Assessment of doses to the public from the expected operations of the proposed Hinkley Point C Power Station

A review of NNB GenCo's dose assessment by the Environment Agency

An independent dose assessment by the Environment Agency

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Executive summary

NNB Generation Company Limited (NNB GenCo) has submitted an application for an environmental permit for a proposed new power station at Hinkley Point in Somerset. NNB GenCo is planning to install 2 UK European Pressurised Water Reactor units (UK EPR) to create a new power station. The new power station will be referred to as Hinkley Point C and will be located next to the existing Hinkley Point A and B power stations. Under the Environmental Permitting Regulations 2010, the Environment Agency requires applications for permits for radioactive waste disposals and discharges to include an assessment of the impacts of liquid and gaseous radioactive waste disposals on the public and the environment. NNB GenCo includes such an assessment in its application for an environmental permit. This assessment was in a submission that supported the application.

The annual maximum radioactive liquid and atmospheric discharges from the 2 proposed reactors were used as the basis for assessing doses to the local population and collective doses to the UK, Europe and the World populations. NNB GenCo also considered the effect of discharges made at the operating limits they were proposing and whether there were likely to be significant differences in dose at its proposed limits or at the maximum expected discharges. NNB GenCo presented a detailed site-specific assessments of doses to candidate representative persons, and collective doses to the UK, European and World populations (truncated at 500 years), estimated using the PC CREAM 98 software. The doses from expected short-term releases, the potential impact of build-up of radionuclides in the environment and of dose rates to representative non-human biota were also assessed.

As part of the determination process, the Environment Agency has decided that an in-depth independent review of the NNB GenCo assessment supported by an independent dose assessment would provide an appropriate level of scrutiny. This independent review and assessment takes account of the discharge information, design and site-specific information, provided by NNB GenCo in its submission. The aim of the independent assessment was to:

- Review and validate the assumptions made by NNB GenCo in its dose assessments;
- Verify and confirm the outcomes of the dose assessments made by NNB GenCo;
- Carry out an independent dose assessments to provide a final view on the validity of the dose assessments carried out by NNB GenCo.

For the validation and verification activity, the approach to dose assessment used by NNB GenCo was reviewed and the outcomes confirmed by repeating the calculations.

Verification and confirmation of the NNB GenCo assessment outcome

NNB GenCo estimated the annual effective doses to the most exposed members of the local population, arising from the maximum annual radioactive discharges to atmosphere from Hinkley Point C to be 4.5 µSv/y (to infants). It was possible to confirm the results of the NNB GenCo assessment. NNB GenCo estimated the annual effective doses to the most exposed members of the local population, arising from maximum annual liquid radioactive discharges from Hinkley Point C to be 1.1 µSv/y (to adults). It was possible to confirm the results of the NNB GenCo assessment. NNB GenCo estimated maximum direct radiation dose of around 0.8 µSv/y, to a walker along the site fence and a maximum direct dose of around 0.001µSv/y to local residents. These doses were confirmed.

NNB GenCo predicted the highest dose from the maximum anticipated short-term releases to atmosphere to be 0.45 µSv/y. It was possible to repeat this assessment result, albeit with the application of alternative simple assumptions for terrestrial food pathways.

The total collective doses (truncated at 500 years) to the UK, European and World populations, arising from the predicted maximum atmospheric and liquid discharges from Hinkley Point C, were predicted to be 0.4, 3.2 and 27 manSv per year of discharge, respectively. The corresponding per caput doses were predicted to be in the nSv range. It was possible to reproduce the collective doses from liquid discharges. The outcomes of the verification assessment for atmospheric discharges were identical to NNB GenCo's results for World population, but between 75% and 90% for UK and EU populations.

NNB GenCo's submission included assessments of doses to the candidates for the critical group (candidates for the representative person)[1], taking account of exposure arising from liquid and atmospheric discharges from all three power stations at Hinkley Point. The dose to the representative person (infant member of a farming family) was predicted to be 17 µSv/y for the combined discharges from all three power stations at Hinkley Point, of which 4.5 µSv/y was from Hinkley Point C. NNB GenCo considered the contribution of direct radiation pathways to the representative person to be negligible. These outcomes were confirmed, albeit with minor differences for doses from atmospheric pathways.

NNB GenCo also assessed doses to the public from discharges at its proposed limit for the site. The predicted doses were within 6% of the doses assessed at the maximum expected discharges.

The NNB GenCo assessment of the buildup of radionuclides in the environment was confirmed with the same results. NNB GenCo also estimated the potential doses to exposed members of the public arising from the buildup of radionuclides in the environment. The predicted dose to an adult member of the fishing family (1.1 µSv/y) was considered to be representative of the highest dose that may arise in the future from the buildup of radionuclides in the marine environment. The dose to a construction worker from exposure to contaminated land was estimated to be 0.004 µSv/y due to atmospheric discharges from Hinkley Point C and 0.02 µSv/y for atmospheric discharges from all three power stations at Hinkley Point. These assessments were reviewed but not repeated. NNB Genco had made use of previously published model for doses from contaminated land for construction worker doses.

The NNB GenCo assessment of dose rates to representative non-human biota from maximum annual atmospheric and liquid discharges was also repeated. The results were close to those presented by NNB GenCo, although there were some minor differences in the predicted dose rates to terrestrial organisms.

Review and validation of the assessment approach used by NNB GenCo

The assessment approach used by NNB GenCo was reviewed for validity by detailed critical review of the approach and parameters used in the assessments presented by NNB GenCo. The review was conducted against existing practise and accepted approaches. This review showed that NNB GenCo had mostly used standard approaches, with some differences at a detail level which would have some effect on the outcome, in some cases leading to higher estimates of dose and in some cases lower estimates of dose.

For the overall environmental modelling, NNB GenCo applied PC CREAM 98 throughout its assessment. A revised version of this software tool (PC CREAM-08) was released in 2008/9. Both versions of the model are considered to be valid for prospective dose assessments. However there are differences in the detail in some data that describe the transfer of radioactivity through the environment, PC CREAM-08 using more up to date data, in particular transfer parameters and Kd values and a different European population for collective dose. The impact of these changes was considered in the independent dose assessment. The location of the nearest receptor at 1.3km and 1.7km from the site was questioned, as it represents the current situation. 60 years in future, people could be living closer to the site than they do now. The effect of being closer to the site (500m) in future was considered in the independent dose assessment.

For estimation of internal exposure, NNB GenCo has adopted the radiation risk factors published by ICRP in 1991 and reviewed and restated in 2007 and internal dose coefficients published by ICRP in 1996 and as laid down in European Legislation at around the same time. The Health Protection Agency has previously advised that the use of the 1996 dose coefficients and ICRP recommended risk factors for radiation protection of the public is valid.

Independent dose assessment

An independent assessment of doses to the public from expected discharges from Hinkley Point C was made, following the recommendations contained in the dose assessment principles document, including the guidance on habit data, and using information provided by NNB GenCo in its submission. For some parts of the independent assessment assumptions and inputs that were different to those adopted by NNB GenCo were used, including use of the more recent PC-CREAM-08 software and the future location of the receptors or reference groups. The assessment was based on discharge information provided by NNB GenCo and site-

[1] The 'representative person' is 'an individual receiving a dose that is representative of the more highly exposed individuals in the population' [NDAWG, 2011]. The term representative group is equivalent to, and now replaces, the term 'critical group' used by NNB GenCo in their submission.

specific and other generic assumptions in accordance with recommendations on best practice and people living closer to the site than NNB GenCo had assumed.

The first stage of the independent assessment was to apply our Initial Radiological Assessment approach. A more detailed assessment was then undertaken, in which the following were assessed for liquid and atmospheric discharges:

- the annual dose to the representative person for Hinkley Point C;
- the potential short-term doses from the maximum anticipated short-term discharges from normal operation;
- collective doses to the UK, European and World populations truncated at 500 years;
- annual dose to a representative person due to combined future operations of all three power stations at Hinkley Point;
- the total dose to a representative person, including the contribution from other sites and previous operations;
- dose rates to a range of reference organisms in the terrestrial and marine environments.

The PC-CREAM-08 software was used and the dose assessment principles document was followed.

Direct radiation was estimated and included following the NNB GenCo approach and information provided by the ONR.

As a final check the outcome of the independent assessment was compared with the NNB GenCo dose assessment outcomes.

Our independent assessment predicted the dose to representative members of the public from atmospheric discharges of 7.2 µSv/y to adult local residents who consume locally produced milk. The ingestion of carbon-14 in milk accounts for the majority of the dose predicted from atmospheric discharges. This was similar to the assessment outcome from NNB GenCo.

At the maximum liquid discharges, the highest dose to members of the public from marine discharges has been predicted to be around 3.7 µSv/y to an adult consumer of crustaceans. The dose arises primarily from carbon-14 in fish and crustaceans. This was similar to the assessment outcome from NNB GenCo.

For the direct radiation pathway, our independent assessment was based on the approach presented by NNB GenCo, however our assessment was made assuming one or more houses at 500m from the site. Houses do not currently exist at this distance – however the assessment covers 60 years of operation and so it is prudent to consider future changes to land use. For a house at this distance direct radiation were assessed as ranging from 0.1 to 0.4 µSv/y. Allowance was made for walking close to the site which added 0.8 µSv/y, giving a total shine dose of 0.9 µSv/y to 1.2 µSv/y.

The total dose from Hinkley Point C was therefore 8.4 µSv/y to a resident at 500m from the site who consumes local food produced on average 500m from the site. The outcomes of both our assessment and NNB GenCo's assessments are below the dose constraint of 300 µSv/y (and the proposed dose constraint for new nuclear power stations of 150 µSv/y)

Our independent assessment also made an estimate of the dose to the representative person (a local adult consumer of milk) arising from future operation of all three power stations at Hinkley Point, taking account of atmospheric and liquid discharges from all three power stations. The dose to representative person for discharges from the site as a whole was estimated to be 15.5 µSv/y. This is made up from 7.2 µSv/y from atmospheric and liquid discharges from Hinkley Point C and 8.3 µSv/y from atmospheric and liquid discharges from Hinkley Point B; discharges from the incinerator at Hinkley Point B and from atmospheric and liquid discharges from Hinkley Point A. The outcomes of both our assessment and NNB GenCo's assessments are well below the site dose constraint of 500 µSv/y.

The results of our independent assessment differ slightly to those presented by NNB GenCo because different assumptions about habits and the location of local residents were applied in our assessment. Our independent assessment also applied data from the more recent version of the PC CREAM software (PC CREAM 08).

Our independent assessment also included the assessment of the total dose arising from future operations and decommissioning activities at Hinkley Point A, B and C stations and from historic operations at Hinkley Point and from other sources. The total dose to a resident 500m from Hinkley Point C who drinks local milk and eats local food is around 27 µSv/y. This is made up of the prospective dose from gaseous and liquid discharges from all three power stations at Hinkley Point of 15.5 µSv/y; expected direct radiation from Hinkley Point C of 1.2 µSv/y; current direction radiation from Hinkley Point A and B of 5 µSv/y; and the current dose arising from historic discharges and other sources of 5 µSv/y. The total dose to a local consumer of crustaceans who spends time on the beach was estimated to be 43 µSv/y. This is made up of the prospective dose from gaseous and liquid discharges from all three power power stations at Hinkley Point of 7.4 µSv/y;and the current dose arising from historic discharges and other sources of 36 µSv/y. Both these figures are significantly less than the dose limit for members of the public of 1000 µSv/y.

There were some differences between the outcome of our independent assessment of collective doses and those presented in the NNB GenCo submission for the UK, Europe and the world. In the independent assessment, using PCREAM-08 the predicted collective doses are higher for the UK by 30%, lower for the EU by 25% and the same for the world. Collective doses to the world are dominated by atmospheric discharges of carbon-14.

The highest estimated dose arising from short-term releases in the independent assessment was 5.2 µSv, which is greater than the 0.45 µSv/y predicted by NNB GenCo. This difference is a reflection of the differences in the assumption about the location of the exposed group, and to a certain extent to the greater level of simplification and conservatism implicit in the independent assessment of the contribution from terrestrial foods than in that undertaken by NNB GenCo. The concentrations of radionuclides in selected terrestrial foodstuff after one year following a single short term release event were found to be below the EC recommended food intervention levels (CFILs). If we assume that the total annual discharge was made over a short period then the predicted dose was 72µSv and the CFILs were still not exceeded.

Our independent assessment also included an assessment of the dose rates to non-human biota from maximum annual atmospheric and liquid discharges, on the basis of a range of reference organisms in the terrestrial and marine environments. The dose rates to the limiting organisms in these environments were predicted to be 0.007 and 0.008 µGy/h. These doses are about 4000 times lower than those at which effects on populations would start to occur.

Conclusion

We were able to verify and confirm the assessment of doses made by NNB GenCo.

We reviewed NNB GenCo's approach for validity and were able to confirm its approach was valid overall and followed appropriate practice.

We undertook an independent assessment ourselves. This was based on the review of the NNB GenCo approach but with some changes made to receptor point locations near to the site.

The outcomes of the independent assessment were compared with those provided by NNB GenCo. There was broad agreement between the doses predicted by NNB GenCo and those predicted in our assessment.

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Introduction

1 In June 2006, in response to a request from the Energy Minister, we (the Environment Agency) established a two phased process for the consideration of new nuclear power stations. The first phase addresses generic design matters and the second deals with applications for permits under the Environmental Permitting (England and Wales) Regulations 2010 for specific sites.

2 We carried out detailed assessments of the environmental effects of two candidate designs under the Generic Design Assessment (GDA) arrangements [Ref.1 & 2]. The GDA assessments were based on generic site description and characteristics proposed by the requesting parties that reflected the relevant constraints of potential sites in England and Wales.

3 In 2011 NNB GenCo applied for a Development Consent Order and a Nuclear Site licence for a new power station at Hinkley Point. They also applied to the Environment Agency for Environmental Permits for the disposal of radioactive waste, the operation of standby diesel generators and the discharge of cooling waters and trade effluent. The proposed power station is known as Hinkley Pint C and will comprise two reactors of the UK EPR type [Ref. 3]. Discharges of radioactivity will need to be made during the operation and decommissioning of this power station. Therefore NNB GenCo needs to apply for new Environmental Permits from the Environment Agency for its proposed power station. The application for the Environmental Permit must include an assessment of the potential impacts of liquid and gaseous radioactive waste discharges on the public and the environment. The application should be supported with sufficient information to allow determination of the application, including the assessment of the impact of permitted discharges of radioactivity. For the proposed Hinkley Point C power station, we decided that an in-depth independent review of the NNB GenCo assessment supported by an independent site specific dose assessment would provide an appropriate level of scrutiny of the assessment of the impact of permitted discharges of radioactivity provided by NNB GenCo.

4 We have set out requirements in our guidance note for part RSR-B3 of the permit application [Ref. 4] for the applicant to provide a prospective dose assessment at its proposed permit limits for discharges and for any on-site disposal (such as incineration, but not on-site disposal of solid waste to land).

5 The NNB GenCo submission included an assessment of annual individual and collective doses arising from maximum annual liquid and gaseous discharges, and of potential short-term doses from the maximum anticipated short-term discharges from normal operation [Ref. 3]. The submission also proposed permit limits that grouped together the nuclides that were expected to be discharged. The differences between the maximum expected discharges and the permit limits proposed by NNB GenCo were also considered. These assessments were based on the UK EPR design and site characteristics of Hinkley Point [Ref. 3].

6 We commissioned a review of the assessments forming part of the NNB GenCo submission which included a critical review of the NNB GenCo's submission which involved a review and validation of the assumptions made by NNB GenCo and a verification and confirmation of the outcomes of the dose assessments reported by NNB GenCo.

7 We have also undertaken an independent assessment of the impact of expected liquid and gaseous discharges from the proposed Hinkley Point C power station, and made an assessment of doses at the limits proposed by NNB GenCo. We have also assessed the total dose from the site including the total impact of past and future discharges from Hinkley Point A and Hinkley Point B.

Report layout

8 The report is divided into 3 parts:

- Part 1:- Review and validate the assumptions made by NNB GenCo in its dose assessments.
- Part 2:- Verification and confirmation of the outcomes of the dose assessments carried out by NNB GenCo.

- Part 3:- Make an independent dose assessments to determine whether the dose assessments carried out by NNB GenCo are appropriate and for future regulatory use.

PART 1: Review and Validation of the NNB GenCo Assessment

9 The radiological assessment approach taken by NNB GenCo was reviewed using NDAWG publications and other guidance to confirm the validity of the approach.

Discharge data used in the assessments

10 One of the key data inputs for prospective dose assessments is information on the radionuclides to be discharged and the quantity of each (source term). During normal operations, the expected discharges can be predicted and used to inform the permit limits. The NNB GenCo submission includes information on the predicted annual and rolling average monthly liquid and gaseous radioactive discharges from Hinkley Point C [Ref. 3]. These annual values are representative of maximum discharges under normal operating conditions. Review of the discharge information is not part of the dose assessment review in this report, however as the discharge information is central to the assessment outcomes the discharge data has been summarised for clarity.

11 NNB GenCo has also proposed discharge limits based on its maximum expected discharges for normal operations. For the NNB GenCo's proposed permit limits, some of the radionuclides that will be discharged have been grouped together. Some other radionuclides that are not proposed to be subject to limits are included to ensure the assessment takes all expected discharges into account. This is an additional step which is not required in the Environment Agency's guidance. Some groups of radionuclides expected to be subject to limits were assessed at expected mixtures for those groups.

12 NNB GenCo's proposed limits are very similar to the maximum expected discharges. A summary of the annual maximum radioactive discharges to the atmosphere [Ref 3] and the proposed limits are given in Table 1. The maximum short-term discharges to atmosphere, envisaged to occur under normal operational conditions as a result of outages, start up or when purging the cooling system [Ref. 3], are presented in Table 2. The annual maximum liquid radioactive discharges [Ref. 3] and the proposed limits are shown in Table 3.

13 NNB GenCo made two assessments – one main dose assessment based on the maximum expected discharges and a second assessment based on its proposed limits. For the assessment of doses due to discharges from all three power stations at Hinkley Point and total dose, discharges from Hinkley Point A and B are assumed to occur at the current permit limits (Table 1 and Table 3).

Review of applicant's assessment approach

14 The assessment in the NNB GenCo submission included an assessment of the impacts of discharges to atmosphere, liquid discharges to the marine environment and from direct radiation. The assessments of individual doses to representative persons (critical groups) from discharges were undertaken using PC CREAM 98 [Ref 6].

15 The contribution from direct shine was estimated using simple conservative assumptions regarding on-site dose rates and the location of representative persons (critical groups).

16 An assessment of the potential dose from the maximum anticipated short-term atmospheric discharge from normal operation was also made. The ADMS dispersion model [Ref 7] was used and the activity concentrations in terrestrial foods were estimated using a dynamic modelling approach derived from the HPA FARMLAND model [Ref 8].

17 The collective doses arising from maximum annual atmospheric and liquid discharges were also assessed, using PC CREAM 98 and the associated population and agricultural production grids.

18 The NNB GenCo submission also included an assessment of potential impacts of annual atmospheric and liquid discharges to non-human species - representative terrestrial and marine organisms. These assessments were undertaken using the ERICA Tool (May 2009 version) [Ref 9] and the Environment Agency's R&D 128 assessment procedure for wildlife [Ref. 10].

19 A review of the approaches adopted by NNB GenCo is given in detail in Appendix 2.

20 Members of the public can be exposed to radionuclides discharged to atmosphere or to the marine environment by a range of exposure pathways. The exposure pathways considered in the NNB GenCo assessment were based on knowledge of the nature of nuclear sites, the dispersion of radionuclides following release, site specific information on land use around the site and information on people's habits. The NNB GenCo assessment made use of generic habit data for members of the public using the top two method for assessing doses from discharges from the proposed Hinkley Point C site. The current recommended approach for using human habit data if site specific data are available is to create a series of human habit profiles and calculate doses for each to identify the representative individual. This approach tends to be more realistic and leads to lower doses than the top two approach.

21 Internal exposure from breathing in radionuclides or ingesting them in food was estimated using dose co-efficients for the public published by ICRP in 1996 and included in European legislation at that time [Ref 17&18]. ICRP also restated its recommended cancer risk factors from radiation dose [ref 17]. The ICRP approach was confirmed as being best practise by the Health Protection Agency (HPA). HPA has previously advised that the ICRP dose coefficients and ICRP advice on radiation protection remain appropriate for use in radiation protection of the public.

22 In its 2007 recommendations, the ICRP updated its radiation protection advice. Much remains unchanged, however one of the changes was adoption of new terminology for the most exposed group. The long standing term 'critical group' is being replaced by a new term 'representative person'. HPA has advised that the meaning of the new term is that same as 'critical group' and that gradual adoption of the new term should be undertaken. NNB GenCo have retained the former term (Critical Group).

Atmospheric discharges

23 For the assessment of impacts from atmospheric discharges the following pathways have been considered:-

- ***Internal irradiation*** following inhalation of radionuclides discharged to atmosphere and from resuspension of deposited material;
- ***Internal irradiation*** from the ingestion of radionuclides incorporated into locally produced foods following deposition of radionuclides discharged to atmosphere;
- ***External irradiation*** from radionuclides in the atmosphere and deposited on the ground following discharge to atmosphere.

24 NNB GenCo identified a farming family spending time at 1.3km and 1.7km from the point of discharge from Hinkley Point C as the basis for a potential representative person. The doses from all atmospheric pathways were assessed using the PLUME and ASSESSOR modules of PC CREAM 98 [Ref. 6], based on the predicted maximum annual discharges from Hinkley Point C, as presented in Table 1. The doses arising from releases from Hinkley Point A and B power stations were also assessed, based on the current permit limits for those sites[2]. Three age groups were considered in both assessments. The assumptions and parameters applied by NNB GenCo were reviewed and generally found to be consistent with good practice. However, the merit of considering a location closer to the discharge point was noted. The general application of PC CREAM 98, rather than the more recent version of this software PC CREAM-08, was also queried, as discussed in Appendix 2. However we do not expect the

[2] The authorised discharge limits for Hinkley Point A have since then been reduced.

use of older software to significantly affect the result. Changes to assessment outcome can be expected at a detail level for some radionuclides when using the two versions of the code. In the independent assessment – PC-CREAM-08 was used and the outcomes were compared. This showed some changes but the overall outcomes were similar. The approach used to define habits to the potential exposure groups is consistent with the options for good practice, although it differs to that used in the independent assessment, as discussed in Part 2 of this report.

