation, start-up, shutdown, maintenance, and expected events.

Since the expected events can have significant influence on the discharges, they are identified by systematic analysis along the effluent streams of UK HPR1000 and will be verified and analysed by OPEX data and theoretical evaluation.

More information on expected events, including the definition, the assumption, the method and the preliminary list of expected events for UK HPR1000, is provided in *Expected Event List for UK HPR1000*, Reference [12].

6.5.3 Significant Radionuclides

Significant radionuclides selection criteria and relevant requirements are defined in the following two documents:

a) The European Commission document, *Commission Recommendation of 18 December 2003 on standardised information on radioactive airborne and liquid* *discharges into the environment from nuclear power reactors and reprocessing plants in normal operation*, 2004/2/Euratom, Reference [15]; and,

b) The EA's guidance, *Criteria for setting limits on the discharge of radioactive waste from nuclear sites* June 2012, Reference [16].

Reference [15] recommends a series of criteria and a range of essential radionuclides whose discharges shall be assessed. Reference [16] provides more detailed recommended criteria for significant radionuclides selection.

The selection of significant radionuclides for environmental protection is based on the criteria and the list given in both these two documents, as follows:

a) Are significant in terms of radiological impact on people (that is, the dose to the most exposed group at the proposed limit exceeds 1 μSv per year);

   The radiological impact to the public has been assessed based on the proposed annual discharge limits for the radionuclides existing in discharges in PCER Chapter 7. According to this criterion and the dose assessment results, C-14 has been selected as significant radionuclide since only the doses to the public resulted from the gaseous and liquid C-14 discharges have exceeded 1 μSv per year.

b) Are significant in terms of radiological impact on non-human species (this only needs to be considered where the impact on reference organisms from the discharge of single radionuclide at the proposed limit exceeds 10 μGy/h);

   According to the dose assessment results to the non-human species at the proposed discharge limits presented in PCER Chapter 7, no radionuclide has exceed the threshold and been selected by applying this criterion.

c) Are significant in terms of the quantity of radioactivity discharged (that is, the discharge of a radionuclide exceeds 1 TBq per year);

   The proposed limit for UK HPR1000 has been estimated based on OPEX data, as shown in Sub-chapter 6.6.3 and supporting document *Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000*, Reference [14]. Based on this criterion and proposed limit for each radionuclide, H-3, C-14, Xe-131m, Xe-133 and Xe-135 have been selected for the gaseous discharges, while H-3 has been selected for the liquid discharges.

d) May contribute significantly to collective dose (this only needs to be considered where the collective dose truncated at 500 years from the discharges of all radionuclides at the proposed limits exceeds 1 man-sievert per year to any of the UK, European or World populations);

   According to the collective dose assessed at proposed limits to the UK, European or World populations in PCER Chapter 7, the gaseous C-14 can have significant contribution to the collective dose of EU and World populations as considering the first past and global circulation together. The predicted dose of gaseous C-14 for EU and World population groups are 1.23 manSv and 27.0 manSv respectively which exceed of 1 manSv. Thus, the gaseous C-14 has been selected as significant radionuclide.

For liquid discharges, no radionuclides have been selected since collective dose at their proposed limits have exceeded the threshold.

e) Are constrained under national or international agreements or is of concern internationally;

No radionuclides have been identified as a constraint against this criterion.

f) Are indicators of plant performance, if not otherwise limited on the above criteria;

Xe-133, I-131 and I-133 are important fission products and have been selected as indicators for the fuel reliability.

In addition, the total gamma/beta are also measured for the gaseous discharges to indicate the performance of HEPA filters of HVAC system while the total gamma is measured for the liquid discharges to indicate the performance of TEU [LWTS].

g) For the appropriate generic categories from the RSR Pollution Inventory (e.g. “alpha particulate” and “beta/gamma particulate” for discharges to air) to limit any radionuclides not otherwise covered by the limits set on the above criteria.

There are no additional radionuclides needed to be selected under this criterion

Therefore, the selected significant radionuclides are as shown in T-6.5-1.

T-6.5-1 Significant Radionuclides

Definition Criteria	Gaseous	Liquid
Dose to most exposed person (greater than 1 μSv a^{-1})	C-14	C-14
Dose to non-human species (greater than 10 μGy/h for exposure from a single source)	-	-
Discharged activity (greater than 1 TBq a^{-1})	H-3, C-14, Xe-131m, Xe-133, Xe-135	H-3
Collective Dose (greater than 1 manSv)	C-14	-

Definition Criteria	Gaseous	Liquid
Plant performance indicators	a) Fuel failure: Xe-133, I-131, I-133 b) Performance of HVAC system (HEPA filters): Total gamma / beta	a) Fuel failure: I-131, I-133 b) Performance of TEU [LWTS]: Total gamma

6.5.4 Correction Factors

Even though the OPEX units selected are similar to UK HPR1000, there are still some differences in design features, for example, the power, the system or the process design, which may have influences on discharges. To quantify these influences on discharges, the correction factors are defined and estimated as follows:

a) H-3

The difference in power influences the production of H-3, and therefore the resulting discharges of H-3, since H-3 is not abated within PWRs. Thus, a correction factor defined by power ratio is considered to be applied to the OPEX data of H-3. The BAT demonstration for H-3 is provided in PCER Chapter 3.

b) C-14

Firstly, the coverage and purge gas of primary circuit tanks for UK HPR1000 is nitrogen, while that for the CGN OPEX units is hydrogen. Nitrogen can be dissolved in primary coolant and carried into the reactor core, where it can be activated into C-14. Thus, nitrogen can be one of the main sources for C-14 via neutron activation.

Secondary, the difference in power can also influence the production of C-14, and therefore the resulting discharges of C-14, since it is not abated in PWR.