Liquid discharges

25 For discharges of liquids to coastal waters:

- ***External irradiation*** following incorporation of radionuclides into coastal sediment, including exposure to the skin from handling of fishing gear which has come into contact with the sediment.
- ***Internal irradiation*** following the ingestion of radionuclides in marine fish and shellfish caught along the coast;

26 NNB GenCo included an assessment of the inhalation of seaspray, which is normally not considered to be a major dose pathway.

27 NNB GenCo considered doses to a representative fishing family and houseboat family. The assessment was made using the DORIS and ASSESSOR modules of PC CREAM 98, based on the predicted maximum annual discharges from Hinkley Point C. The doses arising from releases from Hinkley Point A and B power stations were also assessed, based on the current permit limits for those stations. Three age groups were considered in both assessments. The assumptions and parameters applied by NNB GenCo were reviewed and generally found to be consistent with general practice, as discussed in Appendix 2.

28 NNB GenCo undertook an assessment of external doses to houseboat dwellers due to occupancy on water and over sediment (from radionuclides in water and in sediment) using Microshield software. This assessment was reviewed and generally found to be reasonable. The assessment approach has not been repeated, although an approach based on the application of external dose coefficients presented in the US EPA FGR 12 publication [Ref 12] were used (see Appendix 2).

Review of approach to estimate individual doses from direct radiation

29 NNB GenCo undertook an assessment of the potential contribution from direct radiation from a waste store located close to the site boundary. It was assumed that the outer wall of the waste store lies along the boundary between the site and an undesignated area and that the dose rate at 1 m from the wall is 0.5 μSv/h. The dose rate at representative distances at which members of the public are located or have access to (local residences and the site fence) were assessed using simple geometric assumptions. The potential representative persons considered were as follows: walker at 0.04 km and local residents at 1.3 km and 1.7 km from the waste store [Ref. 3].

30 This approach was reviewed and repeated and generally found to be reasonable and likely to be conservative (see Appendix 2).

Review of approach to estimate total doses from the combined discharges from Hinkley Point A, B and C

31 An assessment was also undertaken of the total doses from liquid discharges and gaseous discharges from Hinkley Point C taken together. The total dose was estimated by considering two groups - a farming family with marine exposure pathways and a fishing family with exposure to atmospheric pathways. A similar assessment was also undertaken for discharges from all three power stations at Hinkley Point. The overall approach was considered to be reasonable. However, direct radiation was not included – whereas its inclusion is appropriate in some assessments (see Appendix 2).

Review of approach to estimate collective dose

32 Collective doses to UK, EU and World populations (truncated at 500 years) from maximum annual atmospheric and liquid discharges were calculated using PC CREAM 98 [Ref. 6]. This approach is consistent with good practice, except for the use of PC CREAM 98 rather than the more recent version of this software.

Review of approach to estimate doses from short-term releases

33 NNB GenCo also assessed potential doses to representative persons arising from short-term (24 hour) releases to the atmosphere from Hinkley Point C. The predicted short-term releases were based on the maximum anticipated monthly discharges under normal operating conditions [Ref. 3]. Doses from ingestion of contaminated foodstuff, inhalation of plume, and external dose from plume immersion and ground deposition were assessed. In assessing potential doses via ingestion of contaminated foodstuff, NNB GenCo used an approach that involved the replication of the dynamic food chain model FARMLAND within the compartmental modelling software ModelMaker to derive time integrated activity concentration in foodstuff [Ref. 3]. This approach was considered to be reasonable, although rather complex. An alternative approach was applied in the independent assessment, based on simple assumptions for transfers to terrestrial food [Ref. 11 & 15].

Review of approach to estimate non-human dose rates

34 Doses to non-human species were calculated using the ERICA Tool (May 2009 version) [Ref. 9] and the Environment Agency R&D 128 approach [Ref. 10] for the calculation of exposures from noble gases. This approach was reviewed and considered to be consistent with good practice.

Review of approach to estimate build up of radionuclides in the environment

35 Where discharges are likely to be ongoing for a number of years, build up of some radionuclides in parts of the environment can be expected. Buildup can be a complex process with additions from ongoing discharges and nuclide specific concentration effects in some environments, with counterbalancing effects such as loss by decay and dispersion which may partly or completely match the buildup effects. The default approach is to model build up over a 50 year period because this is the approximate lifetime of a nuclear site and the majority of nuclides will come to equilibrium for a constant input within this time frame. Both versions of PC CREAM (98 and 08) allow for buildup over 50 years, make use of nuclide specific concentration factors, and allow for decay and dispersion. Over the 60 year lifespan of the plant the model predicts that levels of radionuclides will reach equilibrium with the discharges made, if the discharges are fairly constant over the time.

36 The NNB GenCo submission includes an assessment of the build up of radionuclides discharged into the atmosphere using air concentration values and soil concentration per unit deposition rates values obtained from ASSESSOR and FARMLAND modules of PC CREAM 98 (respectively) [Ref. 6]. Where discharges are likely to be ongoing for a number of years, build up of some radionuclides in parts of the environment can be expected. Buildup may be a complex process with additions.

37 The build-up of radionuclides in seabed sediment and in unfiltered seawater was calculated for discharges of radioactive liquids into the marine environment using the DORIS module of PC CREAM 98 [Ref. 6].

38 The approach used to derive the activity concentrations in the environment was reviewed and calculations repeated. The applicability of the dose assessment approach adopted was not repeated. NNB GenCo had applied the methodology for assessing doses from contaminated land (see Appendix 2).

Summary of the review findings

39 The assessment approach used by NNB GenCo was reviewed for validity by detailed critical review of the approach and parameters used in the assessments presented by NNB GenCo. The review was conducted against existing practise and accepted approaches. This review showed that NNB GenCo had mostly used standard approaches, with some differences at a detail level which were unlikely to have a significant effect on the outcome.

40 For the overall environmental modelling, NNB GenCo applied PC CREAM 98 throughout its assessment. A revised version of this software tool (PC Cream ’08) was released in 2008/9. Both versions of the model are considered to be valid for prospective dose assessments. However there are differences in the detail in some data that describe the transfer of radioactivity through the environment, PC CREAM-08 using more up-to-date data, in particular transfer parameters for the environment and Kd values for uptake onto sediment. The overall impact of the changes was small. The outcome from the independent dose assessments (which used PC-CREAM-08) is similar to the outcomes from NNB GenCo using PC-CREAM-98.

41 The location of the nearest receptor to the site for atmospheric releases was also queried. Currently the nearest groups of people are 1.3 to 1.7km from the site. However over the 60 years of planned operations this could change so that people are nearer. The highest air concentrations are predicted at a few hundred metres from the site. Therefore the independent assessment assumed groups of people living at 500m from the site. The habit data used were taken from generic UK data and used in the top two approach. Additional information was informed by recent site specific habit survey around the site. Current recommendations are that where site specific habit data are available, the data should be arranged into a series of profiles and the doses for each profile determined. The most affected profile is then identified as the representative person. The top two approach is likely to be conservative and generate an overestimate of doses.

42 For estimation of internal exposure, NNB GenCo has adopted the radiation risk factors published by ICRP in 1991 and reviewed and restated in 2007 and internal dose coefficients published by ICRP in 1996 and as laid down in European Legislation at around the same time. The Health Protection Agency has previously advised that the use of the 1996 dose coefficients and ICRP recommended risk factors for radiation protection of the public is valid.

PART 2: Verification and confirmation of the NNB GenCo assessment

43 The second stage was to verify the assessment outcomes provided by NNB GenCo by attempting to repeat and confirm the dose assessment results found by NNB GenCo using its input data and the same models. [Ref. 3]. This process was designed to identify any errors that may arise from inappropriate application of data or incorrect application of models or calculation errors.

44 The doses calculated by NNB GenCo from annual discharges of radionuclides to the atmosphere and to the marine environment were confirmed by repeating the assessment and reviewing the doses. The verification applied the same approaches, assessment parameters and assumptions used by NNB GenCo as contained in its report.

Verification of individual dose from discharges and direct radiation

45 In its detailed assessment, NNB GenCo estimated the annual effective doses to the most exposed members of the local population (farming family), arising from the predicted annual maximum radioactive discharge from Hinkley Point C to atmosphere, to be 4.4 µSv/y (to infants). It was possible to repeat this assessment outcome; the verification result was within 0.3 µSv/y of the result presented by NNB GenCo. See Table 4.

46 NNB GenCo estimated doses from the maximum annual liquid radioactive discharges from Hinkley Point C to the candidates for the representative person (adult member of fishing family) of 1.1 µSv/y. It was possible to repeat this assessment outcome. See Table 4.

47 The highest dose from direct radiation estimated by NNB GenCo was to a walker, who will spend time at the site fence. A dose of between 0.8 and 1.5 µSv/y was estimated, depending on the occupancy assumptions applied. The doses to local residents (at 1.3 and 1.7 km from the site) were of the order of a few nSv/y. It was possible to repeat these outcomes.

48 It was concluded that the candidate representative persons (farming and fishing families) would not receive a significant contribution from direct radiation from Hinkley C.

Verification of total doses from all three power stations.

49 NNB GenCo estimated the highest total dose from discharges from Hinkley Point C and from all three power stations at Hinkley Point, to be 4.5 µSv/y and 17.2 µSv/y, respectively (see Tables 4 and 5). In both cases, the farming family infant (assumed to be exposed to both terrestrial and marine exposure pathways) was predicted to receive the highest dose and therefore considered to be the representative person. It was possible to confirm these assessment outcomes for Hinkley Point C by repeating the calculation to within 0.3 µSv/y of NNB GenCo's estimates. The verification outcome for the dose from Hinkley Point A, B and C together was 4µSv/y higher than NNB GenCo's estimates.

50 The farming family is assumed to be located at 1.7 km from the source of direct radiation and, as indicated above, the dose rate at this location was negligible. This exposure route was therefore not assumed to contribute to the dose to the representative person.

Verification of the short-term release dose assessment

51 NNB GenCo estimated the highest potential dose of 0.45 µSv to an infant due to short duration (24-hour) releases from Hinkley Point C. This dose is dominated by contribution from the ingestion of carbon-14 in milk. It was possible to repeat this assessment outcome to within 10% of NNB GenCo's estimates (0.47 µSv) using a simplistic approach based on the modification of concentration factors contained within the FARMLAND module of PC CREAM.

52 The assessment was also repeated using food concentration factors recommended by NDAWG [Ref. 15]. The highest estimated dose using this approach was 1.8 µSv to an infant, a factor of 4 higher than NNB GenCo estimates.

53 Doses from non food pathways (inhalation dose, external dose from immersion in plume and external dose from deposited activity) were similar to NNB GenCo's outcomes.

Verification of the collective dose assessment

54 NNB GenCo estimated the collective dose truncated at 500 years from atmospheric discharges to be 0.4, 3 and 25 manSv per year of discharge to the UK, Europe and World populations respectively. The corresponding results for liquid discharges were 0.02, 0.2 and 2.2 manSv per year of discharge respectively (see Table 7). It was possible to repeat the outcomes for liquid discharges. However, the results of the verification assessment for atmospheric releases for UK and EU populations were between 75 and 90% of the values estimated by NNB GenCo and the same for the world population (See Table 7).

Verification of the modelling of build up of radionuclides in the environment

55 The results of the assessment of the build up of radionuclides from atmospheric discharges were of a similar order of magnitude and generally within rounding differences of those reported by NNB GenCo for both Hinkley Point C and the total discharges from all three power stations at Hinkley Point.

56 The build up of radionuclides in sediment and unfiltered seawater was assessed using the same approach as outlined in the NNB GenCo submission. The results obtained are in agreement with the activity concentrations reported by NNB GenCo for both Hinkley Point C and for all three power stations at Hinkley Point.

57 The results of the repeat assessment are presented in Tables 8 and 9.

Verification of the non-human dose rate assessment

58 The results of the verification assessment for habitat 1 (terrestrial) organisms were of a similar magnitude and generally within rounding differences of the dose rates predicted by NNB GenCo. The results of the verification assessment for habitat 2 (marine) organisms were found to be in agreement with NNB GenCo's results. For habitat 3 (coastal), the outcomes of the verification assessment for Hinkley Point C were similar to those reported by NNB GenCo, but higher for the total dose rates due to discharges from all three power stations at Hinkley Point.

59 The SRS model within ERICA was used by NNB GenCo to determine dose rates to organisms in habitat 4 (freshwater pond). It was not clear how the discharge rates applied by NNB GenCo were derived. The results of the verification assessment for freshwater organisms were of a similar magnitude, but greater than those predicted by NNB GenCo.

60 It was possible to replicate dose rates to non-human species in habitat 2 (marine) due to discharges of liquids to the marine environment for both Hinkley Point C and all three power stations at Hinkley Point. Dose rates to organisms inhabiting terrestrial, coastal and freshwater environments were also replicated, but with some minor differences, especially for discharges of gaseous wastes from all three power stations.

61 A summary of the results of the verification assessments for non-human species is presented in Table 10.

Summary of the verification findings.

62 The detailed dose assessments undertaken by NNB GenCo were repeated using the same assumptions and the results were confirmed as being the same as or close to NNB GenCo outcomes.

63 Differences were observed for doses associated with discharges to atmosphere. The doses associated with discharges to atmosphere from all three power stations at Hinkley Point were higher than NNB GenCo's estimates by up to 4 µSv/y for the representative person. The reason for this disparity has not been fully established, although it is deemed likely to have resulted from minor differences in the configuration of the three power stations relative to the location of the representative person.

64 Differences were also observed in the predicted external doses to houseboat dwellers, which are likely to have resulted from the use an alternative external dose model [Ref. 12] to that used by NNB GenCo. However, the contribution of this pathway to the total dose to houseboat dwellers is insignificant.

65 The collective dose assessments undertaken by NNB GenCo were also repeated using the same methods, assumption and parameters. It was possible to reproduce NNB GenCo's outcome for liquid discharges. However, it was not possible to reproduce NNB GenCo's outcome for doses to UK and EU populations from discharges to the atmosphere, which were lower than the NNB GenCo estimates.

66 The assessed doses to representative persons due to short duration releases to the atmosphere were repeated using two alternative approaches based on the application of modified food concentrations factors obtained from PC CREAM and food concentration factors recommended by NDAWG [Ref. 15]. The outcomes of the verification assessment were within 10% of NNB GenCo's results for the PC CREAM approach and around a factor of 4 higher than NNB GenCo estimates for the NDAWG approach. Carbon-14 accounts for around 80 - 90% of ingestion doses. NNB GenCo adopted the PC CREAM food concentrations factors for carbon-14 and tritium in its assessment of doses from short

term releases and this is thought to be the reason for the close agreement between the outcome of our PC CREAM approach and NNB GenCo's estimates.

PART 3: Independent Dose Assessment

Approach taken

67 A tiered approach was adopted in undertaking the independent assessment. Stage 1 and Stage 2 of our Initial Radiological Assessment procedure was applied. This was followed by a more detailed site specific assessment using a spreadsheet system developed using parameters primarily derived from PC CREAM 08 [Ref. 11]. Doses from short duration releases to atmosphere from Hinkley Point C were also assessed. Collective doses were also assessed.

68 The parameters and assumptions adopted in the site specific assessments were informed by the review of the NNB GenCo approach (see part 1). The modelling was carried out using PC CREAM 08 augmented by an external dose rate model from FGR-12. Environmental levels were modelled using the relevant modules of PC CREAM 08 and these data were used to assess dose rates to non-human species. The modelling allowed for build up assuming ongoing discharges over a period of 50 years.

69 As a further check, the results of the independent assessment were compared with the NNB GenCo dose assessment results.

70 The details and results of these assessments are given below and presented in more detail in Appendices 3 – 10, as follows:

- Appendix 3: Independent Initial Radiological Assessment
- Appendix 4: Independent Radiological Assessment of Discharges to Atmosphere
- Appendix 5: Independent Radiological Assessment of Liquid Discharges;
- Appendix 6: Independent Radiological Assessment of Collective Doses;
- Appendix 7: Independent Radiological Assessment of Doses from Potential Short-term Releases ;
- Appendix 8: Independent Assessment of Doses from Direct Radiation;
- Appendix 9: Independent Assessment of Dose from future discharges from all three power stations at Hinkley Point and total dose from past discharges from these power stations and others.
- Appendix 10: Independent Assessment of Radiological Doses to Non-human Species

71 Internal exposure from breathing in radionuclides or ingesting them in food was estimated using dose co-efficients for the public published by ICRP in 1996 and included in European legislation at that time [Ref 17&18]. ICRP also restated its recommended cancer risk factors from radiation dose [ref 17]. The ICRP approach was confirmed as being best practise by the Health Protection Agency (HPA). HPA has previously advised that the ICRP dose coefficients and ICRP advice on radiation protection remain appropriate for use in radiation protection of the public.

72 Dispersion and build up in the environment was modelled using the PC CREAM 08 software system.

73 Discharge information data was taken from the NNB GenCo submission and shown in Tables 1 and 3.

Initial radiological assessment

74 Stages 1 and 2 of our Initial Radiological Assessment (IRA) methodology [Ref. 5] have been applied to the predicted maximum annual gaseous and liquid discharges from the two proposed UK EPR power plants at Hinkley Point C, presented in Tables 1 and 3 [Ref. 3]. The assessments were undertaken using the initial radiological assessment spreadsheet tools.

75 Stage 1 assessments were performed using default, conservative parameters contained in the initial assessment spreadsheets. Stage 2 assessments were performed using dispersion parameters presented in the NNB GenCo submission [Ref. 3]. These are an effective stack height of 23 m and a volumetric exchange rate of 3.17×10^3 m^3/s for the local marine compartment.

76 The population groups assessed are Local Habitant and Fisherman, for doses due to atmospheric and liquid discharges respectively.

77 The results of our Initial Radiological Assessment are presented in Table 11. For the stage one assessment, the annual doses to the local inhabitant and fisherman groups, arising from the maximum annual discharges from Hinkley Point C, were predicted to be 110 µSv/y and 370 µSv/y, respectively. Both groups were therefore predicted to exceed 20 µSv/y such that a more realistic assessment was warranted. At Stage 2, the doses to these population groups were predicted to be 16 µSv/y and 3.5 µSv/y, respectively.

78 The initial assessment system also calculated dose rates to the worst affected terrestrial and marine organisms are also provided. The predicted dose rates to the worst affected organisms in the terrestrial and marine environments, resulting from the maximum annual discharges from Hinkley Point C, were found to be in the region of 0.6 µGy/h for the Stage 1 assessment (see Table 12). In Stage 2, the dose rates to the worst affected terrestrial and marine organisms were predicted to be around 0.02 and 0.006 µGy/h respectively. These dose rates are below the trigger value of 1 µGy/h from a single site, above which the total impact from all local discharges on any protected habitat in the area would require further consideration.

Detailed dose assessments from individual doses and direct radiation

Atmospheric discharges

79 For our independent assessment of discharges to atmosphere, local residents with a range of observed habits were identified as potential candidates for the representative person. The candidate representative person was assumed to live at 500 m from the Hinkley Point C stack. This person was assumed to consume green vegetables, root vegetables and fruit grown at this location, and to source other terrestrial foods including milk from a farm at a representative distance of 500 m from the stack. The assessment made use of site specific habit data taken from the Cefas 2011 report for the Hinkley Point area [Ref. 16], arranged in 13 profiles of integrated habits. Other generic habit data such breathing rates were taken from NRPB-W41 [Ref. 14]. An effective stack height of 23.3m was assumed. The PLUME and FARMLAND models within PC CREAM 08 [Ref 11] were used to derive environmental concentration data, which was then transcribed onto a spreadsheet based assessment programme to calculate the consequential doses. The sources of other assessment input data are presented in Appendices 4.

80 An adult milk consumer, located close to the Hinkley Point site, was predicted to receive the highest doses due to atmospheric discharges from Hinkley Point C, and may therefore be taken to be the candidate representative person from this discharge route. This person is conservatively assumed to live at 500 m from the point of discharge, consistent with the Environment Agency's Initial Radiological Assessment approach [Ref. 5]. At the maximum annual atmospheric discharge levels presented in the NNB GenCo submission, the highest dose was to an adult milk consumer has been predicted to be 7.2 µSv/y (see Table 13). The highest contribution to dose was from consumption of carbon-14 in milk. Details of the assessment and results to all age groups are presented in Appendix 4.

Liquid discharges

81 For our independent assessment of liquid discharges to the marine environment, site specific information on the local marine environment near Hinkley Point was used. The dispersion of liquid discharges was modelled using the DORIS module of PC CREAM 08 [Ref. 11] and the output was transcribed onto a spreadsheet based assessment programme to determine the potentially most exposed members of the public. The assessment made use of site specific habit data taken from the Cefas 2011 report for the Hinkley Point area [Ref. 16], arranged in profiles of integrated habits. Other

generic habit data such as inadvertent ingestion of sediment and seawater were taken from NRPB-W41 [Ref. 14]. The sources of other assessment input data are presented in Appendices 5.

82 For liquid discharges, the adult consumer of crustaceans was predicted to receive the highest dose from discharges from Hinkley Point C, and may therefore be taken to be the candidate representative person from this discharge route. The maximum annual liquid radioactive discharges presented in the NNB GenCo submission has been predicted to give rise to a dose of around 0.5 µSv/y to this person (see Table 13). The main pathways were consumption of carbon-14 in fish and crustaceans. Details of the assessment and results including the breakdown of doses by radionuclide and pathway are included in Appendix 5.

Individual dose from direct radiation

83 Exposure of the public from direct radiation from nuclear sites in the UK is the responsibility of the Office of Nuclear Regulation (ONR). The ONR require site operators to measure direct radiation at the site perimeter and estimate exposure to a reference group on an annual basis.

84 Our assessment assumes a house close to the site - 500m from a site source store. Direct radiation is based on a standard model for dose rate with distance (Appendix 9). It is also assumed that the resident walks close to the store each day for about 10minutes and receives a dose of 0.8 µSv/y. The dose from direct radiation for a residence at 500m, including walking close to the store was predicted to be between 0.9 and 1.2 µSv/y.

85 The direct radiation dose from the existing Hinkley Point A and B power stations has also been assessed as 5 µSv/y based on data contained in RIFE reports for 2006 – 2010. Further information is presented in Appendix 8.

Doses to the representative person from Hinkley Point C discharges

86 Doses to candidates for the representative person from Hinkley Point C discharges and from direct radiation were calculated. The habits of the candidates for representative person were based on the profiles of integrated habits data presented in the Cefas 2011 report for the Hinkley Point [Ref. 16] area. The representative person was the candidate receiving the highest dose from an appropriate combination of liquid discharges, atmospheric discharges or direct radiation. The discharge assumptions were the maximum expected discharges as shown in Table1 and Table 3 and also discharges made at NNB GenCo's the proposed limits (also shown in Table 1 and Table 3).

87 From liquid discharges from Hinkley Point C, the doses range from 0.1 to 0.5 µSv/y for the various habit profiles (See appendix 5). The habits profiles for the candidates for the representative person who are most exposed to liquid discharges show that they do not spend time near the site and so direct radiation doses are not included.

88 As indicated above, the adult milk consumer profile has been predicted to receive the highest dose from annual discharges of liquids and gases from Hinkley Point C of 7.2 µSv/y. This person has been assessed to also receive a dose from direct radiation of 1.2 µSv/y from direct radiation. The dose to the representative person from annual maximum discharges and direct radiation, from Hinkley Point C, has therefore been estimated to be 8.4 µSv/y (see Table 13). This is therefore the representative person for Hinkley Point C.

89 As indicated above, the adult milk consumer profile has been predicted to receive the highest dose from annual discharges of liquids and gases from Hinkley Point C of 7.2 µSv/y. This person has been assessed to also receive a dose from direct radiation of 1.2 µSv/y from direct radiation. The dose to the representative person from annual maximum discharges and direct radiation, from Hinkley Point C, has therefore been estimated to be 8.4 µSv/y (see Table 13). This is therefore the representative person for Hinkley Point C.

90 Doses to the representative person are therefore much less than the source dose constraint of 300 µSv/y and the proposed dose constraint for new nuclear power stations and radioactive waste disposal facilities of 150 µSv/y.

91 At present the nearest residence is about 1.5 km from the proposed Hinkley Point C power station. At locations of 1.5km or more from the site, doses from discharges and direct radiation will be lower than those assessed for 500m.

Dose to the representative person from discharges from all three power stations at Hinkley Point.

92 Doses from discharges from the two existing power stations at Hinkley Point A and B and the proposed station at Hinkley Point C were also assessed. The combined dose arising from potential future discharges from all three power stations at Hinkley Point was assessed using a similar approach to that applied to Hinkley Point C. The discharges from Hinkley Point A and B were assumed to be at current permit limits. An incineration facility currently exists on the Hinkley Point B site; and although not currently in use, the facility remains permitted. The potential contribution of this to the total dose has therefore been included.

93 The dose to the representative person (adult milk consumer) from the combined discharges from Hinkley A, B and C was estimated to be around 16 µSv/y. Of this, less than 0.003 µSv/y was predicted to come from marine pathways (see Table 13) and appendix 9. Hinkley Point A and B contributed 0.03 µSv/y and 7.2 µSv/y respectively, assuming discharges at current permit limits. The contribution from Hinkley Point C was 7.2 µSv/y, assuming discharges at maximum annual discharge levels. The incinerator at Hinkley Point B was predicted to contribute 1.1 µSv/y to the total dose, based on the current permit limits.

94 The dose to the candidate representative person most exposed to liquid discharges (adult crustacean consumer) from the combined discharges from all three power stations at Hinkley Point was predicted to be 7.4 µSv/y (see Table 13). This includes a contribution of 0.5 µSv/y from Hinkley Point C, 0.4 µSv/y from Hinkley Point A and less than 0.1 µSv/y from Hinkley Point B. The adult crustacean consumer received a contribution of 6.5 µSv/y from atmospheric discharges from the site. The assessment of contributions from Hinkley Point A and B was based on the current permit limits for these power stations.

95 The combined dose from future discharges from the three power stations ranged from 0.2 to 15.5 µSv/y, much less than the site dose constraint of 500 µSv/y.

Total doses to the public near Hinkley Point from historic and future discharges from Hinkley Point and other sites

96 The doses to the most exposed members of the public near Hinkley Point from future discharges from the A, B and C stations were assessed as 15.5 µSv/y for the individuals most exposed to atmospheric discharges from the site as a whole and 7.4 µSv/y for the individuals most exposed to liquid discharges (of which 6.5 µSv/y arose from atmospheric discharges).

97 The doses to the individuals near the site from historic discharges were estimated from the RIFE reports from the period form 2006 – 2010 [Ref. 13 and earlier RIFE reports] (Appendix 9). For individuals most exposed to historic atmospheric discharges, doses were around 5 µSv/y. For individuals most exposed to historic liquid discharges, doses were around 36 µSv/y.

98 Total dose was calculated taking into account doses from predicted discharges, historic discharges and direct radiation from the site. The calculation of these contributions to total dose is highly site specific.

99 The total dose to the public near the Hinkley Point site using all the information available, ranges from 27-43 µSv/y (Table 14).

100 Total doses to the people most exposed to atmospheric discharges and direct radiation were estimated to be up to 27 μSv/y. This is made up of 16 μSv/y from expected future gaseous discharges from A, B and C stations together, <1μSv/y from future expected discharges of liquids from A, B and C station together, 5μSv/y from A and B station direct radiation, 1.2 μSv/y from C station direct radiation and 5μSv/y from historic gaseous discharges from A and B station and 1.1 μSv/y from the incinerator at Hinkley Point B.

101 Total dose to the public most exposed to future and past liquid discharges near the Hinkley Point site is up to 43μSv/y. This is made up of 6.5 μSv/y from expected future gaseous discharges from A, B and C stations together, 1 μSv/y from future expected discharges of liquids from A, B and C station together and 36μSv/y from historic discharges liquid discharges from A and B station. The latter estimate is dominated by external dose from high beach use, which in turn is affected by uncertainty and variability in the estimate of the excess dose rate above intertidal areas - compared to the UK average background dose rate. No dose from direct radiation from A and B station were assumed (because habits surveys show no habits near enough to the site to lead to any exposure), and no future dose from C station direct radiation.

102 These assessments of dose of 27and 43 μSv/y are well below the dose limit for members of the public of 1000 μSv/y (1 mSv/y).

Short-term release dose assessment

103 An assessment of potential doses arising from short-term releases to atmosphere was undertaken. The ADMS software was used to model the concentration of radionuclides in air and on the ground, based on the maximum predicted monthly discharges to atmosphere from Hinkley Point C under normal operating conditions presented in Table 2 [Ref. 3]. The assessment considered doses via ingestion of contaminated foodstuff, inhalation of radionuclides in plume, external radiation from radionuclides in plume and external radiation from radionuclides deposited on the ground. The approach for doses from ingestion of contaminated food involved the use of food concentration factors recommended by NDAWG [Ref.15]. The concentration of radionuclides in food arising from a single short term release event was estimated using the approach described in Appendix 7 and compared with EC recommended food intervention levels (CFILs).

104 Two assessments were made, one using NNB GenCo's assumptions about short duration discharges and a second bounding calculation assuming that the maximum expected annual discharges from the site were released in 6 hours. The dose assuming NNB GenCo's assumptions about short duration discharges to atmosphere were estimated to be 5.2 μSv to an adult. The dose assuming that the maximum expected annual discharges from the site were released in 6 hours were were estimated to be 72 μSv to an adult. The estimated doses were dominated by the contribution from C-14 in terrestrial foods, as shown in Table 17.

105 The concentration of radionuclides in selected terrestrial foodstuff after one year following a single short-term release event were determined using the approach described in Appendix 7 and compared with EC recommended community food intervention levels (CFILs). The concentration of released radionuclides in food was found to be several orders of magnitude below the CFILs at the predicted short term discharge rates.

106 Assuming that one year's maximum expected discharges occurs over a short time period, the CFILs are not predicted to be exceeded for any radionuclides including C-14.

Collective dose

107 Collective doses arising from annual atmospheric and liquid discharges were assessed, using PC CREAM 08 and the associated population and agricultural production grids [Ref 11]. Collective doses to UK, EU and World populations truncated at 500 years from the maximum annual atmospheric and liquid discharges from Hinkley Point C were calculated using PC CREAM 08 [Ref. 11] (Appendix 6). Per caput doses were also assessed.

108 The collective doses per year of discharge (truncated to 500 years) arising from discharges to the atmosphere and marine environments were as follows (see also Table 15):

- ***Discharges to atmosphere from Hinkley Point C at maximum predicted levels*** – 0.37 manSv per year of discharge for the UK, 2.2 manSv per year of discharge for Europe, and 24.7 manSv per year of discharge for the World;
- ***Discharges to the sea from Hinkley Point C at maximum predicted levels*** – 0.02 manSv per year of discharge for the UK, 0.09 manSv per year of discharge for Europe, and 2.1 manSv per year of discharge for the World;

109 The majority of the collective dose from discharges of radioactive waste to both the atmosphere and to the marine environment arises from carbon-14. Per caput doses were also calculated and found to be in the nSv range, as shown in Table 16.

Non-human dose rate assessment

110 The activity concentrations in environmental media from discharges to atmosphere were derived from intermediate parameters from the PLUME and ASSESSOR modules of PC CREAM 08 [Ref. 11]. Doses to representative reference organisms in the terrestrial and marine environments from maximum atmospheric and liquid discharges were calculated using the predicted environmental concentrations using the ERICA Tool (June 2011 version) [Ref 9] and the Environment Agency's R&D 128 methodology [Ref. 10] for noble gases. Reference terrestrial organisms were assumed to be located 500 m from the release point, whilst reference marine organisms are assumed to inhabit the local marine compartment. Default assumptions regarding the concentration factors and dose calculation factors were applied.

111 A summary of predicted dose rates to these organisms are given in Table 18. The limiting terrestrial organism for discharges to atmosphere is mammal (deer). The dose rate associated with the maximum annual discharge to atmosphere from Hinkley Point C is around 0.003 µGy/h. The limiting organism for liquid releases to the marine environment is reptile, which is predicted to receive a dose rate of the order of 0.001 µGy/h, from the maximum annual liquid discharges from Hinkley Point C.

112 An assessment of the potential combined impact of discharges from all three power stations at Hinkley Point has also been made. The limiting terrestrial organism for discharges to atmosphere was predicted to be a mammal (rat), with a total dose rate of around 0.007 µGy/h from the maximum annual atmospheric discharges from all three power stations. The limiting organism for liquid releases to the marine environment is polychaete worm. The total dose rate to this organism from the maximum annual discharges from all three power stations was predicted to be around 0.008 µGy/h.

113 A total dose rate to the worst affected terrestrial organism due to maximum discharges of noble gases from Hinkley Point C was estimated to be 0.002 µGy/h, while the corresponding dose rate from discharges of noble gases from all three power stations was estimated to be around 0.009 µGy/h.

114 The assessed dose rates to all reference organisms from discharges from all three power stations at Hinkley Point are below the levels that would trigger consideration of total impact of all sources from the site to any protected habitat in the area. The dose rates are also orders of magnitude below the ERICA screening level of 10 µGy/h, which is intended as a trigger for further assessment rather than an indicator of significant impact on non-human biota.

Assessment of doses from sediment entering the body from a wound

115 A screening assessment was made of doses from somebody receiving a wound to the skin into which sediment containing radionuclides can enter the blood stream. Two assessments were made – one using information on radionuclides that are already in sediments in the environment and one using predicted concentrations in sediments from the proposed power station at Hinkley Point C. This shows that based on recent levels seen in the marine environment – doses from a wound would be 0.5 µSv – mostly from Americium 241, whilst an assessment based on predicted concentrations gave doses of 0.002 µSv/y.

Summary of the independent dose assessment

116 At the maximum annual atmospheric and liquid radioactive discharge levels, provided in the NNB GenCo application for a permit and using appropriate site-specific assumptions, the dose to the representative person from Hinkley Point C has been assessed as 8.4 μSv/y (including a contribution of 1.2 μSv/y from direct radiation exposure). The dose will be to an adult milk consumer living 500m from the site and obtaining food and milk produced 500m from the site. This value is less than the source dose constraint of 300 μSv/y, [Ref. 18] and the proposed dose constraint for new nuclear power stations of 150 μSv/y [Ref. 17]. At present there are no houses within 1km of the site, however the site will be operating for 60 years and changes may occur in this timeframe.

117 An assessment of the dose from future discharges from the all three power stations at Hinkley Point for comparison with the site constraint has been made. The predicted dose to the representative person from combined maximum discharges from the existing stations at Hinkley Point A and B, and the proposed Hinkley Point C station, was 16 μSv/y for residents 500m from the site and obtaining food 500m from the site. This is well below the site dose constraint of 500 μSv/y.

118 An assessment of total dose for comparison with the dose limit for members of the public has been made taking account of discharges from all operations on the same site and from all past and current practices. The total dose to the representative person at Hinkley Point from all sources is 27μSv/y for a resident at 500m from the site and obtaining food 500m from the site, and 43μSv/y for liquid related doses. Both are well below the dose limit for members of the public of 1000 μSv/y.

119 The collective doses to UK, EU and World population from atmospheric discharges from Hinkley Point C are around 0.4, 2.2 and 24.7 manSv per year of discharge (respectively). The collective doses from discharges to the marine environment are 0.02 manSv for UK; 0.09 man Sv per year of discharge for the EU populations, and 2.1 man Sv per year of discharge for world population. There is no legal dose limit on collective doses. However IAEA has proposed that collective doses below 1 man Sv per year of discharge/y of discharge can be considered to be sufficiently low to be of no regulatory concern and that the practice from which the collective dose originates may be exempted without further consideration [Ref. 21]. It can be seen that the collective doses to the World population are greater than the exemption levels proposed by the IAEA.

120 Collective doses may be used to derive the average individual dose to members of different population groups, known as per caput doses. The UK regulatory and advisory agencies have stated that discharges giving rise to per caput doses in the range of nanosieverts per year of discharge can be regarded as miniscule [Ref 20]. The average per caput doses for liquid discharges from the proposed Hinkley Point C nuclear power station are lower than those for discharges to atmosphere, for which the highest are for the UK population of 3 nSv per year of discharge. The average per caput doses for Hinkley Point C may therefore be regarded as trivial.

121 Potential doses to members of the public from predicted short-term releases are of the order of 4.8 μSv. This estimated dose is dominated by the contribution of C-14 in terrestrial foods. For normal assumptions about the potential for short duration releases – the CFILS are not exceeded. If it assumed that an entire year's discharge occurs over a short period, the CFILs are predicted not to be exceeded.

Comparison of NNB GenCo Assessment and Our Independent Assessment

122 As a final check, the predicted effective doses to the representative person estimated by NNB GenCo and as a result of our independent assessment were compared. The doses to the representative person from discharges from Hinkley Point C were similar in both assessments – less than about 10 μSv/y.

123 In the NNB GenCo assessment, generic habit data are used while in the independent assessment the habit profiles presented in the 2011 CEFAS habit survey were applied. The assumed location of the representative person and the location of origin of terrestrial foods also differ between the two

assessments; the representative person is assumed to be located at 1.7 km from the Hinkley Point C discharge point for the NNB GenCo assessments, while in the independent assessment, this individual is assumed to be located at 500 m from the discharge point and to derive terrestrial foods 500 m from the site. The NNB GenCo assessment has used the current locations for residents combined with generic conservative habits data. Our independent assessment has used locations for residents close to the site that do not currently exist combined with realistic habit data.

124 The total doses from discharges from the site as a whole differ; in the independent assessment the total dose from discharges (not including direct radiation pathways) is 16 μSv/y while the corresponding value given by NNB GenCo is 17 μSv/y. The NNB GenCo assessment uses conservative top two habits derived from generic profiles and different assumptions about the relative locations of the three power stations with respect to the representative person (at 1.7km), The independent assessment which used habit profiles which are realistic combined with a closer location (500m) to allow for future changes in land use around the site which does not currently exist.

125 There are some differences in detail in assumptions regarding the inclusion of doses from direct radiation. In the NNB GenCo assessment, the representative person is assumed to be located at sufficient distance from the site that the contribution from direct radiation is assumed to be negligible. In the independent assessment, it is assumed that the representative person (who is assumed to live close to the site) may regularly walk along the site fence, as postulated in the NNB GenCo assessment. This would lead to an additional dose of around 1.2 μSv/y to the representative person at 500m. Also, our independent assessment considered direct radiation dose from Hinkley Point A and B of around 5 μSv/y, derived from RIFE reports for 2006 – 2010. NNB GenCo did not consider the contribution of direct radiation from Hinkley Point A and B in its submission.

126 In the independent assessment, the contribution of doses from past discharges and other sources of radiation has been considered in order to assess the total dose to the representative person at Hinkley Point, for comparison with the dose limit. This contribution to total dose has not been explicitly considered in the NNB GenCo assessment. The RIFE reports for 2006 - 2010 indicate that the current dose to high rate terrestrial food consumers from past discharges to air at Hinkley Point is around 5 μSv/y, whilst the dose from groups most exposed to past discharges to the marine environment is up to 36 μSv/y [Ref.13 and earlier RIFE reports]. The independent estimate of the total dose to the representative person from past and future discharges is between 27 and 43 μSv/y, including a contribution of 1.1 μSv/y due to discharges from the incinerator at Hinkley Point B. This is significantly below the dose limit of 1000 μSv/y.

127 The collective doses calculated as part of the independent assessment differ from those presented in the NNB GenCo submission for the UK (where they are higher) and Europe (where they are lower). The results are the same for the world. This is due use of PC-CREAM-08 [Ref. 11 in the independent assessment rather than PC CREAM 98 [Ref. 6], which was used in the NNB GenCo submission. There are 12 European countries considered in PC CREAM-08, whereas PC-CREAM-98 considers more countries with a greater total population.

128 Our independent assessments of predicted doses from short-term releases are greater than those presented by NNB GenCo. This is primarily due to the use of a simplified and conservative approach in the independent assessment to calculate the contribution from ingestion of terrestrial foods, and differences in the assumed location of the exposure group and their habits. The independent assessment also considered the concentration of released radionuclides in food in the year following the release event and compared the results with the EC recommended intervention levels. NNB GenCo did not perform this assessment.

Summary and Conclusions

129 NNB GenCo has applied for a permit to make discharges of radioactive waste from a new nuclear power station at Hinkley Point C. The application included a radiological impact assessment of doses to members of the public and the environment. A 3 part independent assessment has been made of the radiological impact assessment, on behalf of the Environment Agency,

- Part 1:- Review and validate the assumptions made by NNB GenCo in its dose assessments

- Part 2:- Verification and confirmation of the outcomes of the dose assessments carried out by NNB GenCo
- Part 3:- Make an independent dose assessments to determine whether the dose assessments carried out by NNB GenCo are appropriate, and for future regulatory use.

130 **Part 1 – Review and validation of the assumptions made by NNB GenCo in its assessment.** The radiological assessment approach used by NNB GenCo was reviewed and compared with established guidance and best practice. Some minor divergences from standard practice were identified, primarily related to the assumed location of the nearest habitation and the application of non-standard inhalation rate for adults. The NNB GenCo assessment was undertaken with PC-CREAM 98, which has recently been replaced by PC CREAM-08. The assessment had made use of the ICRP risk factors and internal dose factors published in ICRP-72 and which are now part of EC legislation. HPA has recently reviewed all the dose factors including some alternative factors and concluded that the ICRP approach remains the most appropriate and sound basis for radiation protection decisions involving the public.

131 **Part 2 – Verification and confirmation of the outcomes of the dose assessments carried out by NNB GenCo**. The assessments made by NNB GenCo show that the radiological impact from discharges at the maximum expected discharges are likely to be low. NNB GenCo estimated the annual effective doses to the most exposed members of the local population, arising from the predicted annual maximum radioactive discharge to atmosphere, to be 4.4 µSv/y (to infants). It was possible to repeat the NNB GenCo assessment outcome albeit with minor differences of the order of 0.3 µSv/y (at 4.7µSv/y) for Hinkley Point C.

132 NNB GenCo estimated doses from the maximum annual liquid radioactive discharges to the marine candidates for the representative person (fisherman and family). Adults were predicted to receive the highest doses from liquid discharges from Hinkley Point C of around 1 µSv/y. NNB GenCo also presented doses to a family of houseboat dwellers arising from liquid discharges. The highest dose of around 0.3 µSv/y from Hinkley Point C. It was possible to repeat the NNB GenCo assessment outcomes, with the exception of the contribution from external dose from sediment. However, both NNB GenCo's estimates and the outcome of the verification assessment agree that the contribution of this pathway to the total dose to houseboat dwellers is very low.

133 NNB GenCo also proposed some limits on discharges to atmosphere and liquids to the marine environment and made a second assessment of doses at these limits. NNB GenCo's proposed limits are very similar to the maximum expected discharges and the assessed doses were within a few percent of the doses at maximum expected discharges. We carried out an assessment at proposed limits as part of the independent dose assessment and found that the doses were very similar.