Therefore, theoretical calculation is considered to correct the discharge OPEX data of C-14. The BAT demonstration for C-14 is provided in PCER Chapter 3.

c) Noble gases

The TEG [GWTS] abatement process is different between UK HPR1000 and CGN OPEX units: UK HPR1000 adopts delay beds while CGN OPEX units adopt the decay storage tanks. By comparison and analysis of these two schemes, their abatement effects for noble gases are similar. Therefore, the discharges of noble gases from UK HPR1000 and CGN OPEX units will be almost the same. Correction is deemed not necessary for noble gases.

d) Others (except H-3, C-14 and noble gases)

For other radionuclides (except H-3, C-14 and noble gases), the abatement process of UK HPR1000 is similar with that of CGN OPEX units. The difference in power may influence their production, but this difference can be neglected when it comes to discharges, because the abatement process can counteract these influences. Correction is deemed not necessary for them.

The estimated correction factor for each radionuclide is as shown in T-6.5-2.

T-6.5-2 Correction Factors for Different Radionuclides in Effluents

Phases	Radionuclides / Groups	Correction Factors
Gaseous Effluents	H-3	1.09
	C-14	1.62
	Noble Gases	1.00
	Halogen (including iodines and bromines)	1.00
	Others (except H-3, C-14, noble gases and halogen)	1.00
Liquid Effluents	H-3	1.09
	C-14	1.62
	Others (except H-3 and C-14)	1.00

The detailed definition and estimation are provided in the supporting document *Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000*, Reference [14].

6.5.5 Headroom Factors

During normal operation, there will be some fluctuations of gaseous and liquid discharges due to variations in discharges related to expected events, start up, shut down and maintenance activities. To better detect and control the operating state of UK HPR1000, it is necessary to define reasonable minimum headroom factors for the discharges, so as to define the discharge limits for normal operation.

The headroom factors for UK HPR1000 are defined and estimated mainly based on the contribution of expected events, considering also 0.5 margin due to the uncertainty of new built reactors. Since the expected events are still under verifying and analysing, a reasonable conservative margin for expected events has been considered at element 3 entry.

The current values of headroom factors for different radionuclides are as shown in T-6.5-3.

T-6.5-3 Headroom Factors for Different Radionuclides in Effluents

Phases	Radionuclides / Groups	Headroom Factors
Gaseous	H-3	7.68E+00

Phases	Radionuclides / Groups	Headroom Factors
Effluents	C-14	5.32E+00
	Noble Gases	1.44E+01
	Halogen (including iodines and bromines)	1.98E+01
	Others (except H-3, C-14, noble gases and halogen)	5.50E+00
Liquid Effluents	H-3	3.68E+00
	C-14	4.79E+00
	Others (except H-3 and C-14)	4.47E+00

The detailed definition and estimation are provided in the supporting document *Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000*, Reference [14].

6.6 Estimated Discharges and Proposed Limits

6.6.1 Monthly Discharges

The monthly discharges of UK HPR1000 are defined as the expected monthly performance of UK HPR1000. They are taken as the averages of the basic OPEX data with adequate corrections mentioned in Sub-chapter 6.5.4. The estimated monthly discharges of UK HPR1000 based on the current basic OPEX data (CGN OPEX data) are given in T-6.6-1.

The detailed estimation of UK HPR1000 monthly discharges is provided in the supporting document *Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000*, Reference [14].

6.6.2 Annual Releases

The annual releases of UK HPR1000 (12 rolling months) are defined as the expected annual performance of UK HPR1000. They are taken as the accumulation of the UK HPR1000 monthly discharges over 12 months. The estimated annual releases of UK HPR1000 based on the current basic OPEX data (CGN OPEX data) are given in T-6.6-1.

The detailed estimation of UK HPR1000 annual releases is provided in the supporting document *Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000*, Reference [14].

6.6.3 Proposed Annual Discharge Limits

The proposed annual discharge limits (12 rolling months) are defined based on the expected annual release and adequate headroom resulting from the contribution of possible expected events during normal operation mentioned in Sub-chapter 6.5.5. The proposed annual discharge limits of UK HPR1000 based on the current basic OPEX data (CGN OPEX data) and current consideration of headroom factors are as shown in T-6.6-1.

The detailed estimation of annual limits is provided in the supporting document *Methodology and Estimation of Discharges and Limits for UK HPR1000*, Reference [14].

6.6.4 Short Term Releases

The maximum monthly discharges of UK HPR1000 are defined as the short term releases of UK HPR1000. They are taken as the maximum monthly discharges of the basic OPEX data with adequate corrections mentioned in Sub-chapter 6.5.4. Since the expected events are still under verification and analysis, reasonable conservative margins for the maximum monthly discharges are considered at element 3 entry.

The estimated maximum monthly discharges of UK HPR1000 based on the current basic OPEX data (CGN OPEX data) and adequate margins applied due to expected events are given in T-6.6-1.

The detailed estimation of UK HPR1000 maximum monthly discharges is provided in the supporting document *Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000*, Reference [14].