134 The collective dose to the UK was estimated to be 0.4 man Sv per year of discharge from atmospheric discharges while the corresponding values for the European and World populations were estimated to be 3.0 and 24.6 man Sv per year of discharge respectively. The collective doses from maximum liquid discharges were 0.02, 0.2 and 2.2 (to the UK, European and World population respectively. The per caput dose to all population groups were estimated to be of the order of 2 – 7 nSv. It was possible to repeat these assessments, although the estimated doses to UK and EU population from atmospheric releases were lower than NNB GenCo estimates.

135 **Part 3 independent dose assessment** The review outputs were used together with best practice guidance and other data as an input to the design of an independent assessment – which was undertaken on behalf of the Environment Agency.

136 We carried out an independent prospective radiological assessment. This was for maximum radioactive discharges expected from Hinkley Point C and using site-specific characteristics, habit data and other parameters in accordance with best practice recommendations, identified in Appendix 2. The assessment was made using PC CREAM-08 and with the ICRP published factors that HPA has reviewed and indicated are appropriate for radiation protection of the public.

137 The assessment was then made a second time using the NNB GenCo proposed limits. Our assessment considered releases to the atmosphere, liquid discharges and direct radiation from the proposed Hinkley Point C nuclear power station.

138 Doses from predicted discharges to atmosphere, liquid discharges to the marine environment and from direct radiation from Hinkley Point C nuclear power station ranged from 1 to 8.4 μSv/y, depending on the habits of and location of the people being assessed. All the assessed doses are significantly less than the existing source dose constraint of 300 μSv/y and the proposed dose constraint for new nuclear power stations of 150 μSv/y. Repeating the assessment with NNB GenCo's proposed discharge limits gave a more or less identical dose outcome.

139 The doses predicted were similar to those assessed by NNB GenCo because of the assumptions about combination of proximity to the site and habit data

140 The dose from combined future discharges from Hinkley Point A, B and C have also been assessed and ranged from 16 μSv/y. The assessment included a dose of 1.1μSv/y arising from discharges from the incinerator at Hinkley Point B**.** This is well below the site dose constraint of 500 μSv/y to the predicted doses has also been considered. Our independent assessment used the more recent PC CREAM 08 software.

141 Our independent assessment also estimated the total dose to the representative person arising from direct radiation, future discharges from all three power stations at Hinkley Point and total dose from historic discharges at Hinkley Point and other sources. The total dose was compared with the dose limit for members of the public of 1000 μSv/y [Ref. 18]. The total dose to a representative person at Hinkley Point, including a contribution from potential future operations at Hinkley Point A, B and C is therefore of the order of 27-43 μSv/y. This is significantly below the dose limit for members of the public of 1000 μSv/y.

142 Collective doses, truncated at 500 years, have been assessed for predicted releases to atmosphere and for liquid discharges to sea. The highest collective doses (to the world population) arise from discharges to atmosphere, and are predicted to be 24.8 manSv per year of discharge. The corresponding value for liquid discharges is 2.1 man Sv per year of discharge. The total world collective dose from both liquid discharges and discharges to atmosphere is 27 man Sv per year of discharge. All these results are above the level the IAEA proposed as being of no regulatory concern [Ref. 21]. The average per caput doses have been calculated from the collective doses to UK, Europe and the world and their populations, which range from 3 to 7 nSv. Per caput doses at this level may be regarded as trivial [Ref 20].

143 Potential doses to members of the public from predicted short-term releases could be of the order of 5.2 μSv assuming discharges at NNB GenCo's assumptions and up to 72 μSv assuming the maximum annual discharge is released over a short period. These estimated doses are dominated by the contribution of C-14 in terrestrial foods. The concentration of radionuclides in terrestrial foodstuff in the year following a single short term release event were found to be below the EC recommended food intervention levels at the predicted release rates. Even if it is assumed that the maximum annual discharge is released over a short period then the CFILs are not exceeded.

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Table 1. NNB GenCo predicted maximum annual discharges to atmosphere from Hinkley Point C, current permit limits for Hinkley Point A and B (GBq)[3] and NNB GenCo's proposed limits for Hinkley Point C

Radionuclide	Hinkley Point C (max)$	Hinkley Point B	Hinkley Point A[4]	Hinkley Point C (proposed limits)
Ar-41	1.31E+03	1.00E+05	-	-
C-14	1.40E+03	3.70E+03	6.00E+02	1.40E+03
Co-58	6.12E-02	-	-	-
Co-60[5]	7.22E-02	1.10E+00	1.50E-01	-
Cs-134	5.62E-02	-	-	-
Cs-137	5.04E-02	-	-	-
H-3	6.00E+03	1.20E+04	1.50E+03	6.00E+03
I-131	3.64E-01	1.50E+00	-	4.00E-01
I-133	4.36E-01	-	-	-
Kr-85	6.26E+03	-	-	-
S-35		3.50E+02	-	-
Xe-131m	1.35E+02	-	-	-
Xe-133	2.84E+04	-	-	-
Xe-135	8.92E+03	-	-	-
Noble gases	(4.5E+04)*-	-	-	4.5E+04
Other fission and activation products	(2.4E-01)+	-	-	2.4E-01

*The sum of Ar-41, Kr-85, Xe-131m, Xe-133 & Xe-135
+ The sum of Co-58, Co-60, Cs-134 & Cs-137

$ Used in the dose assessment

[3] The data for Hinkley Point B and A are the permit limits for those power stations

[4] These permit limits for Hinkley Point A presented in this table have been revised subsequent to NNB GenCo's assessments. The new permit limits are 750 GBq for H-3, 50GBq for C-14 and 0.05 GBq for other beta.

[5] Beta radionuclides discharged from Hinkley Point A and B were modelled as Co-60. The value for Co-60 discharges for Hinkley Point B comprises 0.1 GBq of Co-60 and 1GBq of other beta radionuclides. The value for Hinkley Point A is entirely other beta radionuclides.

Table 2. NNB GenCo predicted short-term discharges to atmosphere from Hinkley Point C

Radionuclide	Total release in 24 hours (Bq)	Emission rate over 24 hours (Bq/s)
Ar-41	1.45E+11	1.68E+06
C-14	1.00E+11	1.16E+06
Co-58	1.53E+07	1.77E+02
Co-60	1.81E+07	2.09E+02
Cs-134	1.40E+07	1.62E+02
Cs-137	1.26E+07	1.46E+02
H-3	3.00E+11	3.47E+06
I-131	1.37E+08	1.59E+03
I-133	1.63E+08	1.89E+03
Kr-85	6.95E+11	8.04E+06
Xe-131m	1.50E+10	1.74E+05
Xe-133	3.16E+12	3.66E+07
Xe-135	9.90E+11	1.15E+07

Table 3. NNB GenCo predicted maximum annual liquid discharges to the marine environment from Hinkley Point C, current permit limits for Hinkley Point A and B (GBq)[6] and NNB GenCo's proposed limits for Hinkley Point C

Radionuclide	Hinkley Point C (max)$	Hinkley Point B	Hinkley Point A[7]	Hinkley Point C (proposed limits)
Ag-110m	1.14E+00	-	-	-
C-14	1.90E+02	-	-	1.90E+02
Co-58	4.14E+00	-	-	-
Co-60	6.00E+00	1.00E+01	-	-
Cr-51	1.20E-01	-	-	-
Cs-134[8]	1.12E+00	8.00E+01	7.00E+02	-
Cs-137	1.89E+00	1.00E+02	1.00E+03	1.90E+00
H-3	1.50E+05	6.50E+05	1.80E+03	2.00E+05
I-131	1.00E-01	-	-	-
Mn-54	5.40E-01	-	-	-
Ni-63	1.92E+00	-	-	-
OBT	-	1.63E+03	-	-
S-35	0.00E+00	2.00E+03	-	-
Sb-124	9.80E-01	-	-	-
Sb-125	1.63E+00	-	-	-
Te-123m	5.20E-01	-	-	-
Other fission and activation products	(1.81E+01) +-	-	-	1.81E+01

$ Used in the dose assessment

+ Ag-110m, Co-58, Co-60, Cr-51, Cs-134, Mn-54, Ni-63, Sb-124, Sb-125 and Te-123m

[6] The data for Hinkley Point B and A are the permit limits for those power stations

[7] These permit limits for Hinkley Point A presented in this table have been revised subsequent to NNB GenCo's assessments. The new permit limits are 1 TBq for H-3, 1 TBq for C-14 and 0.7 TBq for other radionuclides.

[8] For Hinkley Point A and B, 'other radionuclides' were modelled as Cs-134

Table 4. Summary of verification assessment and NNB GenCo estimates of individual doses arising from maximum atmospheric and liquid discharges from Hinkley Point C (μSv/y)*

Candidates for representative person	Age group	Verification assessment of doses from Hinkley Point C discharges				NNB GenCo results
		Atmospheric	Liquid	Direct radiation	Total	
Farming family	Adult	2.6	0.3	0	2.9	2.7
	Child	2.4	0.3	0	2.7	2.5
	Infant	4.7	0.1	0	4.8	4.5
Fishing family	**Adult**	2.1	1.1	0	3.2	3.0
	Child	2.2	0.3	0	2.5	2.3
	Infant	3.7	0.1	0	3.8	3.6

* Rounded to 2 significant figures

Table 5. Summary of verification assessment and NNB GenCo estimates of individual doses arising from maximum atmospheric and liquid discharges from all three power stations at Hinkley Point (μSv/y)*

Candidates for representative person	Age group	Verification assessment of doses from discharges from Hinkley Point A, B & C				NNB GenCo results
		Atmospheric	Liquid	Direct radiation	Total	
Farming family	Adult	8.0	0.86	0	8.9	6.8
	Child	8.7	0.55	0	9.3	7.3
	Infant	21	0.25	0	21	17
Fishing family	Adult	6.8	2.8	0	9.6	7.8
	Child	7.6	0.7	0	8.3	6.5
	Infant	17	0.2	0	17	13

Table 6. Summary of verification assessment and NNB GenCo estimates of effective dose to local inhabitants from potential short-term releases from Hinkley Point C (μSv/y)

Radionuclide category	Repeat assessment results (PC CREAM derived food concentration data)			NNB GenCo results		
	Adult	Child	Infant	Adult	Child	Infant
Fission and activation products	2.31E-03	1.27E-03	1.73E-03	4.01E-03	1.84E-03	1.59E-03
Iodines	1.04E-02	2.16E-02	9.41E-02	2.31E-03	3.25E-03	6.22E-03
Noble gases	1.15E-02	6.89E-03	5.36E-03	5.72E-03	3.43E-03	2.67E-03
Tritium	6.51E-03	9.46E-04	7.33E-04	4.43E-03	4.54E-03	9.85E-03
C-14	2.45E-01	1.88E-01	3.70E-01	2.38E-01	2.17E-01	4.29E-01
Total short-term dose	2.76E-01	2.19E-01	4.72E-01	2.58E-01	2.32E-01	4.51E-01

Table 7. Summary of verification assessment and NNB GenCo estimates of collective doses (man Sv per year of discharge) and per caput doses (nSv) from Hinkley Point C

	Repeat assessment results			NNB GenCo results		
Discharge route	**UK**	**EU**	**World**	**UK**	**EU**	**World**
Atmospheric	0.27	2.7	24.6	0.36	3.0	24.60
Marine	0.02	0.20	2.2	0.02	0.20	2.20
Total	**0.29**	**2.9**	**26.8**	**0.38**	**3.20**	**26.80**
Per caput (nSv)	5.3	4.2	2.7	6.9	4.6	2.7

Table 8. Summary of verification assessment and NNB GenCo estimates of build-up of radionuclides in the environment due to atmospheric discharges from Hinkley Point C and all three power stations at Hinkley Point (Bq/m3 for air concentration; Bq/kg for soil concentration)

	Repeat assessment results				NNB GenCo results			
	Hinkley Point C		Hinkley Point A, B & C		Hinkley Point C		Hinkley Point A, B & C	
Radionuclide	**Air conc (Bq/m3)**	**Soil conc (Bq/kg)**	**Air conc (Bq/m3)**	**Soil conc (Bq/kg)**	**Air conc (Bq/m3)**	**Soil conc (Bq/kg)**	**Air conc (Bq/m3)**	**Soil conc (Bq/kg)**
Co-58	3.69E-06	9.00E-05	3.69E-06	9.00E-05	3.60E-06	8.80E-05	3.60E-06	8.80E-05
Co-60	4.35E-06	2.35E-03	2.70E-05	1.46E-02	4.30E-06	2.30E-03	2.70E-05	1.50E-02
I-131	2.19E-05	5.05E-04	4.89E-05	1.13E-03	2.10E-05	4.80E-04	4.80E-05	1.10E-03
I-133	2.63E-05	6.34E-05	2.63E-05	6.34E-05	2.60E-05	6.30E-05	2.60E-05	6.30E-05
Cs-134	3.39E-06	7.80E-04	3.39E-06	7.80E-04	3.30E-06	7.60E-04	3.30E-06	7.60E-04
Cs-137	3.04E-06	7.11E-03	3.04E-06	7.11E-03	3.00E-06	5.90E-03	3.00E-06	5.90E-03
S-35	0.00E+00	0.00E+00	6.50E-03	1.99E-01	0.00E+00	0.00E+00	6.50E-03	2.10E-01

Table 9. Summary of verification assessment and NNB GenCo estimates of build-up of radionuclides in the environment due to liquid discharges from Hinkley Point C and all three power stations at Hinkley Point (Bq/l for water; Bq/kg for sediment)

	Repeat assessment results				NNB GenCo result			
	Hinkley Point C		Hinkley Point A, B & C		Hinkley Point C		Hinkley Point A, B & C	
Radionuclide	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
H-3	1.56E+0	1.07E+0	8.35E+0	5.68E+0	1.57E+0	1.07E+0	8.38E+0	5.69E+0
C-14	1.99E-3	1.19E-1	1.99E-3	1.19E-1	2.00E-3	1.19E-1	2.00E-3	1.19E-1
S-35	0.00E+0	0.00E+0	1.78E-2	4.81E-3	0.00E+0	0.00E+0	1.78E-2	4.82E-3
Cr-51	8.26E-7	5.29E-7	8.26E-7	5.29E-7	8.28E-7	5.28E-7	8.28E-7	5.28E-7
Mn-54	5.34E-6	4.02E-5	5.34E-6	4.02E-5	5.34E-6	4.03E-5	5.34E-6	4.03E-5
Co-58	3.56E-5	6.20E-5	3.56E-5	6.20E-5	3.56E-5	6.20E-5	3.56E-5	6.20E-5
Co-60	6.20E-5	2.55E-3	1.65E-4	6.80E-3	6.20E-5	2.56E-3	1.65E-4	6.38E-3
Ni-63	2.01E-5	3.60E-3	2.01E-5	3.60E-3	2.01E-5	3.60E-3	2.01E-5	3.60E-3
Ag-110m	1.12E-5	1.17E-5	1.12E-5	1.17E-5	1.12E-5	1.17E-5	1.12E-5	1.17E-5
Sb-124	8.20E-6	2.10E-6	8.20E-6	2.10E-6	8.21E-6	2.10E-6	8.21E-6	2.10E-6
Sb-125	1.68E-5	6.62E-5	1.68E-5	6.62E-5	1.68E-5	6.60E-5	1.68E-5	6.60E-5
Te-123	2.2E-20	5.9E-18	2.2E-20	5.9E-18	2.2E-20	5.9E-18	2.2E-20	5.9E-18
Te-123m	4.80E-6	2.44E-6	4.80E-6	2.44E-6	4.81E-6	2.44E-6	4.81E-6	2.44E-6
Te-125m	1.05E-6	6.56E-5	1.05E-6	6.56E-5	1.05E-6	6.55E-5	1.05E-6	6.55E-5
I-131	3.87E-7	4.47E-9	3.87E-7	4.47E-9	3.89E-7	4.46E-9	3.89E-7	4.46E-9
Cs-134	1.15E-5	7.71E-5	8.00E-3	5.37E-2	1.15E-5	7.73E-5	8.00E-3	5.39E-2
Cs-137	1.98E-5	9.89E-4	1.15E-2	5.77E-1	1.98E-5	9.88E-4	1.15E-2	5.75E-1

Table 10. Summary of verification assessment and NNB GenCo estimates of risk quotients and dose rates to the limiting reference organisms from atmospheric and liquid discharges from Hinkley Point C and all three power stations at Hinkley Point (μGy/h)

Discharge route	Organism	Repeat assessment results				NNB GenCo results			
		Hinkley Point C		Hinkley Point A, B & C		Hinkley Point C		Hinkley Point A, B & C	
		RQ[9]	Total dose rate	RQ	Total dose rate	RQ	Total dose rate	RQ	Total dose rate
Atmos-pheric	Amphibian	4.3E-4	4.3E-3	9.6E-4	9.6E-3	3.6E-4	3.6E-3	7.0E-4	7.0E-3
	Bird	4.5E-4	4.5E-3	9.9E-4	9.9E-3	3.7E-4	3.7E-3	7.2E-4	7.2E-3
	Mammal (Deer)	4.5E-4	4.5E-3	9.9E-4	9.9E-3	3.7E-4	3.7E-3	7.2E-4	7.2E-3
	Mammal (Rat)	4.5E-4	4.5E-3	9.9E-4	9.9E-3	3.7E-4	3.7E-3	7.3E-4	7.3E-3
	Reptile	4.5E-4	4.5E-3	9.9E-4	9.9E-3	3.7E-4	3.7E-3	7.2E-4	7.2E-3
	Tree	4.3E-4	4.3E-3	1.0E-3	1.0E-2	3.6E-4	3.6E-3	7.1E-4	7.1E-3
	Badger	4.4E-4	4.4E-3	9.8E-4	9.8E-3	4.2E-4	4.2E-3	8.1E-4	8.1E-3
	Bat	4.4E-4	4.4E-3	9.8E-4	9.8E-3	3.7E-4	3.7E-3	7.1E-4	7.1E-3
Liquid	(Wading) bird	1.1E-4	1.1E-3	3.0E-4	3.0E-3	1.1E-4	1.1E-3	3.0E-4	3.0E-3
	Mammal	1.3E-4	1.3E-3	3.2E-4	3.2E-3	1.3E-4	1.3E-3	3.2E-4	3.2E-3
	Reptile	1.3E-4	1.3E-3	5.2E-4	5.2E-3	1.3E-4	1.3E-3	5.2E-4	5.2E-3

Table 11. Independent assessment of doses from maximum annual discharges using the Environment Agency Initial Radiological Assessment approach (μSv/y)

Discharge route	Estimated dose to representative person	
	Stage 1	Stage 2
Atmospheric discharges (local inhabitant)[a]	110	16
Liquid discharges (fisherman)[b]	370	3.5

a Stage 1: release assumed to be 0 m and Stage 2: 20 m
b Stage 1: volumetric exchange rate 100 m^3/s and at Stage 2: 3.17 10^3 m^3/s

Table 12. Independent assessment of dose rates to non-human biota from maximum annual discharges using Environment Agency Initial Radiological Assessment approach (μGy/h)

Discharge route	Estimated dose to worst affected non-human biota	
	Stage 1	Stage 2
Atmospheric discharges (terrestrial organism)[a]	0.6	0.02
Liquid discharges (marine organism)[b]	0.6	0.006

a Stage 1: release assumed to be 0 m and Stage 2: 20 m
b Stage 1: volumetric exchange rate 100 m^3/s and at Stage 2: 3.17 10^3 m^3/s

[9] The risk quotient (RQ) is the ratio of estimated dose rates to the screening dose rate, used as a screening tool to aid decision. RQ<1 are indicative of low risk situations in which case it may be decided that no further action is necessary.

Table 13. Independent assessment of doses to the candidate representative persons from direct radiation and releases to atmospheric and liquid discharges at maximum predicted discharges for C station and discharge limits for A and B stations (μSv/y)

Profile name	Age group	Hinkley Point C discharges and direct radiation				Hinkley Point A, B & C discharges		
		Terrestrial	Marine	Direct radiation	Total	Terrestrial	Marine	Total
Milk consumer and resident at 500m	Adult	7.2	0.002	1.2	8.4	16	0.002	16
Crustacean consumer	Adult	3.2	0.5	0	3.7	6.5	0.9	7.4

Table 14. Independent assessment of the total dose to representative person from Hinkley Point Site, including contributions from Hinkley Point A, B and C, direct radiation, historic discharges and other sources (μSv/y)

Representative person	Prospective doses from atmospheric discharges from A,B and C combined	Prospective doses from liquid discharges from A,B and C combined	Direct Radiation from A&B	Direct radiation from C	Doses from past discharges from A&B	Total
Adult milk consumer at 500m	15.5+	<1	5	10.4	5	36
Adult crustacean consumer	6.5#	0.9	0	0	36	43

+ See table A9.2 also
# See table A9.4 also

Table 15. Independent assessment of collective doses to UK, EU-12 and World populations truncated at 500 years from maximum annual discharges from Hinkley Point C (man Sv per year of discharge)

Release	Population		
	UK	Europe	World
Atmospheric (1st pass)	0.22	1.30	+
Atmospheric (GC)	0.15	0.89	24.7
Atmospheric (total)	***0.37***	***2.2***	***24.7***
Liquid (1st Pass)	0.005	0.02	0.02
Liquid(GC)	0.01	0.08	2.1
Liquid (total)	***0.02***	***0.09***	***2.1***
Total	**0.39**	**2.3**	**26.8**

+First pass dose for world population is not calculated

Table 16. Independent assessment of average per caput doses (nSv) at maximum discharge levels truncated at 500 years (Hinkley Point C)

Pathway	Dose per person		
	UK	Europe	World
Atmospheric discharges	6.2	6.1	2.5
Marine discharges	0.3	0.3	0.21
Total	**6.5**	**6.4**	**2.7**

Table 17. Independent assessment of effective dose to local inhabitants from predicted potential short-term releases to atmosphere from Hinkley Point C (μSv/y)

	NNB GenCo's predicted short-term discharges			Maximum predicted annual discharges		
Radionuclide	Adult	Child	Infant	Adult	Child	Infant
Ar-41	1.10E-02	1.10E-02	1.10E-02	1.02E-01	1.02E-01	1.02E-01
C-14	5.10E+00	2.90E+00	2.60E+00	7.17E+01	4.01E+01	3.57E+01
Co-58	3.50E-04	1.80E-04	1.30E-04	1.38E-03	7.19E-04	5.02E-04
Co-60	3.40E-03	1.80E-03	1.20E-03	1.38E-02	7.12E-03	4.87E-03
Cs-134	1.60E-03	7.90E-04	5.30E-04	6.28E-03	3.17E-03	2.14E-03
Cs-137	6.20E-04	3.10E-04	2.10E-04	2.49E-03	1.25E-03	8.43E-04
H-3	3.20E-03	2.00E-03	1.50E-03	6.37E-02	4.05E-02	3.01E-02
I-131	1.10E-03	1.00E-03	1.20E-03	2.92E-03	2.66E-03	3.13E-03
I-133	2.60E-04	2.40E-04	3.40E-04	7.08E-04	6.46E-04	9.17E-04
Kr-85	2.10E-04	2.10E-04	2.10E-04	1.91E-03	1.91E-03	1.91E-03
Xe-131m	6.70E-06	6.70E-06	6.70E-06	5.99E-05	5.99E-05	5.99E-05
Xe-133	5.30E-03	5.30E-03	5.30E-03	4.81E-02	4.81E-02	4.81E-02
Xe-135	1.40E-02	1.40E-02	1.40E-02	1.25E-01	1.25E-01	1.25E-01
Total	**5.20E+00**	**2.90E+00**	**2.60E+00**	**7.21E+01**	**4.05E+01**	**3.60E+01**

Table 18. Independent assessment of dose rates to the worst affected terrestrial and marine organisms due to combined discharges from all three power stations at Hinkley Point (μGy/h).

Organism	Total dose rate
Terrestrial organism: Mammal (Rat)	6.55E-03
Marine organism: Polychaete worm	8.07E-03

Appendix 1 – Verification of NNB GenCo's Radiological Assessments for the Proposed Hinkley Point C

Introduction

A1.1 Established principles and guidance for prospective assessment of public doses indicate that a staged approach should be applied to the assessment of the dose to the representative person. The Environment Agency has established an Initial Radiological Assessment (IRA) approach, which provides dose per unit release values to allow a simple, single step conservative assessment of doses from discharges to be made. It is recommended that if effective doses from this approach are less than 20 µSv/y no further assessment would be warranted for the purpose of authorising discharge of radioactive waste to the environment. While such an assessment was undertaken at the GDA stage, no such results were presented in the application for an environmental permit; NNB GenCo provided a detailed assessment of doses to representative persons and to non-human biota. The Environment Agency's IRA was, however, performed as part of the independent assessment, as described in more detail in Appendix 3.

A1.2 This appendix provides details on the verification stage of the independent review and assessment, in which the NNB GenCo approach, parameters and assumptions were replicated, as far as possible, in order to verify the outcomes of the assessment in the submission.

A1.3 The annual maximum radioactive atmospheric and liquid discharges for Hinkley C were provided in the NNB GenCo submission, and are included in Tables 1 and 3 [Ref. A1.1]. For the assessment of dose due to discharges from all three power stations at Hinkley Point and total doses, Hinkley Point A and B were assumed to discharge at the current permit limits, also presented in Tables 1 and 3. It should be noted that the discharge authorisation for Hinkley Point A was revised in 2010. NNB GenCo applied the previous permit limits in its assessments. The short term release assumptions are given in Table 2.

Radiological assessment for humans

A1.4 The doses to candidates for the representative person from the predicted annual maximum atmospheric discharges were calculated for Hinkley Point C and for discharges from all three power stations at Hinkley Point using the models and assumptions specified in the NNB GenCo submission [Ref. A1.1]. Both sets of results are presented in Tables A1.1 – A1.2. NNB GenCo estimated the annual effective doses to the most exposed members of the local population, arising from the predicted annual maximum radioactive discharge to atmosphere, to be 4.4 µSv/y (to infants). The corresponding predicted dose for atmospheric discharges from all three power stations at Hinkley Point was 17 µSv/y. It was possible to repeat the NNB GenCo assessment outcome albeit with minor differences of the order of 0.3 µSv/y (at 4.7µSv/y) for Hinkley Point C and 4 µSv/y (at 21 µSv/y) for all three power stations at Hinkley Point.

A1.5 NNB GenCo estimated doses from the maximum annual liquid radioactive discharges to the marine candidates for the representative person (fisherman and family). Adults were predicted to receive the highest doses from liquid discharges from Hinkley Point C of around 1 µSv/y. The corresponding predicted dose for discharges from all three power stations at Hinkley Point was 2.8 µSv/y (see Table A1.3 – A1.4). NNB GenCo also presented doses to a family of houseboat dwellers arising from liquid discharges. The highest dose of around 0.3 µSv/y from Hinkley Point C and 0.8 µSv/y from all three power stations were predicted (see Tables A1.5 – A1.6). It was possible to repeat the NNB GenCo assessment outcomes, with the exception of the contribution from external dose from sediment. However, both NNB GenCo's estimates and the outcome of the verification assessment agree that the contribution of this pathway to the total dose to houseboat dwellers is insignificant.

A1.6 The NNB GenCo submission also includes an assessment of the annual doses to the farming and fishing families from both atmospheric and marine discharges from Hinkley Point C. Infants are predicted to receive the highest dose from combined discharges of around 4 -5 µSv/y. The

relevant data are presented in Tables A1.7 and A1.8, which also demonstrates that the verification assessment results are close to those in the NNB GenCo submission.

A1.7 NNB GenCo predicted the total effective dose to the representative person (infant member of farming family) to be 17.2 µSv/y. The representative person is affected by both liquid and gaseous discharge from all three power stations ay Hinkley Point; the contribution from direct radiation is assumed to be negligible at the location of the representative person (see Table A1.9). Table A1.10 presents the total effective dose to the fishing family due to both liquid discharges and discharges to air from all three power stations at Hinkley Point.

A1.8 The NNB GenCo application for a permit includes consideration of the build up of radionuclides in the environment. For atmospheric releases, the activity concentrations in air and soil in the 60th year of discharge were assessed, using PC CREAM 98 [Ref. A1.2], for Hinkley Point C and for all three power stations at Hinkley Point. For liquid discharges, the activity concentrations in unfiltered seawater and seabed sediment were assessed, using PC CREAM 98. The assessments were repeated and the results, presented in Tables A1.11 and A1.12 are equivalent to those presented by NNB GenCo.

Short duration releases to atmosphere

A1.9 The results of the NNB GenCo assessment of potential doses from potential short-term releases from the UK EPR are presented in Tables A1.13. NNB GenCo estimated the highest effective dose from short-term releases to be 0.45 µSv per discharge to an infant. Around 95% of this dose was estimated to arise from ingestion doses and C-14 was identified as the dominant radionuclide.

A1.10 NNB GenCo adopted an ad-hoc time-dependent modelling approach in the assessment of dose from ingestion of contaminated foodstuff, which it was not possible to repeat within the scope of this project. An alternative approach based on the application of HPA methodology and NDAWG guidance has been used. The elements of this approach are outlined in more detail in Appendix 2. It was possible to repeat this assessment outcome to within 10% of NNB GenCo estimates (0.47 µSv) using a simplistic approach based on the modification of concentration factors contained within the FARMLAND module of PC CREAM. The use of NDAWG recommendation resulted in the higher dose of 1.8 µSv to infant, a factor of 4 greater than NNB GenCo estimates.

Collective dose

A1.11 The collective dose results included in the NNB GenCo submission are presented in Table A1.14. The collective dose to the UK was estimated to be 0.4 man Sv per year of discharge from atmospheric discharges while the corresponding values for the European and World populations were estimated to be 3.0 and 24.6 man Sv per year of discharge respectively. The collective doses from maximum liquid discharges were 0.02, 0.2 and 2.2 (to the UK, European and World population respectively. The per caput dose to all population groups were estimated to be of the order of 2 – 7 nSv. It was possible to repeat these assessments, although the estimated doses to UK and EU population from atmospheric releases were slightly lower than NNB GenCo estimates.

Dose rates to non-human biota

A1.12 The assessments of dose rates to terrestrial and marine organisms from maximum atmospheric and liquid discharges from Hinkley Point C and all three power stations were assessed using the ERICA Tool [A1.3], supported by the Environment Agency R& D 128 approach [A1.4], for releases of noble gases. The results are presented in Table A1.15 – A1.18. The values for marine organisms are equivalent to those presented by NNB GenCo, but there were some minor differences for predicted dose rates to terrestrial organisms. In all cases, the predicted dose rates are significantly below any existing dose rate benchmarks.

Summary

A1.13 The detailed dose assessments undertaken by NNB GenCo were repeated using the same assumptions and the results were found to be in agreement with, or close to NNB GenCo outcomes, albeit with some differences for doses associated with discharges to atmosphere. The doses from discharges to atmosphere from all three power stations at Hinkley Point were higher than NNB GenCo's estimates by up to 4 μSv/y for the representative person. The reason for this disparity has not been fully established, although it is deemed likely to have resulted from minor differences in the configuration of the three power stations relative to the location of the representative person. There were also some differences in the predicted external doses to houseboat dwellers; however, the contribution of this pathway to the total dose to houseboat dwellers is insignificant.

A1.14 The collective dose assessments undertaken by NNB GenCo were also repeated using the same methods, assumption and parameters. It was possible to reproduce NNB GenCo's outcome for liquid discharges. However, it was not possible to reproduce NNB GenCo's outcome for doses to UK and EU populations from discharges to the atmosphere, which were lower than NNB GenCo estimates.

A1.15 The assessed doses to representative persons due to short duration releases to the atmosphere were repeated using alternative approaches for the ingestion pathway to that used by NNB GenCo. The outcomes of the verification assessment were within 10% of NNB GenCo's results for the PC CREAM approach and around a factor of 4 higher than NNB GenCo estimates for the NDAWG approach.

References

A1.1 NNB GenCo, UK EPR Hinkley Point C, Radioactive Substances Regulation Environmental Permit Application, NNB-OSL-REP-000155 (2011).

A1.2 Mayall A, Cabianca T, Attwood C, Fayers C A, Smith J G, Penfold J, Steadman D, Martin G, Morris T P and Simmonds J R. PC CREAM-97 (PC CREAM-98 code update) NRPB Chilton NRPB-SR-296 (EUR 17791) (1997).

A1.3 ERICA Assessment Tool, http://www.erica-tool.com/

A1.4 Copplestone, D et al, Impact Assessment of Ionising Radiation on Wildlife, R&D Publication 128 Environment Agency, Bristol (2001)

Table A1.1 Annual dose to farming family from maximum atmospheric discharges from Hinkley Point C (µSv/y)

Age group	Pathways													Repeat total	NNB GenCo results
	Inhalation	Cld. Gamma	Dep. Gamma	Resus.	Cloud Beta	Dep. Beta	Green veg.	Root veg.	Cow meat	Sheep Meat	Milk	Milk Prod.	Fruit		
Adult	2.7E-1	3.4E-2	1.9E-2	1.2E-6	1.8E-3	1.1E-3	1.1E-1	7.3E-1	2.4E-1	6.9E-2	4.3E-1	6.5E-1	9.6E-2	**2.6E+0**	***2.4E+0***
Child	2.1E-1	2.0E-2	9.5E-3	1.5E-6	1.8E-3	4.6E-4	1.0E-1	2.2E-1	1.8E-1	3.8E-2	9.3E-1	7.2E-1	5.5E-2	**2.4E+0**	***2.2E+0***
Infants	1.1E-4	6.8E-7	3.2E-3	2.3E-7	1.7E-8	1.8E-5	2.2E-4	1.5E-4	2.9E-4	7.9E-5	1.6E-2	1.5E-2	2.4E-4	**4.7E+0**	***4.4E+0***

Table A1.2 Annual dose to farming family from maximum atmospheric discharges from all three power stations at Hinkley Point (µSv/y)

Age group	Pathways													Repeat total	NNB GenCo results
	Inhalation	Cld. Gamma	Dep. Gamma	Resus.	Cloud Beta	Dep. Beta	Green veg.	Root veg.	Cow meat	Sheep Meat	Milk	Milk Prod.	Fruit		
Adult	5.9E-1	2.4E-1	8.5E-2	2.3E-5	4.4E-3	1.3E-3	2.4E-1	1.6E+0	9.4E-1	4.4E-1	1.3E+0	2.4E+0	2.1E-1	**8.0E+0**	**6.0E+0**
Child	4.7E-1	1.4E-1	4.3E-2	2.0E-5	4.4E-3	5.1E-4	2.3E-1	4.9E-1	8.4E-1	3.3E-1	3.0E+0	3.0E+0	1.2E-1	**8.7E+0**	**6.7E+0**
Infant	3.6E-1	1.1E-1	2.9E-2	1.7E-5	4.4E-3	2.6E-4	1.0E-1	4.6E-1	9.8E-1	2.9E-1	1.0E+1	8.2E+0	2.8E-1	**2.1E+1**	**1.7E+1**

A1.3 Annual dose to fishing family from maximum liquid discharges from Hinkley Point C (µSv/y)

Age group	Pathways								Repeat total	NNB GenCo results
	Fish	Crustac.	Molluscs	Gamma(s)	Beta(s)	Gamma(f)	Beta(f)	Seaspray		
Adult	7.88E-01	2.56E-01	3.20E-02	1.52E-03	4.60E-07	1.20E-05	7.90E-06	3.65E-10	**1.08E+00**	***1.08E+00***
Child	2.73E-01	3.50E-02	0.00E+00	1.36E-04	4.11E-08	0.00E+00	0.00E+00	3.10E-10	**3.08E-01**	***3.00E-01***
Infant	1.21E-01	0.00E+00	0.00E+00	7.77E-06	2.35E-09	0.00E+00	0.00E+00	2.03E-10	**1.21E-01**	***1.20E-01***

A1.4 Annual dose to fishing family from liquid discharges from all three power stations at Hinkley Point (µSv/y)

Age group	Pathways								Repeat total	*NNB GenCo results*
	Fish	Crustac.	Molluscs	Gamma(s)	Beta(s)	Gamma(f)	Beta(f)	Seaspray		
Adult	2.18E+00	5.02E-01	6.25E-02	8.76E-02	2.62E-04	6.91E-04	2.06E-04	3.27E-09	**2.83E+00**	***2.8E+00***
Child	6.05E-01	6.27E-02	0.00E+00	7.82E-03	2.34E-05	0.00E+00	0.00E+00	2.42E-09	**6.75E-01**	***6.7E-01***
Infant	2.42E-01	0.00E+00	0.00E+00	4.47E-04	1.34E-06	0.00E+00	0.00E+00	1.46E-09	**2.42E-01**	***2.4E-01***

A1.5 Annual dose to houseboat dwelling family from liquid discharges from Hinkley Point C (µSv/y)

Age group	Pathways						Repeat total	NNB GenCo results
	Fish	Crustac.	Molluscs	Gamma(s)	Beta(s)	Seaspray		
Adult	2.24E-01	4.33E-02	3.20E-02	4.82E-03	9.17E-08	3.80E-11	**3.04E-01**	***3.00E-01***
Child	2.55E-01	3.50E-02	0.00E+00	4.82E-03	9.17E-08	3.41E-11	**2.94E-01**	***3.00E-01***
Infant	1.21E-01	0.00E+00	0.00E+00	4.82E-03	9.17E-08	2.46E-11	**1.26E-01**	***1.24E-01***

A1.6 Annual dose to houseboat dwelling family from liquid discharges from all three power stations at Hinkley Point (µSv/y)

Age group	Pathways						Repeat total	*NNB GenCo results*
	Fish	Crustac.	Molluscs	Gamma(s)	Beta(s)	Seaspray		
Adult	6.15E-01	8.52E-02	6.25E-02	2.86E-02	5.14E-05	3.41E-10	**7.92E-01**	***7.9E-01***
Child	5.72E-01	6.27E-02	0.00E+00	2.86E-02	5.14E-05	2.62E-10	**6.64E-01**	***6.6E-01***
Infant	2.42E-01	0.00E+00	0.00E+00	2.86E-02	5.14E-05	1.73E-10	**2.71E-01**	***2.7E-01***

A1.7 Annual to farming family with terrestrial and marine exposure from Hinkley Point C (µSv/y)

Age group	Marine pathways									Atm. pathways (total)	Combined total	NNB GenCo results
	Fish	Crustac.	Molluscs	Gamma(s)	Beta(s)	Gamma(f)	Beta(f)	Seaspray	Total			
Adult	2.21E-01	4.36E-02	3.17E-02	3.05E-04	9.32E-08	0.00E+00	0.00E+00	4.97E-11	3.03E-01	2.63E+00	**2.93E+00**	**2.70E+00**
Child	2.72E-01	3.46E-02	0.00E+00	3.05E-04	9.32E-08	0.00E+00	0.00E+00	3.65E-11	3.03E-01	2.42E+00	**2.73E+00**	**2.50E+00**
Infant	1.21E-01	0.00E+00	0.00E+00	3.05E-04	9.32E-08	0.00E+00	0.00E+00	2.66E-11	1.21E-01	4.68E+00	**4.80E+00**	**4.50E+00**

A1.8 Annual dose to fishing family with marine and terrestrial exposure from Hinkley Point C (µSv/y)

Age group	Terrestrial pathways														Marine pathways (total)	Combined total	NNB GenCo results
	Inhalation	Cld. Gamma	Dep. Gamma	Resus	Cloud Beta	Dep. Beta	Green veg.	Root veg.	Cow meat	Sheep Meat	Milk	Milk Prod.	Fruit	Total			
Adult	2.2E-1	3.3E-2	1.9E-2	1.0E-6	1.8E-3	1.1E-3	1.1E-1	2.9E-1	2.4E-1	6.9E-2	4.3E-1	5.8E-1	9.7E-2	2.1E+0	1.1E+0	**3.2E+0**	**3.0E+0**
Child	2.1E-1	2.0E-2	9.6E-3	1.5E-6	1.8E-3	4.6E-4	1.0E-1	2.2E-1	1.7E-1	3.8E-2	6.9E-1	6.1E-1	5.5E-2	2.2E+0	3.1E-1	**2.5E+0**	**2.3E+0**
Infant	1.7E-1	1.6E-2	6.6E-3	1.9E-6	1.8E-3	2.3E-4	4.3E-2	2.1E-1	1.4E-1	2.3E-2	1.7E+0	1.2E+0	1.3E-1	3.7E+0	1.2E-1	**3.8E+0**	**3.6E+0**

A1.9 Annual to farming family with terrestrial and marine exposure from all three power stations at Hinkley Point (µSv/y)

Age group	Marine pathways									Atm. pathways (total)	Combined total	NNB GenCo results
	Fish	Crustac.	Molluscs	Gamma(s)	Beta(s)	Gamma(f)	Beta(f)	Seaspray	Total			
Adult	4.80E-01	2.50E-01	4.30E-02	8.70E-02	2.60E-04	6.90E-04	2.10E-04	4.40E-10	8.60E-01	8.00E+00	8.86E+00	6.8E+00
Child	4.20E-01	4.20E-02	0.00E+00	8.70E-02	2.60E-04	6.90E-04	2.10E-04	2.80E-10	5.50E-01	8.70E+00	9.25E+00	7.3E+00
Infant	1.60E-01	0.00E+00	0.00E+00	8.70E-02	2.60E-04	6.90E-04	2.10E-04	1.90E-10	2.50E-01	2.10E+01	2.13E+01	1.7E+01

A1.10. Annual dose to fishing family with marine and terrestrial exposure from all three power stations at Hinkley Point (µSv/y)

Age group	Terrestrial pathways														Marine pathways Total	Combined Total	NNB GenCo results
	Inhalation	Cld. Gamma	Dep. Gamma	Resus	Cloud Beta	Dep. Beta	Green veg.	Root veg.	Cow meat	Sheep Meat	Milk	Milk Prod.	Fruit	Total			
Adult	5.9E-1	2.4E-1	8.5E-2	2.3E-5	4.4E-3	1.3E-3	2.4E-1	6.5E-1	9.4E-1	4.4E-1	1.3E+0	2.1E+0	2.1E-1	6.8E+0	2.83E+0	**9.63E+0**	**7.8E+0**
Child	4.7E-1	1.4E-1	4.3E-2	2.0E-5	4.4E-3	5.1E-4	2.3E-1	4.9E-1	8.4E-1	3.3E-1	2.3E+0	2.6E+0	1.2E-1	7.6E+0	6.75E-1	**8.28E+0**	**6.5E+0**
Infant	3.6E-1	1.1E-1	2.9E-2	1.7E-5	4.4E-3	2.5E-4	1.0E-1	4.6E-1	9.8E-1	2.9E-1	6.9E+0	7.2E+0	2.8E-1	1.7E+1	2.42E-1	**1.72E+1**	**1.3E+1**

Table A1.11. Build-up of radionuclides in the environment due to atmospheric discharges from Hinkley Point C and all three power stations at Hinkley Point (Bq/m3 for air; Bq/kg for soil)