T-6.6-1 Estimated Discharges and Limits for Gaseous and Liquid Effluents

Phases	Radionuclides / Groups	Monthly Discharges (Bq)	Maximum Monthly Discharges (Bq)	Annual Releases (Bq)	Proposed Limits (Bq)
Gaseous Effluents	H-3	5.96E+10	4.84E+11	7.15E+11	5.49E+12
	C-14	2.40E+10	1.81E+11	2.88E+11	1.53E+12
	Noble Gases	8.02E+10	3.51E+12	9.63E+11	1.39E+13
	Iodines	4.94E+05	7.00E+07	5.93E+06	1.17E+08
	Others (including bromine) (except H-3, C-14, noble gases and iodines)	3.03E+05	1.40E+06	3.63E+06	2.09E+07
Liquid Effluents	H-3	1.84E+12	5.51E+12	2.21E+13	8.11E+13
	C-14	5.59E+08	3.12E+09	6.71E+09	3.22E+10
	Others (except H-3 and C-14)	2.39E+07	6.64E+07	2.87E+08	1.29E+09

6.7 Comparison with Other Plants around the World

The international PWR OPEX data including discharges of European fleet (UK fleet, French fleet and German fleet) and American fleet from 2002 to 2016 have been collected respectively from the *European Commission Radioactive Discharges Database (RADD)*, Reference [17], and *United States Nuclear Regulatory Commission (US) (NRC) Radioactive Effluent and Environmental Reports*, Reference [18]. Those from representative European fleet and American fleet have been selected as comparison OPEX data. The annual averages of the selected international OPEX data and the estimated annual discharges of UK HPR1000 based on the current basic OPEX data (CGN OPEX data) have been normalised to 1000MWe and compared as shown in T-6.7-1 and F-6.7-1~F-6.7-7.

a) Gaseous discharges

For gaseous C-14, it can be seen in F-6.7-1 that the estimated UK gaseous C-14 annual discharge of HPR1000 is higher than that of the majority of comparable plants. This is because, UK HPR1000 adopts nitrogen as the coverage and purge gas for primary circuit tanks instead of hydrogen, which can be one of the main sources for C-14 (via neutron activation). In fact, the UK HPR1000 gaseous annual discharge of C-14 is close to those of German Emsland Plant and Grafenrheinfeld Plant, both of which also adopt nitrogen as their coverage and purge gas for the primary circuit tanks.

For H-3, noble gases, iodines and other radionuclides, the UK HPR1000 gaseous annual discharges are in the range of international discharges (mostly lower than the majority of comparable plants), as shown in F-6.7-2, F-6.7-3, F-6.7-4 and F-6.7-5.

b) Liquid discharges

For liquid discharges, according to F-6.7-6 and F-6.7-7, the UK HPR1000 annual discharges of H-3 and other radionuclides are lower than majority of comparable plants.

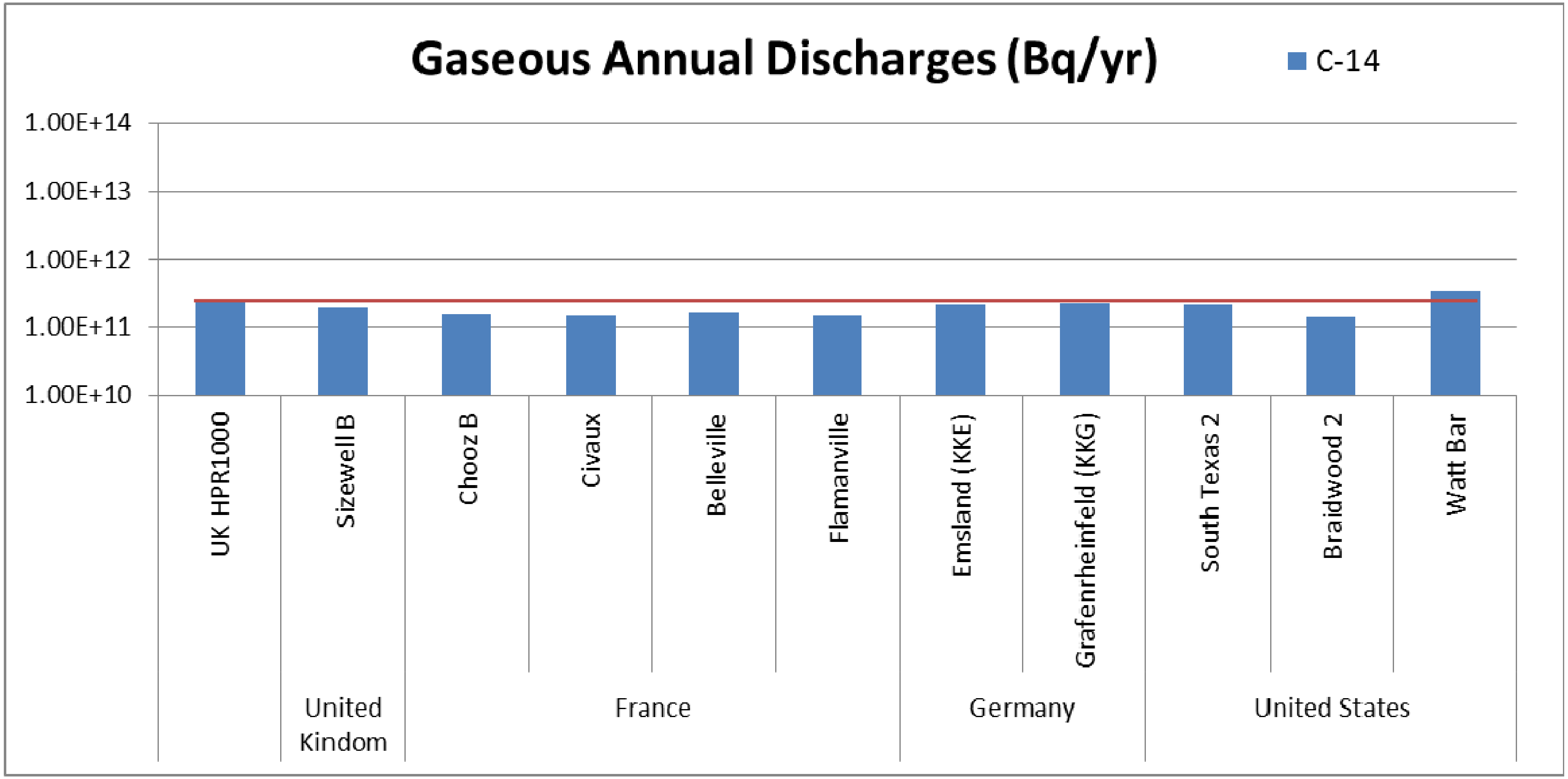
In addition, differences in the reporting approaches can also have an influence on the discharge OPEX data: In the UK, France and China, the conservative reporting approach is adopted, which means to report half of the detection limit for the main radionuclides when their values are below the detection limits (the measured values are null); while in the United States and Germany, the measurement-based reporting approach is adopted, which means to report null or “below LoD” when their values are below the detection limits (the measured values are null). Therefore, the discharges of UK HPR1000, UK fleet and French fleet are normally higher for the main radionuclides than those of American fleet and German fleet.