Radio nuclide	Repeat assessment results				NNB GenCo results			
	Hinkley Point C		Hinkley Point A, B & C		Hinkley Point C		Hinkley Point A, B & C	
	Air conc (Bq/m3)	Soil Conc (Bq/kg)	Air conc (Bq/m3)	Soil Conc (Bq/kg)	Air conc (Bq/m3)	Soil Conc (Bq/kg)	Air conc (Bq/m3)	Soil Conc (Bq/kg)
Co-58	3.69E-06	9.00E-05	3.69E-06	9.00E-05	3.60E-06	8.80E-05	3.60E-06	8.80E-05
Co-60	4.35E-06	2.35E-03	2.70E-05	1.46E-02	4.30E-06	2.30E-03	2.70E-05	1.50E-02
I-131	2.19E-05	5.05E-04	4.89E-05	1.13E-03	2.10E-05	4.80E-04	4.80E-05	1.10E-03
I-133	2.63E-05	6.34E-05	2.63E-05	6.34E-05	2.60E-05	6.30E-05	2.60E-05	6.30E-05
Cs-134	3.39E-06	7.80E-04	3.39E-06	7.80E-04	3.30E-06	7.60E-04	3.30E-06	7.60E-04
Cs-137	3.04E-06	7.11E-03	3.04E-06	7.11E-03	3.00E-06	5.90E-03	3.00E-06	5.90E-03
S-35	0.00E+00	0.00E+00	6.50E-03	1.99E-01	0.00E+00	0.00E+00	6.50E-03	2.10E-01

Table A1.12. Build-up of radionuclides in the environment at year 60 due to liquid discharges from Hinkley Point C and all three power stations at Hinkley Point (Bq/l for water; Bq/kg for sediment)

Radio nuclide	Repeat assessment results				NNB GenCo result			
	Hinkley Point C		Hinkley Point A, B & C		Hinkley Point C		Hinkley Point A, B & C	
	water	sediment	water	sediment	water	sediment	water	sediment
H-3	1.56E+00	1.07E+00	8.35E+00	5.68E+00	1.57E+00	1.07E+00	8.38E+00	5.69E+00
C-14	1.99E-03	1.19E-01	1.99E-03	1.19E-01	2.00E-03	1.19E-01	2.00E-03	1.19E-01
S-35	0.00E+00	0.00E+00	1.78E-02	4.81E-03	0.00E+00	0.00E+00	1.78E-02	4.82E-03
Cr-51	8.26E-07	5.29E-07	8.26E-07	5.29E-07	8.28E-07	5.28E-07	8.28E-07	5.28E-07
Mn-54	5.34E-06	4.02E-05	5.34E-06	4.02E-05	5.34E-06	4.03E-05	5.34E-06	4.03E-05
Co-58	3.56E-05	6.20E-05	3.56E-05	6.20E-05	3.56E-05	6.20E-05	3.56E-05	6.20E-05
Co-60	6.20E-05	2.55E-03	1.65E-04	6.80E-03	6.20E-05	2.56E-03	1.65E-04	6.38E-03
Ni-63	2.01E-05	3.60E-03	2.01E-05	3.60E-03	2.01E-05	3.60E-03	2.01E-05	3.60E-03
Ag-110m	1.12E-05	1.17E-05	1.12E-05	1.17E-05	1.12E-05	1.17E-05	1.12E-05	1.17E-05
Sb-124	8.20E-06	2.10E-06	8.20E-06	2.10E-06	8.21E-06	2.10E-06	8.21E-06	2.10E-06
Sb-125	1.68E-05	6.62E-05	1.68E-05	6.62E-05	1.68E-05	6.60E-05	1.68E-05	6.60E-05
Te-123	2.16E-20	5.85E-18	2.16E-20	5.85E-18	2.16E-20	5.86E-18	2.16E-20	5.86E-18
Te-123m	4.80E-06	2.44E-06	4.80E-06	2.44E-06	4.81E-06	2.44E-06	4.81E-06	2.44E-06
Te-125m	1.05E-06	6.56E-05	1.05E-06	6.56E-05	1.05E-06	6.55E-05	1.05E-06	6.55E-05
I-131	3.87E-07	4.47E-09	3.87E-07	4.47E-09	3.89E-07	4.46E-09	3.89E-07	4.46E-09
Cs-134	1.15E-05	7.71E-05	8.00E-03	5.37E-02	1.15E-05	7.73E-05	8.00E-03	5.39E-02
Cs-137	1.98E-05	9.89E-04	1.15E-02	5.77E-01	1.98E-05	9.88E-04	1.15E-02	5.75E-01

Table A1.13. Effective dose to local inhabitants from potential short-term releases from Hinkley Point C (μSv/y)

	Age group	Inhalation	Cloud Gamma	Dep. Gamma	Green veg.	Root veg.	Fruit	Milk	Cow meat	Sheep meat	Total dose
PC CREAM	Adult	1.6E-2	1.2E-2	2.4E-4	2.9E-3	9.7E-2	1.3E-2	9.3E-2	3.3E-2	9.5E-3	2.8E-1
	Child	1.2E-2	6.9E-3	1.2E-4	2.8E-3	2.9E-2	7.4E-3	1.3E-1	2.4E-2	5.2E-3	2.2E-1
	Infant	8.8E-3	5.4E-3	8.4E-5	1.3E-3	2.7E-2	1.7E-2	3.9E-1	2.0E-2	3.1E-3	4.7E-1
NDAWG	Adult	1.6E-2	1.2E-2	2.4E-4	9.3E-3	4.3E-1	5.5E-2	3.6E-1	2.3E-1	8.2E-2	1.2E+0
	Child	1.2E-2	6.9E-3	1.2E-4	9.4E-3	1.3E-1	3.2E-2	5.3E-1	1.7E-1	4.6E-2	9.3E-1
	Infant	8.8E-3	5.4E-3	8.4E-5	4.0E-3	1.2E-1	7.5E-2	1.5E+0	1.4E-1	2.7E-2	1.8E+0

Table A1.14: Collective dose (man Sv per year of discharge) and per caput dose (nSv) from Hinkley Point C

	Repeat assessment results			NNB GenCo result		
Discharge route	**UK**	**EU**	**World**	**UK**	**EU**	**World**
Atmospheric	0.27	2.73	24.60	0.36	3.00	24.60
Marine	0.02	0.20	2.20	0.02	0.20	2.20
Total	**0.29**	**2.93**	**26.80**	**0.38**	**3.20**	**26.80**
Per caput (nSv)	5.27	4.19	2.68	6.91	4.57	2.68

Table A1.15. Risk Quotients and dose rates to terrestrial organisms from maximum annual atmospheric discharges from Hinkley Point C and all three power stations at Hinkley Point (μGy/h)

	Repeat assessment results				NNB GenCo result			
	Hinkley Point C		Hinkley Point A, B & C		Hinkley Point C		Hinkley Point A, B & C	
Organism	**RQ**	**Total dose rate**	**RQ**	**Total dose rate**	**RQ**	**Total dose rate**	**RQ**	**Total dose rate**
Amphibian	3.68E-04	3.68E-03	7.33E-04	7.33E-03	3.62E-04	3.62E-03	7.01E-04	7.01E-03
Bird	3.79E-04	3.79E-03	7.55E-04	7.55E-03	3.74E-04	3.74E-03	7.23E-04	7.23E-03
Bird egg	2.60E-04	2.60E-03	5.24E-04	5.24E-03	2.57E-04	2.57E-03	4.94E-04	4.94E-03
Detritivorous invertebrate	1.49E-04	1.49E-03	3.08E-04	3.08E-03	1.47E-04	1.47E-03	2.78E-04	2.78E-03
Flying insects	1.46E-04	1.46E-03	3.01E-04	3.01E-03	1.44E-04	1.44E-03	2.72E-04	2.72E-03
Gastropod	1.48E-04	1.48E-03	3.06E-04	3.06E-03	1.47E-04	1.47E-03	2.77E-04	2.77E-03
Grasses & Herbs	2.59E-04	2.59E-03	5.80E-04	5.80E-03	2.56E-04	2.56E-03	4.93E-04	4.93E-03
Lichen & bryophytes	2.59E-04	2.59E-03	5.80E-04	5.80E-03	2.56E-04	2.56E-03	4.93E-04	4.93E-03
Mammal (Deer)	3.80E-04	3.80E-03	7.56E-04	7.56E-03	3.74E-04	3.74E-03	7.24E-04	7.24E-03
Mammal (Rat)	3.80E-04	3.80E-03	7.57E-04	7.57E-03	3.74E-04	3.74E-03	7.25E-04	7.25E-03
Reptile	3.80E-04	3.80E-03	7.56E-04	7.56E-03	3.74E-04	3.74E-03	7.23E-04	7.23E-03
Shrub	2.60E-04	2.60E-03	5.80E-04	5.80E-03	2.56E-04	2.56E-03	4.93E-04	4.93E-03
Soil Invertebrate (worm)	1.49E-04	1.49E-03	3.08E-04	3.08E-03	1.47E-04	1.47E-03	2.78E-04	2.78E-03
Tree	3.69E-04	3.69E-03	7.94E-04	7.94E-03	3.64E-04	3.64E-03	7.05E-04	7.05E-03
Badger	3.76E-04	3.76E-03	7.49E-04	7.49E-03	4.17E-04	4.17E-03	8.06E-04	8.06E-03
Bat	3.75E-04	3.75E-03	7.47E-04	7.47E-03	3.69E-04	3.69E-03	7.14E-04	7.14E-03

Table A1.16. Risk Quotients and dose rates to coastal/ terrestrial organisms from maximum atmospheric discharges from Hinkley Point C and all three power stations at Hinkley Point (µGy/h)

Organism	Repeat assessment results				NNB GenCo results			
	Hinkle Point C		Hinkley Point A, B & C		Hinkle Point C		Hinkley Point A, B & C	
	RQ	Total dose rate	RQ	Total dose rate	RQ	Total dose rate	RQ	Total dose rate
Amphibian	2.23E-05	2.23E-04	9.73E-05	9.73E-04	2.14E-05	2.14E-04	1.41E-04	1.41E-03
Bird	2.30E-05	2.30E-04	1.00E-04	1.00E-03	2.20E-05	2.20E-04	1.46E-04	1.46E-03
Bird egg	1.58E-05	1.58E-04	6.96E-05	6.96E-04	1.51E-05	1.51E-04	9.89E-05	9.89E-04
Detritivorous invertebrate	9.03E-06	9.03E-05	4.14E-05	4.14E-04	8.65E-06	8.65E-05	5.53E-05	5.53E-04
Flying insects	8.83E-06	8.83E-05	4.07E-05	4.07E-04	8.46E-06	8.46E-05	5.41E-05	5.41E-04
Gastropod	9.00E-06	9.00E-05	4.14E-05	4.14E-04	8.63E-06	8.63E-05	5.50E-05	5.50E-04
Grasses & Herbs	1.57E-05	1.57E-04	8.12E-05	8.12E-04	1.51E-05	1.51E-04	9.91E-05	9.91E-04
Lichen & bryophytes	1.57E-05	1.57E-04	8.12E-05	8.12E-04	1.51E-05	1.51E-04	9.89E-05	9.89E-04
Mammal (Deer)	2.30E-05	2.30E-04	1.00E-04	1.00E-03	2.21E-05	2.21E-04	1.46E-04	1.46E-03
Mammal (Rat)	2.30E-05	2.30E-04	1.00E-04	1.00E-03	2.21E-05	2.21E-04	1.46E-04	1.46E-03
Reptile	2.30E-05	2.30E-04	1.00E-04	1.00E-03	2.21E-05	2.21E-04	1.46E-04	1.46E-03
Shrub	1.57E-05	1.57E-04	8.12E-05	8.12E-04	1.51E-05	1.51E-04	9.91E-05	9.91E-04
Soil Invertebrate (worm)	9.02E-06	9.02E-05	4.14E-05	4.14E-04	8.65E-06	8.65E-05	5.53E-05	5.53E-04
Tree	2.23E-05	2.23E-04	1.09E-04	1.09E-03	2.15E-05	2.15E-04	1.42E-04	1.42E-03
Badger	2.28E-05	2.28E-04	9.93E-05	9.93E-04	2.46E-05	2.46E-04	1.62E-04	1.62E-03
Bat	2.27E-05	2.27E-04	9.91E-05	9.91E-04	2.18E-05	2.18E-04	1.44E-04	1.44E-03

Table A1.17. Risk Quotients and dose rates to marine organisms from maximum liquid discharges from Hinkley Point C and all three power stations at Hinkley Point (µGy/h)

	Repeat assessment results				NNB GenCo results			
	Hinkley Point C		Hinkley Point A, B & C		Hinkley Point C		Hinkley Point A, B & C	
Organism	RQ	Total dose rate	RQ	Total dose rate	RQ	Total dose rate	RQ	Total dose rate
(Wading) bird	1.10E-04	1.10E-03	2.99E-04	2.99E-03	1.10E-04	1.10E-03	2.99E-04	2.99E-03
Benthic fish	8.03E-05	8.03E-04	1.36E-04	1.36E-03	8.06E-05	8.06E-04	1.36E-04	1.36E-03
Benthic mollusc	6.64E-05	6.64E-04	1.07E-04	1.07E-03	6.67E-05	6.67E-04	1.08E-04	1.08E-03
Crustacean	6.83E-05	6.83E-04	1.04E-04	1.04E-03	6.86E-05	6.86E-04	1.04E-04	1.04E-03
Macroalgae	4.87E-05	4.87E-04	9.61E-05	9.61E-04	4.90E-05	4.90E-04	9.63E-05	9.63E-04
Mammal	1.28E-04	1.28E-03	3.16E-04	3.16E-03	1.28E-04	1.28E-03	3.17E-04	3.17E-03
Pelagic fish	8.11E-05	8.11E-04	1.30E-04	1.30E-03	8.14E-05	8.14E-04	1.30E-04	1.30E-03
Phytoplankton	9.58E-07	9.58E-06	4.69E-06	4.69E-05	9.85E-07	9.85E-06	4.72E-06	4.72E-05
Polychaete worm	6.74E-05	6.74E-04	1.49E-04	1.49E-03	6.76E-05	6.76E-04	1.50E-04	1.50E-03
Reptile	1.28E-04	1.28E-03	5.21E-04	5.21E-03	1.28E-04	1.28E-03	5.20E-04	5.20E-03
Sea anemones or true corals - colony	6.65E-05	6.65E-04	2.26E-04	2.26E-03	6.66E-05	6.66E-04	2.26E-04	2.26E-03
Sea anemones or true corals - polyp	6.50E-05	6.50E-04	1.75E-04	1.75E-03	6.52E-05	6.52E-04	1.75E-04	1.75E-03
Vascular plant	5.01E-05	5.01E-04	7.65E-05	7.65E-04	4.99E-05	4.99E-04	7.63E-05	7.63E-04
Zooplankton	6.15E-05	6.15E-04	9.36E-05	9.36E-04	6.18E-05	6.18E-04	9.40E-05	9.40E-04

Table A1.18. Risk Quotients and dose rates to terrestrial organisms from maximum annual atmospheric discharges of noble gases from Hinkley Point C and all three power stations at Hinkley Point (µGy/h)

	Repeat assessment results				NNB GenCo results			
	Hinkley Point C		Hinkley Point A, B & C		Hinkley Point C		Hinkley Point A, B & C	
Organism	RQ	Total dose rate	RQ	Total dose rate	RQ	Total dose rate	RQ	Total dose rate
Bacteria	2.86E-07	2.86E-08	4.26E-07	4.26E-08	2.43E-09	2.43E-08	4.25E-09	4.25E-08
Lichen	9.25E-04	9.25E-05	1.39E-03	1.39E-04	7.89E-06	7.89E-05	1.40E-05	1.40E-04
Tree	1.01E-03	1.01E-04	1.53E-03	1.53E-04	8.65E-06	8.65E-05	1.53E-05	1.53E-04
Shrub	1.01E-03	1.01E-04	1.53E-03	1.53E-04	8.65E-06	8.65E-05	1.53E-05	1.53E-04
Herb	1.01E-03	1.01E-04	1.53E-03	1.53E-04	8.65E-06	8.65E-05	1.53E-05	1.53E-04
Seed	1.05E-03	1.05E-04	1.59E-03	1.59E-04	9.22E-06	9.22E-05	1.63E-05	1.63E-04
Fungi	1.17E-03	1.17E-04	1.76E-03	1.76E-04	9.94E-06	9.94E-05	1.75E-05	1.75E-04
Caterpillar	1.81E-03	1.81E-04	2.73E-03	2.73E-04	1.56E-05	1.56E-04	2.70E-05	2.70E-04
Ant	6.88E-04	6.88E-05	1.03E-03	1.03E-04	5.83E-06	5.83E-05	1.03E-05	1.03E-04
Bee	1.66E-03	1.66E-04	2.50E-03	2.50E-04	1.45E-05	1.45E-04	2.50E-05	2.50E-04
Woodlouse	9.36E-04	9.36E-05	1.41E-03	1.41E-04	8.00E-06	8.00E-05	1.41E-05	1.41E-04
Earthworm	2.18E-07	2.18E-08	3.31E-07	3.31E-08	1.87E-09	1.87E-08	3.31E-09	3.31E-08
Her. Mammal	3.62E-04	3.62E-05	5.50E-04	5.50E-05	3.10E-06	3.10E-05	5.50E-06	5.50E-05
Car. Mammal	4.24E-04	4.24E-05	6.40E-04	6.40E-05	3.62E-06	3.62E-05	6.40E-06	6.40E-05
Rodent	3.41E-04	3.41E-05	5.10E-04	5.10E-05	2.90E-06	2.90E-05	5.10E-06	5.10E-05
Bird	1.48E-04	1.48E-05	7.30E-04	7.30E-05	9.62E-06	9.62E-05	1.71E-05	1.71E-04
Bird egg	8.39E-04	8.39E-05	1.27E-03	1.27E-04	7.15E-06	7.15E-05	1.27E-05	1.27E-04
Reptile	4.66E-04	4.66E-05	7.00E-04	7.00E-05	3.93E-06	3.93E-05	7.00E-06	7.00E-05

Appendix 2 – Review of NNB GenCo's Assessment Approach and Summary of Key Independent Parameters

Introduction

A2.1 Following the verification assessment (the results of which are presented in Appendix 1), the next stage of this work was to undertake a detailed critical review of the approach and parameters used in the assessments presented for consideration by NNB GenCo [Ref. A2.1]. This review was undertaken using matrices for each assessment process. The criteria and approaches used were compared with the latest regulatory and advisory body guidance. Supporting notes and comments and decisions regarding the approaches to be adopted during the subsequent independent assessment outlined in this report are noted in Tables A2.1 to A2.9 and key points noted below.

A2.2 This work has not assessed the validity of maximum annual discharges provided by NNB GenCo. The validation of the dose assessments submitted by NNB GenCo is discussed in Appendix 1.

Review findings

A2.3 NNB GenCo applied PC CREAM 98 throughout its assessment. A revised version of this software tool (PC Cream '08) was released in 2008/9, which has been applied in the independent assessment with PC CREAM 98 applied for the verification assessment. Both versions of the model are considered to be valid for prospective dose assessments. However there are differences in the detail in some data that describe the transfer of radioactivity through the environment, PC CREAM-08 using more up to date data, in particular transfer parameters and Kd values and a different European population for collective dose. This may lead to some differences in detailed results due to, for example, modified transfer parameters and Kd values and grid data. The impact of using PC-CREAM-08 was considered in the independent dose assessment.

A2.4 In the NNB GenCo assessment, the candidates for representative person for atmospheric releases and the origin of terrestrial foods were both assumed to be located at 1.7 km from the discharge point [Ref. A2.1]. The standard approach is to assume a location at 100m as a starting point and then to vary this depending on site specific data. The impact of the distance assumptions was considered as part of the independent assessment.

A2.5 Habits data applied in the NNB GenCo assessment for the candidates for the representative person from atmospheric pathways were based on the CEFAS 2006 habit report [Ref A2.4] using a top two approach. In this approach, the two terrestrial foods giving rise to the highest doses are assumed to be consumed at high rates while other foods are consumed at average rates and 100% of terrestrial foods were assumed to be of local origin. Current practise is where site specific habits data are available the data can be formed into profiles and applied to the predicted concentrations. This approach is site specific and is likely to be more realistic than the top two approach. There is site specific habits data from 2006 and 2011 at Hinkley Point which can be formed into profiles and used. The independent dose assessment will be made using the site specific habits data from the 2011 site specific habits survey and the outcome compared with the NNB GenCo assessment.

A2.6 The NNB GenCo approach included derivation of higher inhalation rates for adults for Generic (annual activity-weighted) inhalation rate assumptions, from NRPB-W41 [Ref. A2.4] were used in the independent assessment.

A2.7 For the assessment of marine discharges, the approach applied to calculate doses from marine discharges from organically bound tritium (OBT) is unclear. It appears that the concentration factor for C-14 is applied, although the justification for this choice is unclear. In the independent

assessment, the contribution of OBT is assessed using default assumptions from PC CREAM 08 [Ref A2.5]

A2.8 The NNB GenCo assessment includes consideration of a houseboat dweller as a possible candidate representative person. The assumptions applied in the calculation of the external dose from sediments (e.g. regarding the column of water above bottom sediment at low tide) are unclear. This group has been considered for verification purposes only.

A2.9 The NNB GenCo approach to assess the contribution of terrestrial foods from short term releases to atmosphere was relatively complex and involved the implementation of the FARMLAND model within a software tool. This involved modelling the different stages of deposition, radioactive decay and food production. Repetition of such an approach was beyond the scope of the independent assessment. For the purposes of the independent assessment, a simple method based on the application of factors included in the HPA methodology and NDAWG guidance [Ref. A2.9] has been applied.

A2.10 NNB GenCo presented activity concentrations in environmental media (air, soil, unfiltered water and seabed sediment) in the 60^{th} year of discharge (assuming continuous atmospheric and liquid discharges at maximum levels). These calculations were verified but the subsequent calculation of doses from potential future uses of land and sea (using the NRPB-W36 methodology) were not performed as part of the independent assessment. The dose assessment approach was not developed for this purpose.

A2.11 For assessing internal exposure from radionuclides taken into the body by inhalation or ingestion the applicant has used dose coefficients for ingestion and inhalation for members of the public published by ICRP in 1996 (ICRP-72) and promulgated into other documents including the 1996 EC BSS. The dose coefficients published by ICRP represent committed effective dose (CED) – which takes into account the potential lifetime commitment allowing for the biological behaviour of radionuclides within the body and the pathway by which they were introduced into the body. The effect of the doses was determined using the risk factors recommended by ICRP in 2007 (ICRP-103). These factors have been accepted by HPA, the UK's competent authority, as appropriate for use when making radiation protection decisions.