More detailed information on the international OPEX data, including the scope and the selection of OPEX data, is provided in the supporting document *OPEX Data*

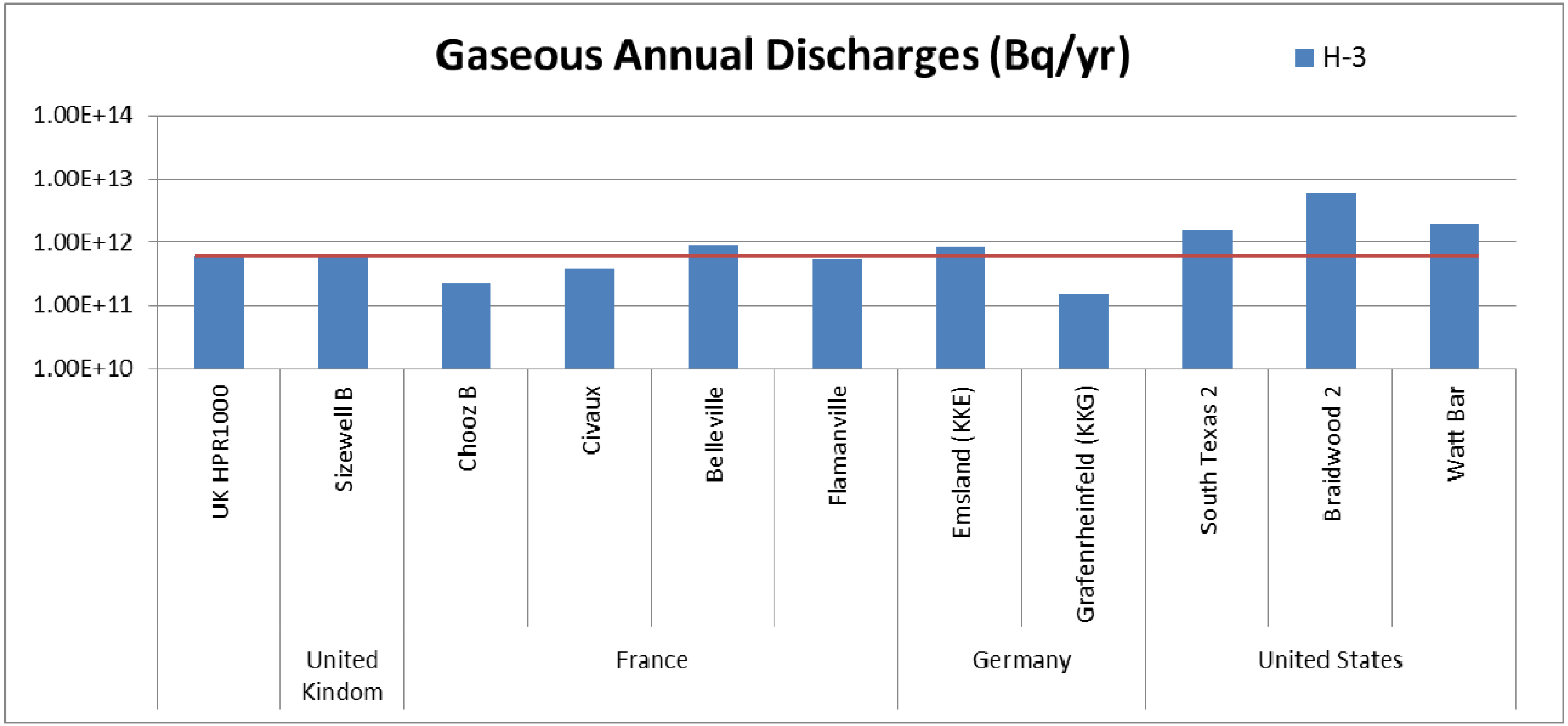
Selected for Quantification of Discharges and Limits for UK HPR1000, Reference [11].

T-6.7-1 Comparison of UK HPR1000 Annual Discharges with International OPEX Data _Normalised to 1000MWe (Reference [19])