A2.12 In assessing the potential impacts on non-human biota, NNB GenCo applied the ERICA Tool and the Environment Agency R&D 128 approach. A similar approach has been applied in the independent assessment. However, there are some anomalies in the way in which NNB GenCo has presented the results and some differences in the specification of potentially exposed protected species between this and the independent approach.

References

A2.1 NNB GenCo, UK EPR Hinkley Point C, Radioactive Substances Regulation Environmental Permit Application, NNB-OSL-REP-000155 (2011).

A2.2 Environment Agency, Initial Radiological Assessment Methodology (Parts 1 and 2), Science Report SC030162/SR1 (2006).

A2.3 Food Standards Agency and Joint Environment Agencies' Report, Radioactivity in Food and the Environment, 2010 (RIFE-16) (2011).

A2.4 Smith, K R and Jones A L, Generalised Habit Data for Radiological Assessments, NRPB-W41, NRPB, Chilton (2003).

A2.5 Mayall A, Cabianca T, Attwood C, Fayers CA, Smith JG, Penfold J, Steadman D, Martin G, Morris TP and Simmonds JR. PC CREAM-97 (PC CREAM-98 code update) NRPB, Chilton NRPB-SR-296 (EUR 17791) (1997).

A2.6 Oatway, W B and Mobbs, SF, Methodology for estimating the doses to members of the public from future use of land previously contaminated with radioactivity, NRPB-W36, National Radiological Protection Board, Chilton (2003).

A2.7 ERICA Assessment Tool, http://www.erica-tool.com/

A2.8 Copplestone, D et al, Impact Assessment of Ionising Radiation on Wildlife, R&D Publication 128 Environment Agency, Bristol (2001)

A2.9 National Dose Assessment Working Group (2011), Guidance on Short Term Release Assessments, NDAWG Guidance Note 6

Table A2.1 Review of the EDF/NNB GenCo approach for assessment of individual dose – discharges to the atmosphere

Section	Criteria	NNB GenCo Approach	Comments on EDF/NNB Genco Approach	Approach used for Independent Assessment
Discharges	Discharge data	Maximum and 'expected best performance' discharges are presented data based on Operational Experience Feedback (OEF) obtained from existing fleet of PWRs. Maximum values are used in the assessment; 12 months rolling limits proposed to take account of operations contingencies, start-ups and shut-downs.	Suitably conservative Rolling 12 month periods consistent with standard practice	Same approach used
		NNB GenCo proposed discharge limits for normal operations. These are based on the maximum expected discharges with consolidation of some radionuclides into group limits.	Assessment of doses at the proposed limits was made and the results are presented as a comparison with doses from maximum discharges.	Assessment made at proposed limits and summary presented
	Radionuclide releases and spectrum	Assessment was performed for individual radionuclides – no grouping of radionuclides. Radionuclides assessed are: Tritium; carbon-14; noble gases (Ar-41, Kr-85, Xe-131m, Xe-133 and Xe-135); cobalt-58; cobalt-60; iodine 131; Iodine 133; caesium-134 and caesium-137;	Identification of complete list of radionuclides releases allows for comprehensive assessment and identification of radionuclides with the highest releases and/or which give rise to the greatest contribution to dose. Together with information other factors, such as feasibility of surveillance, this should provide an appropriate basis for determining whether and how to group nuclides into groups for regulatory purposes	The complete list of radionuclides used in the independent assessment.
	Discharge assumptions	Routine annual atmospheric discharges assumed to be continuous and uniform for 50 years.	Approach appropriate for allowing for build up in the environment and consistent with the revised dose assessment principles paper, developed by the Environment Agency and other relevant bodies.	Same approach used
	Release Points	Physical stack height: 70 m, protruding several metres above building. Effects of building wake on plume accounted for, resulting in an effective release height of 23.3m (1/3 building height).	Reasonable approach	Effective stack height based on 1/3 physical (23.3 m)
	Incineration release	None - Emissions from Hinkley Point B incinerator		Discharges from Hinkley Point B

Section	Criteria	NNB GenCo Approach	Comments on EDF/NNB Genco Approach	Approach used for Independent Assessment
		considered to be minor relative to reactor operation		incinerator included in the Independent Assessment
Receptor Points and pathways	Habits of the reference person	Habitation: farming family located at 1.7 km from UK EPR East stack; map of location provided in Appendix 5 (Chapter 12.2). This location is considered to correspond to the receptor point with highest air and ground concentrations	A location of 1.7 km is unlikely to represent the highest air and deposition concentrations. During the GDA (for similar stack height) distances of 150 – 200 m were identified at the maximum location, depending on the stability category used. It would be reasonable to consider whether the habits and location are sufficiently representative of long-term trends.	Habitation initially assumed to be 100m from release point . Farm location assumed to be 500m from release point. Further review suggested that the maximum air concentrations are 300-500m from the release point, so the assessment was revised to Habitation at 500m, farm location 500m
		Food origin: assumed to be produced at habitation of farming family	Reasonable assumption, given distance of habitation from site. However, it is possible that there are houses closer to the site with fruit and vegetable gardens.	Consider doses from production of fruit and vegetables initially at 100m and then at 500m and other terrestrial foods at 500 m.
Exposure Pathways	External	From cloud and from deposit radionuclides; Location factor for cloud gamma: 0.2 and 0.1 for deposited gamma	Location factors appropriate and consistent with default values presented in EC RP-72 and HPA-RPD-058.	Similar pathways considered
	Inhalation	Considers both plume and resuspended radionuclides; Inhalation rates derived from NRPB-W41 (CEFAS data relevant for people within 1 km of site)	Resuspension approach unclear, although presumably PC CREAM 98 default method applied. Source of inhalation data appropriate for purpose (long-term assessment).	Similar pathways considered
	Ingestion	Consumption of terrestrial foods – excluding grain, cow liver and sheep liver; Ingestion rates derived from CEFAS 06 using Top 2 approach (rather than direct use of profiles). It is argued that this approach is more conservative and more appropriate for long-term assessment. Top two foods as follows: Adults: root vegetables and milk products Children and infants: milk and milk products	This approach is reasonable and conservative. Current guidance recommends use of site specific habits in profiles where appropriate.	Profiles data based on CEFAS 2011 report for Hinkley Point used for Independent Assessment.

Section	Criteria	NNB GenCo Approach	Comments on EDF/NNB Genco Approach	Approach used for Independent Assessment
Modelling of Environmental Concentrations	Meteorology	Site specific meteorological data used. Site specific data for the years from 1999 – 2008 used. Data obtained from the UK Met office	The reasoning for using 9 year collection period for meteorological data is not clear. Presumably data are available for the entire operational period of the Hinkley site. However, this is a long-term average and may be considered to be appropriate – the uncertainties/variability in these data may be considered further if necessary.	Same approach
	Deposition	Deposition and washout coefficients: Particles: 110^{-3}; 110^{-2} m/s (inorganic iodine); zero for noble gases; 510^{-3} for tritium. Washout: 110^{-4} $s^{-.1}$ for 1 µm particles.	Standard assumptions, consistent with default values presented in EC RP 72, except for tritium for which no allowance for deposition is made in EC RP 72 or subsequent PC CREAM 08 methodology (return to atmosphere short compared to half-lives).	Same approach
		Surface roughness value: variable Variable roughness length file assumes 0.01 m over sea, 0.3 m over agricultural land and variable values over Hinkley Point site to account for existing buildings.	Standard assumption, consistent with default values presented in EC RP 72. The stated values are consistent with the default values for sea and very short grass and agricultural areas in the PC CREAM 08 Methodology (HPA-RPD-058).	0.3 m surface roughness length for agricultural land to be assumed
Habits Data	Occupancy	Occupancy: 8,760h/y (100% occupancy)	Reasonable conservative assumption for farming family	100%
		Indoor occupancy: 0.5, 0.8, 0.9 factors for adult, child and infant respectively.	Consistent with conservative interpretation of NRPB-W41, and appropriate for farmer and higher value for child in farming environment. (NB: The standard assumption for indoor occupancy for child is 0.9).	Similar generic data to be applied, consistent with the EA Initial Radiological Assessment.
	Intakes	Breathing rate: 1.12, 0.64, 0.22 m^3/h for adult, child and infant respectively. Inhalation rates derived from NRPB-W41	Source of inhalation rates appropriate for assessment type. The values for infants and children are consistent with the hourly rates presented in NRPB-	Generic annual inhalation rates from NRPB-W41 used.

Section	Criteria	NNB GenCo Approach	Comments on EDF/NNB Genco Approach	Approach used for Independent Assessment
			W41. However, the adult value is higher than the generic hourly rate of 0.92 presented. It would also be more appropriate to use the weighted annual values from NRPB-W41, as follows: Adult: 8.1 10^3; child: 5.6 10^3 and 1.9 10^3 m^3/y for the assessment of continuous releases	
		Ingestion data based on CEFAS 06 using the Top 2 foods with highest contribution to dose consumed at high rates (97.5th percentile), all other foods consumed at average rate; 100% of terrestrial food produced from farm location. Dietary information for children and infants often based on adult patterns due to lack of data	General approach reasonable, although consideration needs to be given to the possibility of closer habitation and vegetable production.	Assessment undertaken using site specific habit profiles data from CEFAS 2011. 100% of foods assumed to be produced locally.
Dose to Terrestrial Candidate for reference person	Dose calculation	Dose coefficients for intakes taken from ICRP Publication 72	Source appropriate	Dose coefficients for intakes taken from HPA-RPD-058 derived from ICRP-72 and the EC BSS
		External dose coefficients taken from Federal Guidance Report No. 12	Source appropriate, although there may be differences in detail between the dose coefficients from deposition from FRG 12 and PC CREAM 98 and 08 due to different assumptions about migration of activity through soil with time.(FRG 12 likely to be more conservative due to assumption that material remains in surface layers)	FGR 12 parameters for external dose from deposition

Table A2.2 Review of NNB GenCo approach for assessment of individual dose – liquid discharges to the marine environment

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
Discharges	Discharge data	Maximum and 'expected best performance' discharges are presented based on Operational Experience Feedback (OEF) obtained from existing fleet of PWRs; only maximum values (for normal operating conditions) used in the assessment; 12 months rolling limits proposed to take account of operational contingencies, start-ups and shut-downs (annual values were proposed during the GDA)	Use of maximum discharge values is a conservative approach; Rolling 12 month periods consistent with standard practice	Use of maximum discharge values proposed It may be appropriate to consider the range of values as part of uncertainty/ variability considerations, if appropriate
	Discharge assumptions	Tritium: 200 TBq Carbon-14:190BGq Caesium-137: 1.9GBq Other fission products: 18.1GBq Higher proposed annual limit for H-3 proposed than in GDA based on observation that at a sister EPR use of higher enriched U-235 results leads to an increase of 60-80 TBq/y in H-3 discharges		
		All discharges assumed to be continuous, uniform, routine releases; 50 year integration time.	Allowance for 50 year accumulation of material in the environment is consistent with dose assessment principles document	Similar approach
	Radionuclide releases and spectrum	Assessment was performed for individual radionuclides – no grouping of radionuclides. Radionuclides proposed for setting liquid discharge limits are: Tritium; Carbon-14; Caesium-137; and Other fission and activation products comprising isotopes: chromium-51, manganese-54, cobalt-58, cobalt-60, nickel-63, silver-110m, tellurium-123m, antimony-124, antimony-125, iodine-131 and caesium-134	Identification of complete list of radionuclides releases allows for comprehensive assessment and identification of radionuclides with the highest releases and/or which give rise to the greatest contribution to dose. Together with information other factors, such as feasibility of surveillance, this should provide an appropriate basis for determining whether and how to group nuclides into groups for regulatory purposes	The complete list of radionuclides used in the independent assessment.

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
	Liquid tritium discharges	Organically bound tritium (OBT) and tritiated water (HTO) considered separately for Hinkley Point B discharges; OBT modelled using concentration factors for carbon-14; This approach is referenced to Environment Agency approach applied during Hinkley Point B – Authorisation review 2005/06.	Basis for approach to OBT unclear	OBT not considered separately for independent assessment
Assessment Methodology/ Dispersion modelling	Modelling Packages	PC Cream 98 (Doris and Assessor modules). The methodology is consistent with GDA approach to allow for comparison	PC CREAM has been updated since the GDA process. PC CREAM 08 is the most recent version; it would be more appropriate to present results using the most recent modelling capabilities – and to compare the results identifying which differences are due to site-specific assumptions or modelling aspects	PC CREAM 08 used
		Microshield Used for assessment of dose to houseboat family from radionuclides in sediment and water using Doris output	General application of software appears to be appropriate	Assessment of external dose rates using FGR 12 methodology
	Marine dispersion parameters	Dispersion parameters based on PC Cream98 marine module (Doris) for Bristol channel	Parameters used considered appropriate for the proposed Hinkley Point C site.	Application of standard parameters for Hinkley Point from PC CREAM 08
Exposure groups	Candidate reference person [10]	1. Fisherman Family 2. Houseboat family 3. Fishing family with terrestrial and marine exposures	Appropriate choice of candidate critical groups, (candidate for representative person) although it is not clear why the houseboat dwellers have been identified for consideration, when this group were not considered for the most recent assessment for Hinkley Point B. The separate specification of groups 1 and 2 is probably unnecessary, although this approach allows the contribution of the different exposure routes to be presented explicitly.	Use of CEFAS profiles to determine candidate reference persons.

[10] NNB GenCo noted their continued use of the term 'critical group' to represent the most exposed group of people in order to ensure consistency with cited references. NNB GenCo acknowledged that the term 'representative person' is now used instead.

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
	Age groups	Age groups assessed: adult, child and infant; embryo/ foetus and breastfed infant not assessed, since the radionuclides relevant for foetal dose assessment (P-32, P-33, Ca-45 and Sr-89) are not present in discharges	Appropriate assumptions	Similar approach
Exposure pathways	External	External exposure to beach sediments (fisherman family); External exposure from handling fishing gear (fisherman family -adults only). External exposure to beach sediment and contaminated water (houseboat family only)	Appropriate identification of external routes of exposure (pending clarification of the houseboat dwelling group)	Similar generic assumptions assumed
	Inhalation (seaspray)	Inhalation of seaspray while on the coast (fisherman and houseboat families) Distance from coast not specified. A distance of 1m may have been applied.	It is reasonable to consider this pathway for beach occupancy periods. Detailed assumptions (incl. distance from sea to be determined in verification assessment)	Similar generic assumptions assumed
	Ingestion	Ingestion of fish, crustacea and molluscs (100% caught in local compartment).	Suitably conservative assumption	Similar approach: 100% fish, crustacean and molluscs derived from local compartment.
Habit data (Fisherman family)	Occupancy habits	Time spent in local compartment: 100% Rates from 2006 Cefas study used	Could not confirm occupancy from Cefas 2006 report on Hinkley Point	CEFAS 2011 report rates applied.
		Beach occupancy (97.5th rates): 1960, 175 and 10 h/y for adults, children and infants respectively. Rates from 2006 Cefas study used	Could not confirm from Cefas 2006 report on Hinkley Point	CEFAS 2011 report rates applied.
	Handling fishing gear	Handling fishing gear (97.5th rate): 1560 h/y (adults only). Rates from 2006 Cefas study used	Values confirmed to be from Cefas 2006 report on Hinkley Point	CEFAS 2011 report rates applied.
	Inhalation rates	Breathing rates (m^3/h): 1.69, 1.12 and 0.35 for adult, child and infant respectively. Breathing rates for adults derived from NRPB W-41 (based on value for workers); breathing rates for child and infant derived from ICRP 66	Source of inhalation rates appropriate for assessment type. The values for infants and children are consistent with the hourly rates presented in NRPB-W41. However, the adult value is higher than the generic hourly rate of 0.92 presented. It would also be more appropriate to use	Standard inhalation rates from NRPB-W41 to be applied.

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
			the weighted annual values from NRPB-W41, as follows: Adult: $8.1x10^3$; child: $5.6x10^3$ and $1.9x10^3$ m^3/y for the assessment of continuous releases	
Habit data (Fisherman family)	Food intake	Ingestion of fish (97.5th rate): 47.2, 11.8 and 2.6 kg/person/ y for adult, child and infant respectively; Ingestion of crustacea (97.5th rate): 15.3 and1.5 kg/person/ y for adult, and child only, respectively; Ingestion of mollusc (97.5th rate): 1.9 kg person/ y for adult only; Food intake data taken from 2006 Cefas report (it is noted that NRPB-W41 ingestion rates would result in higher doses)	The food intake rates used by NNB Genco differ from those used in the radiological assessment in support of the authorisation review for Hinkley Point B (2006). These data will need to be reviewed in more detail and compared with the data included in the draft CEFAS habit data report (2011)	Profiles data from CEFAS 2011 used
Habit data (Houseboat family)	Occupancy habits	Fraction of time spent in regional compartment: 100% (since harbour inhabited by Houseboat family is not in the immediate vicinity of Hinkley Point site) Houseboat family assumed to live in a houseboat all the time; which either floats on water or lies on sediment depending on tide 22 h/ day exposure time applied;	Appears to be reasonable general approach	Considered for verification purposes only. Houseboat family not considered in independent assessment.
		Occupancy on beach (97.5th rates): 5,050 h/y for adults, children and infants alike; Occupancy on water (97.5th rates): 3,080 h/y for adults, children and infants alike Occupancy time for seaspray: 8,130 h/y for adult, child and infant alike	Source of occupancy data unclear	Houseboat family not considered in independent assessment.
Habit data (Houseboat family)	Inhalation rates	Breathing rates (m3/h): 0.92, 0.64 and 0.22 m^3/h for adult, child and infant respectively. Breathing rates derived from NRPB W-41 (generalised inhalation rates)	Reasonable approach, for hourly occupancy rates (NB – the inhalation rate for adults is consistent with the standard rate presented in NRPB-W41)	Houseboat family not considered in independent assessment.
	Water depth	Depth of water at high tide: 10 m Data derived from local of the		Houseboat family not considered in independent

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
		closest harbour around the Hinkley Point area		assessment.
	Food intake	Ingestion of fish (mean rates): 13.4, 11.2 and 2.6 kg/person/ y for adult, child and infant respectively; Ingestion of crustacea (mean rates): 2.6, 1.5 and 0 kg/person/ y for adult, child and infant respectively; Ingestion of mollusc (mean rates): 1.9 kg/person/ y for adult only;	Appropriate basis for assessment. However, *ingestion of fish: only one infant* observation (it would be more appropriate to use a generic value for this age group)	Houseboat family not considered in independent assessment.