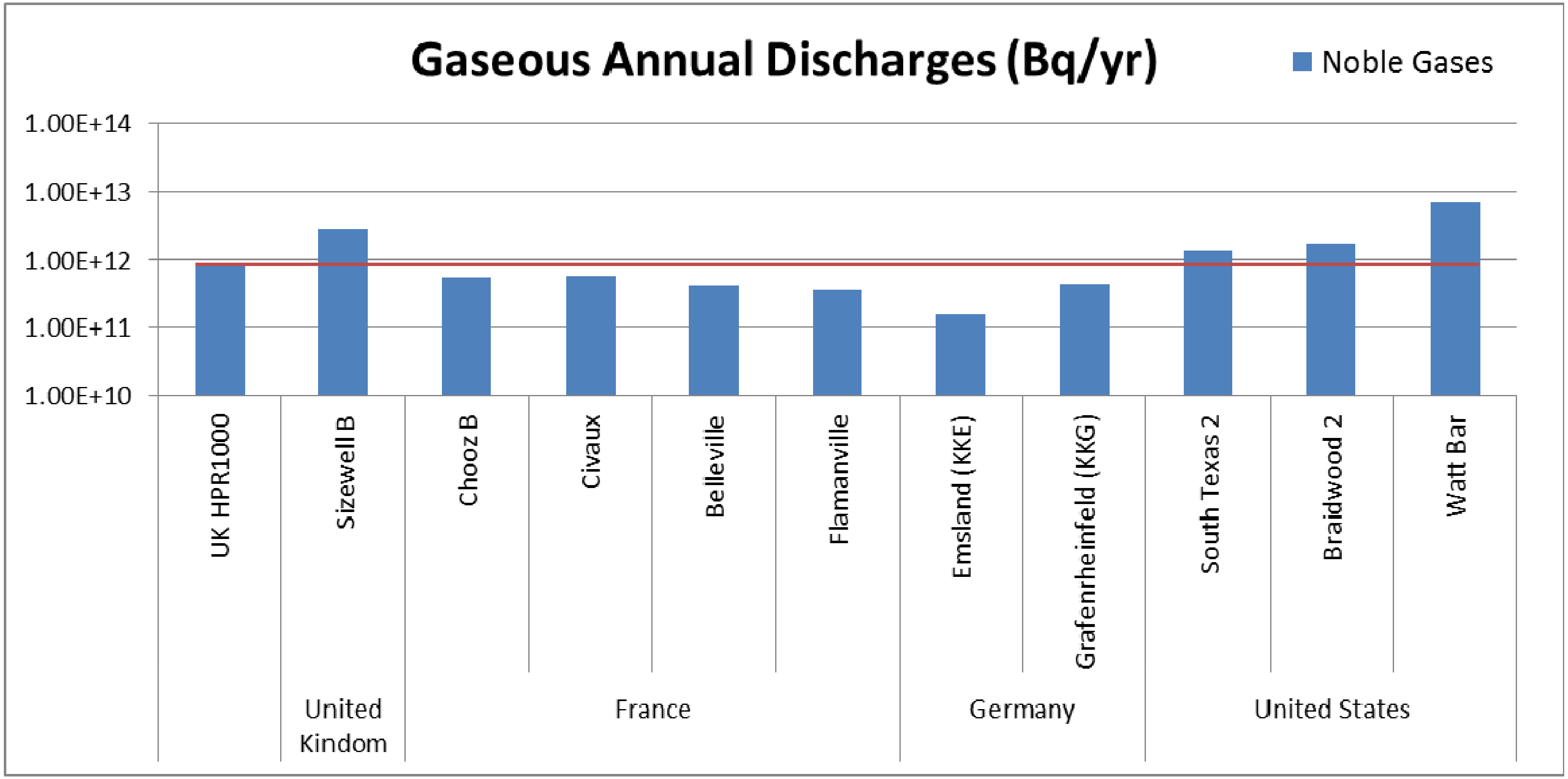
No.	Nation	Site/Unit	Gross Electrical Power (MWe)	Nomalised Gaseous Discharges (Bq/(unit•yr))					Nomalised Liquid Discharges (Bq/(unit•yr))	
				C-14	H-3	Noble Gases	Iodines	Others	H-3	Others
1	—	UK HPR1000	1180	2.44E+11	6.06E+11	8.16E+11	5.03E+06	3.08E+06	1.87E+13	5.93E+09
2	United Kingdom	Sizewell B	1250	1.97E+11	6.49E+11	2.81E+12	1.30E+08	1.71E+07	3.33E+13	1.19E+10
3	France	Chooz B	1560	1.54E+11	2.23E+11	5.44E+11	6.07E+07	2.44E+06	1.64E+13	1.17E+10
4		Civaux	1561	1.51E+11	3.79E+11	5.72E+11	4.04E+07	8.90E+05	1.40E+13	1.14E+10
5		Belleville	1310	1.54E+11	8.80E+11	3.93E+11	2.41E+07	6.60E+06	2.02E+13	1.17E+10
6		Flamanville	1330	1.41E+11	5.26E+11	3.45E+11	1.52E+07	1.36E+06	1.94E+13	1.14E+10
7	Germany	Emsland (KKE)	1363	2.10E+11	8.47E+11	1.55E+11	6.82E+05	5.11E+04	1.29E+13	7.02E+04
8		Grafenrheinfeld (KKG)	1345	2.18E+11	1.48E+11	4.21E+11	3.23E+05	1.83E+06	1.28E+13	4.76E+07
9	United States	South Texas 2	1250	2.16E+11	1.61E+12	1.39E+12	6.70E+06	2.18E+07	2.86E+13	9.33E+09
10		Braidwood 2	1121	1.44E+11	6.16E+12	1.77E+12	3.09E+07	1.42E+06	4.08E+13	1.59E+09
11		Watt Bar 1	1121	3.41E+11	2.00E+12	6.94E+12	9.39E+07	2.94E+07	5.49E+13	1.84E+10



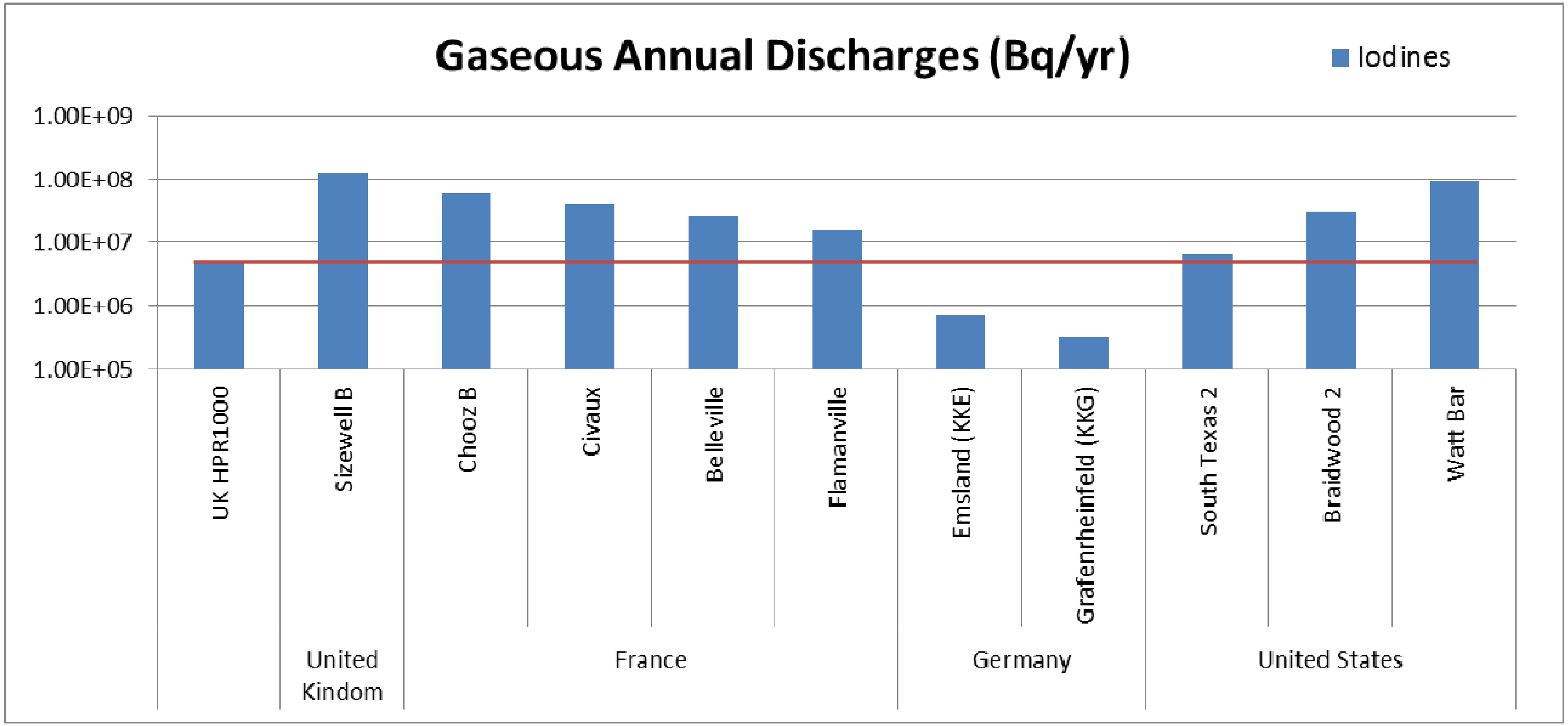
F-6.7-1 Comparison of UK HPR1000 Gaseous Annual Discharges with International OPEX Data _ C-14 (Normalised to 1000MWe)



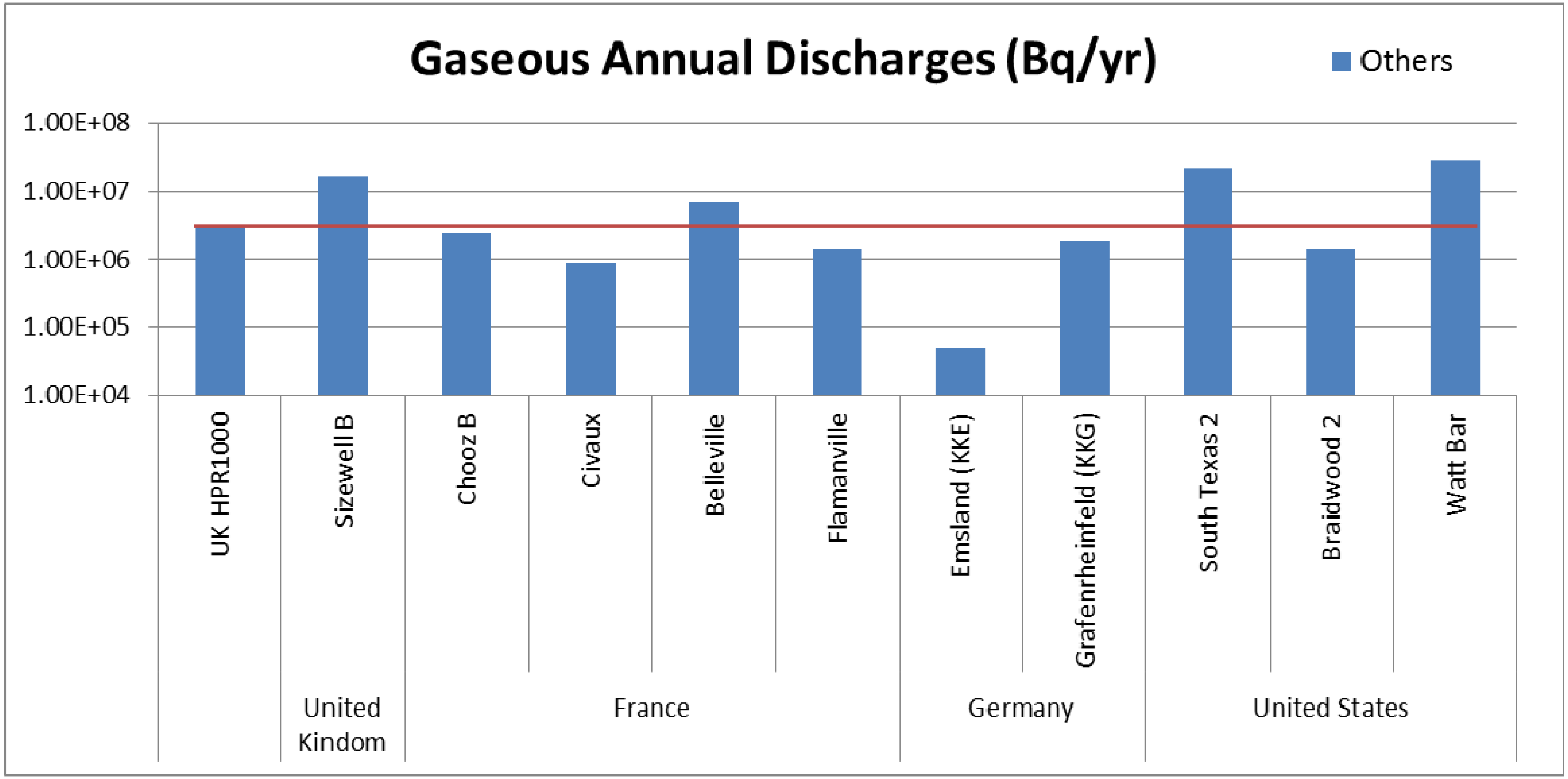
F-6.7-2 Comparison of UK HPR1000 Gaseous Annual Discharges with International OPEX Data _ H-3 (Normalised to 1000MWe)



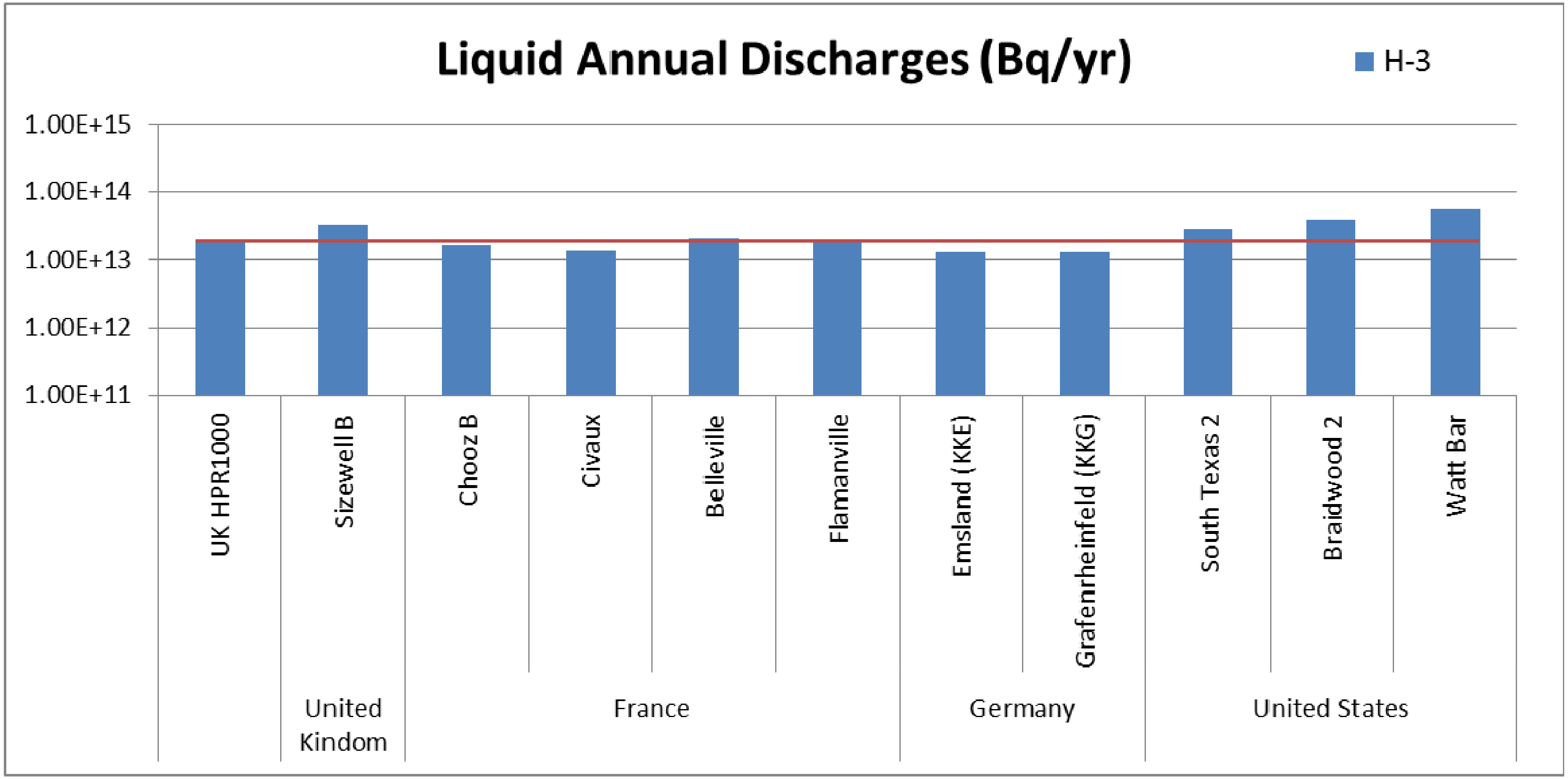
F-6.7-3 Comparison of UK HPR1000 Gaseous Annual Discharges with International OPEX Data _ Noble Gases (Normalised to 1000MWe)



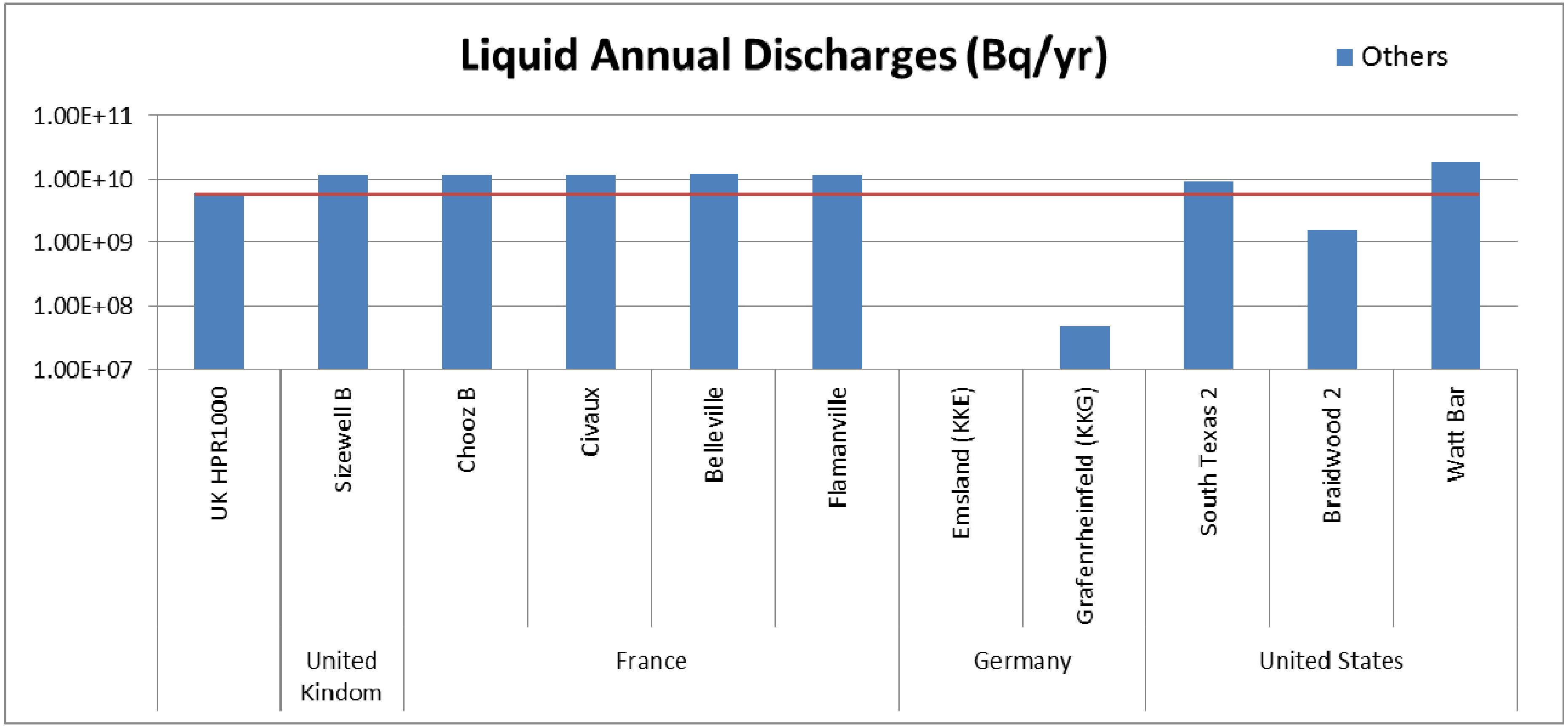
F-6.7-4 Comparison of UK HPR1000 Gaseous Annual Discharges with International OPEX Data _ Iodines (Normalised to 1000MWe)



F-6.7-5 Comparison of UK HPR1000 Gaseous Annual Discharges with International OPEX Data _ Others (Normalised to 1000MWe)



F-6.7-6 Comparison of UK HPR1000 Liquid Annual Discharges with International OPEX Data _ H-3 (Normalised to 1000MWe)



F-6.7-7 Comparison of UK HPR1000 Liquid Annual Discharges with International OPEX Data _ Others (Normalised to 1000MWe)

6.8 Conclusion

This chapter presents the methodology and estimation for quantification of the radioactive gaseous and liquid discharges and limits for UK HPR1000, in line with the relevant P&ID requirements, REPs principles and other related requirements.

The discharge routes and effluent streams are identified according to the system and process design and the radioactive waste management arrangement strategy.

At element 3 entry, on the basis of the current basic OPEX data (CGN OPEX data), considering all possible discharge routes and effluent streams, the UK HPR1000 radioactive gaseous and liquid discharges and limits during normal operation have been estimated. The UK HPR1000 annual releases are compared with the international OPEX data and proved that they are in the range of the representative international discharges.

During element 3, the collection of OPEX data and verification and analysis of expected events will be continued to better refine the estimated discharges and limits. The discharges and limits during GDA process will be finalised and compared with the comparison data (international OPEX data) before the end of element 3.

The estimated discharges and limits are used as inputs for the environmental impact assessment in PCER Chapter 7.

6.9 References

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[5] GNS, Pre-Construction Safety Report Chapter 5 Reactor Core, HPR/GDA/PCSR/0005, Revision 000, September 2018.

[6] GNS, Pre-Construction Safety Report Chapter 6 Reactor Coolant System, HPR/GDA/PCSR/0006, Revision 000, September 2018.

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[11] CGN, OPEX Data Selected for Quantification of Discharges and Limits for UK HPR1000, GHX35000001DNFP03GN, Rev B, September 2018.

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