Table A2.3.Review of NNB GenCo approach for assessment of individual dose – short term releases

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
General approach		Only assumed for gaseous discharges	Approach based on NRPB-W54 Modelling using ADMS 4.0 No short-term liquid discharges considered on basis of holding tanks for liquid discharge – regular short-term releases occurring repeatedly which can be modelled as continuous. This approach was adopted during the GDA. Approach reasonable. Consultation with HPA also indicated that potential for significantly non-homogeneous impacts from liquid discharges less than for atmospheric. It is assumed that short-term releases will not occur at the same time for the two EPR units. Short-term doses calculated for gaseous discharges from a single UK EPR stack.	Atmospheric discharges only considered. Approach based on NRPB W54 methodology and NDAWG guidance.
Release	Timing of release	Summer (1 July)	Most conservative assumption for all foods; based on NRPB-W54	More cautious approach taken with release in 6 hour period applied. Bounding assessment with discharges at annual limits also made.
	Stack height and diameter	Physical height 70 m, stack diameter 3 m. Effective height 23.3m.	Consistent with assumptions for continuous (longer-term) releases; stack height based on ADMS modelling. Height of adjacent reactor building: 60 m	
	Quantity of release	Between 5 and 37% of proposed annual limits	Carbon-14 the radionuclide with the largest impact was only assessed at 5% of the proposed annual limit. We consider these values to be too small	
	Period of release	24 hour release scenario	Greater than the short-term release scenarios presented in HPA report (which does not appear to have been referenced)	
Dispersion	Release rate (exit velocity) Emission rate	9.6 m/s 244,290 m3/h	Release rate of 7m/s used for GDA	
	Meteorological data	Meteorological data for the months of June – August for all the years from 1999 – 2008 used.	Site specific meteorological data based on 10 year weather information obtained from the UK Met office	Similar approach used
	Air concentration	ADMS 4 run with 24 hour averaging time to determine 95th percentile	Based on NDAWG recommendation for conservative assessment	ADMS 4.2 runs with rolling 6 hour averaging time to

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
		and airborne data for a 24 hr release		determine 95th percentile of air and ground concentration for 6 hour release
Radioactive decay		Radioactive decay taken into account for the assessment of short term dose from ingestion and external (deposited) pathways		Similar approach used
Receptors	Receptor point	Location of exposure group for short-term releases assumed to be the same as for continuous releases (1.7 km)	It would be prudent also to consider potential impacts at a closer location	Receptor point 100 m with agricultural produce from 500 m
Exposure Pathways	External irradiation from deposited radionuclides.	The associated dose calculated for the year following the short-term release	Reasonable choice of exposure pathways	Similar pathways considered
	Inhalation and external irradiation from Plume	Associated dose calculated for the period of plume passage (24 hr)		
	Ingestion of foodstuffs	The associated dose calculated in the year following the short-term release		
Food concentration methodology	Food chain models based on FARMLAND/ RP72 Fruit model based on NRPB-W46	Ingestion of contaminated food from 1 July – 30 June following a release event on 1 July assumed. Ingestion dose in 1st year for release of all nuclides except H-3 and C-14. Transfers to crops and intakes from RP-72 Models implemented in ModelMaker4 to replicate FARMLAND	Approach for assessing transfer to terrestrial foods appears to be reasonable, although complex.	Simple approach based on time integrated activity concentrations in food from NDAWG guidance and HPA-RPD-058
	Cow model	3 periods considered: grazing 1 July – 31 October; ingestion of contaminated silage 1 November – 15 April; grazing 15 April – 30 June. Meat & milk – peak concentration assumed to continue all year (except for radioactive decay); Inhalation and ingestion of contaminated feed taken into account for Cs, I and Co isotopes; No processing food losses assumed.		
	Green vegetables model	Concentration at the time of cropping – continuous harvest. Plants growing at the time of deposition, uptake from soil and		Simple approach based on time integrated activity concentrations in food from NDAWG

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
		losses to soil and decay for period since deposition. Cs, I, Co isotopes – green vegetable model used to calculation TIC. Preparation factor of 0.2 (i.e. 80% loss of initial activity) assumed.		guidance and HPA-RPD-058
	Root vegetables model	Based on potatoes: harvesting – 1st July to 1st August; consumption and storage – 1st August to 15th November; Planted – 1st February; harvested for consumption – 15th June to 30th June. Model run for 32 days from 1 July; after which radioactive decay is accounted from concentration at day 32. Activity in soil on 1st February noted and used as soil input for days 349-365. For Cs, I and Co TIC from deposition from the plume. No processing losses assumed.		
	Fruit model	Based on woody tree. Growing season – 1st July to 15th September; harvest -15th September; no fruit – 15th September to 15th April; fruit growth – 15th April to 30th June. Concentration on 77th day recorded – concentration assumed for the rest of the year (taking account of radioactive decay). Cs, I, Co: fruit model used to determine TIC in fruit from plume deposition. No preparation losses assumed.		
	Sheep model	Assumed to graze continuously. Activity is averaged over the period between peak concentration and 30 June (for slaughter any time during the first year). TIC for Cs, I, Co from inhalation and ingestion of contaminated pasture. No preparation losses.		
	Tritium and C-14	Specific activity model Specific activity of each element in food assumed equivalent to that in air. Bq/kg per Bq/m^3 factors		

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
		taken from Environment Agency Initial Assessment Methodology. Factors are for continuous release; modified for 24 hr discharges.		
Reference person Habits	Occupancy	100% at location; Fraction of time spent Indoor: 0.5, 0.8, 0.9 for adult, child and infant respectively	Reasonable approach	Similar approach
	Intakes	Breathing rates based on NRPB-W41 and ICRP66 - values for indoor and outdoor occupancy presented (indoors):0.48, 0.58 and 0.21 m3/h for adult, child and infant respectively Breathing rates (outdoors): 1.75, 0.87 and 0.31 m3/h for adult, child and infant respectively	Derivation of breathing rates for indoor/outdoor occupancy unnecessarily complicated	Breathing rates based on NRPB-W41 values for outdoor occupancy (1.75, 0.87 and 0.31 m3/h for adult, child and infant respectively)
		Ingestion rates derived from Cefas 2006 - top 2 approach: top 2 foods consumed at high rates (97.5th percentile), all other foods consumed at average rate; 100% of food locally produced.	Generally reasonable approach, but will be conservative relative to use of habits profiles.	Habit profiles data from CEFAS 2011 report for Hinkley Point
Dose calculation	Ingestion	Dose calculated using ADMS output (atmospheric/ deposited) concentration, TIC (inhalation/ ingestion) in food (Bq/kg per Bq/m^3); preparation factors, ingestion rates and dose coefficient for ingestion. Concentration factors applied for milk products: 0.44, 6 and 11 for H-3, C-14 and other radionuclides respectively. Concentration factors for milk products, taken from NRPB-M587 and PC CREAM	Reasonable approach	Similar approach
	Inhalation	Calculated for the passage of plume (24 hours); Breathing rate (indoor/outdoor average) modified by an indoor occupancy reduction factor of 0.5 for depositing radionuclides.	The modification of inhalation doses by a reduction factor questionable	No application of reduction factor

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
	External (plume)	Calculated for the passage of plume (24 hours); Activity concentration in air from ADMS; cloud gamma location factor (indoor/outdoor) applied Additional calculations undertaken for skin dose. Dose coefficients taken from FGR-12 and amended with ICRP60 tissue weighting factors	Reasonable approach	Similar approach, although application of location factor for shorter assumed release period (6 hours) not applied
	External (deposit)	Calculated for the year following short-term release Ground contamination from ADMS; indoor/ outdoor occupancy and location factors (deposited gamma) applied; radioactive decay accounted for; Dose coefficients taken from FGR-12	Reasonable approach	Similar approach

Table 2.4. Review of NNB GenCo approach for assessment of individual dose – direct dose assessment

Section	Criteria	NNB Genco approach	Comments on NNB Genco approach	Approach used for Independent Assessment
Methodology	Assumptions	Highest dose from a waste store located close to site boundary. Assumed dose rates: At 1 m from outer wall of building is 0.5 μSv/h (representative of an undesignated area) At receptor point: 1/r for receptors within 2-3 building width; $1/r^2$ for receptors further away.	Assumption about the maximum dose rate at the wall of the waste store likely to be conservative. The representative value for site fence measurements at Sizewell B are lower (4 μSv/y) than the representative site fence value used in the NNB Genco (0.0125 μSv/h, or 110 μSv/y for continuous occupancy).	Similar approach
Scenarios	Walker	Assumes member of the public walking along coastal path close to waste store for 10 min every day. Does not live within the vicinity of site.	Appears to be a reasonable general assumption,	Approach for walker scenario applied
	Local resident 1	Residing all year at a dwelling 1.3 km south of waste store. Receive highest at-home dose.		
	Local resident 2	Residing at a dwelling 1.7 km SE of waste store at location of highest air and ground concentrations (from atmospheric discharges).	Representative of the current candidate critical group (candidate for representative person)	

Table A2.5.Review of NNB GenCo approach for assessment of individual dose – total dose

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
Combined exposures from discharges	Farming family with exposure to marine discharges	High rate terrestrial food consumers who consume locally sourced seafood Beach occupancy (recreational): 400, 175 and 10 hr/y for adult, child and infant respectively. Assumed to spend some recreational time on beach (exposed to seaspray and external dose from sediment). No exposure through fishing gear. Marine food consumption based on average consumption of marine foods from local compartment.	Appropriately conservative generic assumptions.	Habit profiles data from CEFAS 2011 report for Hinkley Point used
	Fishing family with atmospheric exposures	Marine food consumers who consume local terrestrial foods. Outdoor occupancy: 50%, 20% and 10% for adult, child and infant respectively. Assumed live in close proximity to site (same dwelling as farming family) and consume locally sourced foods at average rates. Exposure to cloud and deposited dose, and plume inhalation assumed.	The location assumption is likely to be reasonable; the farming family is located at some distance from the site (1.7 km), which may also be appropriate for a fishing family. The assumptions regarding outdoor occupancy and of locally produced terrestrial foods at average rates are appropriately conservative	Habit profiles data from CEFAS 2011 report for Hinkley Point used

Table A2.6.Review of NNB GenCo approach for assessment of individual dose – Build up of nuclides in local environment

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
Methodology	Terrestrial	ADMS used to predict the location of highest concentration (475m, 105º from eastern HPC stack); PC CREAM 98: Plume and Assessor modules used to calculate actual deposition rate; FARMLAND used to determine activity concentration in soil for unit deposition 23.3m effective stack height and site specific meteorological data used; ADMS coordinates applied in PC CREAM 98 Activity concentrations calculated in the 60th year	These results are presented in the context of the requirement to consider the potential to prejudice legitimate uses of the sea or land. The overall approach applied (NRPB-W36) was developed in order to take account of potential uses of contaminated land). The applicability of W36 methodology questionable.	Considered for verification purposes only. Same approach used.
	Marine	Activity concentration in water and on beach determined using DORIS Dispersion modelled on Bristol Channel characteristics Activity concentrations calculated in the 60th year Tritium discharges treated as tritiated water (HTO).	PC CREAM-98 and PC Doris will model build up in the marine environment over 50 years which will be most noticeable in sediments	Considered for verification purposes only. Same approach used.
Dose calculation methodology	Terrestrial	Scenario: dose to construction worker from exposure to contaminated ground, skin dose, inhalation of contaminated dust, and inadvertent ingestion of contaminated material; Uniform contamination across site and even distribution to 1m depth assumed		This assessment not repeated.
	Marine	Several potential uses of the sea comprising work and recreational activities considered; Commercial fishing was considered to result in highest occupancy and intake; Habits based on fisherman family described for routine marine discharges (CEFAS 06)		This assessment not repeated.

Table 2.7.Review of NNB GenCo approach for assessment of collective dose – discharges to the atmosphere

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
Methodology		Collective dose calculated using PC CREAM 98 for the Hinkley Point site (for population and agricultural grids)	Appropriate application, although it would be more appropriate to use the most recent version of PC CREAM (PC CREAM 08)	Similar approach using PC CREAM 08
Discharges	Discharge assumptions	1 year discharge (in 50th year)		
	Effective release height	23.3 m (21m and 17.8m release heights adopted for HPB and HPA respectively).	Consistent with individual dose calculations; collective dose assessment for cumulative site discharges not presented in report	Similar approach and assumptions
Dispersion	Meteorology	Site specific meteorological data used	Consistent with individual dose calculations	Similar approach and assumptions
		Standard deposition, washout and surface roughness assumptions	Consistent with individual dose calculations	Similar approach and assumptions
Receptor Points and pathways	Population and agricultural grids	UK, Europe and World Constant population assumed. Population data for the UK, Europe and World were assumed to be 55 million, 700 million and 10 billion respectively.		Use of default assumptions from PC CREAM 08
	Contribution to dose	First pass and global circulation	Appropriate consideration of impacts from initial distribution and from globally circulating radionuclides	Similar approach
	Truncation time	500 y.	Consistent with dose assessment principles established by environment agencies and devolved administrations	Similar approach

Table A2.8.Review of NNB GenCo approach for assessment of collective dose – discharges to the marine environment

Section	Criteria	NNB GenCo Approach	Comments on the NNB GenCo Approach	Approach used for Independent Assessment
Methodology		PC CREAM 98 for Hinkley Point (defining marine compartments, characteristics and associated fish catch data)	Appropriate application, although it would be more appropriate to use the most recent version of PC CREAM (PC CREAM 08)	Similar approach using PC CREAM 08
Discharges	Discharge assumptions	Bristol Channel marine module Local compartment volume and depth: 5 10^{9} m^3 and 20 m; Local compartment coastline length: 3 E04 m; Volumetric exchange rate: 1 10^{11} m^3/y; Local compartment suspended sediment load: 2 E-04 t/m^{-3}; Sediment rate: 1 E-04 t m^{-2}/y; Sediment density: 2.6 t/m^{-3}; Local bioturbation rates: 3.6 E-05 m^2/y; and, Local compartment diffusion rate: 3.15 E-02 m^2/y	The values presented are consistent with those used in the radiological assessment in support of the authorisation review for Hinkley B (2006).	Similar approach
Receptor Points and pathways	Beach occupancy	50 man h y^{-1} m^{-1}		Similar approach
	Contribution to dose	First pass and global circulation	Appropriate consideration of impacts from initial distribution and from globally circulating radionuclides	Similar approach

Table A2.9. Review of NNB GenCo approach for the assessment of doses to non-human species

Section	Criteria	NNB GenCo Approach	Comments on the GenCo Approach	Approach used for Independent Assessment
Methodology	Software application	ERICA integrated approach using the ERICA Assessment Tool (ERICA AT).	The ERICA approach is appropriate for this context. It would be possible to conduct an assessment at Tier 1 based on predicted concentrations in environmental media. The NHB dose assessment was conducted at Tier 2 of the ERICA method only.	Similar approach
		SRS 19 models within ERICA AT used to calculate activity concentrations in pond (freshwater and sediment).	There is the potential for inconsistency between activity concentrations used for human and non-human species by application of this model – unless applied only to the freshwater environment which is not considered in human assessment.	Dose rates to freshwater organisms assessed for verification purposes only
		Environment Agency R&D 128 for noble gases Argon-41 and krypton-85 assessed. Argon-41 was used as analogue for isotopes of Xenon (R&D128 does not support the modelling of Xenon isotopes);	Appropriate application of R& D 128; this represents the based approach currently available for assessing dose rates from noble gas releases. The separate presentation of ERICA and R&D 128 results needs to be considered further.	Similar approach
Ecosystems and organisms considered	Range	Following ecosystems are considered: Terrestrial (location: 470m, 105º); Marine (Hinkley Point local compartment); Coastal (3.3km, 91º); Freshwater (location: 470m, 105º)	The need for considering the freshwater habitat is unproven	Only Marine and Terrestrial ecosystems and were assessed for independent assessment
Terrestrial	Location	Species assumed to inhabit an area southeast of the UK EPR stacks, in the direction of prevailing wind(area of highest deposition)		Similar approach
	Modelling of environmental concentration	Activity concentrations in air and soil based on output from PLUME, FARMLAND		Similar approach
	Organisms considered	Default ERICA reference organisms for terrestrial ecosystem plus bats and badgers (using the ERICA 'add organism' function)	Reference organisms choice reasonable; the need for inclusion of bats and badgers unclear	Default reference organisms plus bat badger and fox.
	Other modelling aspects	Concentration ratios for Bats modelled after mammal (rat) whilst CR for Badgers was modelled after mammal (deer). Rats conservatively assumed to live 'on soil'.		Similar approach
Marine	Location	Highest concentrations	Conservative basis	Similar approach

Section	Criteria	NNB GenCo Approach	Comments on the GenCo Approach	Approach used for Independent Assessment
		associated with local compartment used		
	Modelling of environmental concentration	Activity concentrations in water modelled using default parameters for Hinkley Point local compartment within DORIS (PC CREAM 98).	Reasonable assumption – ensures consistency between assessments	Similar approach
	Organisms considered	Default ERICA reference organisms for marine ecosystem	Reasonable approach	Similar approach
Coastal	Location	Local compartment – specific geographical reference points for Bridgwater Bay used Assumed to comprise a marine and terrestrial component	The Bridgwater Bay area is defined as a protected area (Ramsar site). However, according to Natural England[11], the site is a Special Protection Area (SPA) and in the process of being designated a Special Area of Conservation (SAC). There is a need to verify which species are protected at this site but the nature of the designation; it would be reasonable to expect protected bird and wetland species. The sites considered in recent EA Habitats assessments are not discussed.	Assessed only for verification purposes, using similar approach
Coastal	Modelling of environmental concentration	Activity concentrations in the marine component modelled in DORIS; activity concentrations in the terrestrial component assessed using PLUME and FARMLAND		Similar approach
	Organisms considered	ERICA default organisms plus bats and badgers.	The reasons for including bats and badgers is not clear; The form of designation would suggest need to consider dose rates to reference organisms that might be appropriate to protected species (such as marine birds) or the organisms on which they feed.	Similar approach
Freshwater	Location	Pond within the terrestrial habitat area freshwater organisms. Not considered during GDA.	An extensive list of reference organisms are considered, which seem unlikely for a small pond (e.g. mammal, crustacean, pelagic fish). This is likely to be conservative – but it is unclear how this list related to species actually likely to be present.	Assessed only for verification purposes, using similar approach

[11] http://www.naturalengland.org.uk/ourwork/conservation/designatedareas/nnr/1007190.aspx

Section	Criteria	NNB GenCo Approach	Comments on the GenCo Approach	Approach used for Independent Assessment
	Modelling of environmental concentration	No input or output other than rainfall. SRS 19 model used to assess activity concentration in water and sediment.	It is unclear how the SRS 19 approach is used. This approach includes generic models for dispersion in the atmospheric and for input into a small lake (not pond). Hinkley C is not anticipated to discharge into this pond; input into the pond will be from runoff and wet deposition from atmospheric releases. Use of the SRS 19 model would imply some inconsistency between the dispersion approaches (and activity concentrations) applied for humans and non-human species.	Similar approach
	Organisms considered	A range of default ERICA reference organisms for freshwater ecosystem	The range of reference organisms included include some that are unlikely to be present in a pond	Similar approach
Screening value		Erica default (10 µGy/h), although reference is also made to the benchmark of 40 µGy/h used in EA Habitats assessments	The dose rates are below both benchmarks; and it is reasonable to present both with interpretation of their basis. However, there is no note of the uncertainty factors applied and there appears to be some misunderstanding of the dose rates associated with the Risk Quotients (RQs) by not taking account of these factors	Similar approach

Appendix 3 – Independent Initial Radiological Assessment

A3.1 Stages 1 and 2 of the Environment Agency's initial radiological assessment methodology [Ref. A3.1] have been applied to the predicted maximum gaseous and liquid discharges from two proposed UK EPR power plants at Hinkley Point (Hinkley Point C). The assessments were undertaken using spreadsheet tools provided by the Environment Agency.

A3.2 Radionuclide discharge data were obtained from a report prepared by NNB GenCo in support of an Environmental Permit application for the proposed facility under the Environmental Permitting (England and Wales) Regulations 2010 (EPR10).

A3.3 Stage 1 assessments were performed using default, conservative parameters contained in the initial assessment spreadsheets: 0m effective release height for gaseous discharges and 30m/s average coastal exchange rate for discharges of liquid effluents to the marine environment.

A3.4 Stage 2 assessments were performed using dispersion parameters presented in the NNB GenCo reported. An effective release height of 23.3m (accounted for by using scaling factors of 0.28 and 0.03 for food and inhalation/ external exposure respectively) was applied for discharges to the atmosphere and a coastal exchange rate of 3.17 10^3 m/s was used for the local marine compartment around the Hinkley Point Site.

A3.5 The population groups assessed are Local Habitant and Fisherman, for doses due to gaseous and liquid discharges respectively. Dose rates to the worst affected terrestrial and marine organisms are also provided.

A3.6 Tables A3.1 to A3.10 provide the details and results of the initial radiological assessments undertaken. The estimated annual doses to the local inhabitant and fisherman groups were predicted to be 110 and 370 µSv, respectively. Both groups therefore were predicted to exceed 20 µSv for Stage 1 assessment, such that a more realistic assessment was warranted. Therefore a Stage 2 assessment was undertaken using site specific information on marine dispersion and release height for the stacks. At stage 2, the doses to these population groups were predicted to be 16 and 3.5 µSv, respectively. The stage 2 assessment was repeated using NNB GenCo's proposed limits for the site. There are a few differences in the discharge assumptions between the maximum expected discharges and the limits proposed. However these have on a small effect and the predicted doses at the maximum expected discharges and the proposed limits were the same within rounding (Tables A3.11 and A3.12

A3.7 The highest predicted dose rates to the organisms in the terrestrial and marine environments, resulting from the predicted discharge rates, were found to be in the region of 0.6 µGy/h for the Stage 1 assessment. In Stage 2, these dose rates were predicted to be around 0.02 and 0.006 for the worst affected terrestrial and marine organisms, respectively. These dose rates are all significantly below levels, e.g. the level of 10 µGy/h included as a screening level in the ERICA Tool, at which more detailed assessment would be required.

References

A3.1 Environment Agency, Initial Radiological Assessment Methodology (Parts 1 and 2), Science Report SC030162/SR1 (2006).

Table A3.1. Dose per unit release (DPUR) values for gaseous discharges (µSv/y per Bq/y)

Radionuclide	Inhalation DPUR	External DPUR	Food DPUR	Total DPUR
H-3	6.9E-13	0.0E+00	2.7E-13	**9.6E-13**
C-14	3.5E-11	6.4E-17	3.3E-11	**6.8E-11**
Ar-41	0.0E+00	3.2E-12	0.0E+00	**3.2E-12**
Co-58	3.6E-11	2.7E-10	4.4E-12	**3.1E-10**
Co-60	2.2E-10	1.1E-08	5.3E-11	**1.2E-08**
Kr-85	0.0E+00	1.3E-14	0.0E+00	**1.3E-14**
I-131	3.9E-10	3.8E-11	4.1E-09	**4.5E-09**
I-133	9.7E-11	7.6E-12	7.2E-11	**1.8E-10**
Xe-131m*	-	-	-	**-**
Xe-133	0.0E+00	7.0E-14	0.0E+00	**7.0E-14**
Xe-135*	-	-	-	**-**
Cs-134	1.5E-10	3.6E-09	4.7E-10	**4.2E-09**
Cs-137	1.0E-10	6.5E-09	3.8E-10	**7.0E-09**
S-35	2.4E-11	7.6E-17	6.0E-11	**8.4E-11**

**Xe-131m and Xe-135 discharges summed up with Xe-133*
Xe-131m and Xe-135 contributed 4.1E+04 µSv/y (over 99%) to total dose when modelled as 'other Beta/gamma emitters' (I-131)

Table A3.2. Dose per unit release (DPUR) values for liquid discharges (µSv/y per Bq/y)

Radionuclide	External DPUR	Fish/shellfish DPUR	Total DPUR
H-3	0.0E+00	8.9E-16	**8.9E-16**
C-14	1.6E-16	4.6E-10	**4.6E-10**
Cr-51	3.7E-13	2.3E-13	**6.0E-13**
Mn-54	2.2E-10	5.0E-12	**2.3E-10**
Co-58	5.4E-11	1.5E-11	**6.9E-11**
Co-60	2.7E-09	7.5E-11	**2.8E-09**
Ni-63	0.0E+00	3.6E-12	**3.6E-12**
Ag-110m	1.2E-10	3.9E-09	**4.0E-09**
Sb-125	1.5E-11	1.5E-11	**2.9E-11**
I-131	2.5E-15	2.5E-12	**2.5E-12**
Cs-134	8.4E-11	4.0E-11	**1.2E-10**
Cs-137	1.2E-10	2.8E-11	**1.5E-10**
*Other beta/gamma (Sb-124 & Te-123m)**	1.2E-10	2.8E-11	**1.5E-10**
S-35	7.6E-17	6.0E-11	**8.4E-11**
OBT	0.0E+00	3.7E-11	**3.7E-11**

**Cs-137 used as surrogate*

Table A3.3. Dose to local inhabitant from Stage 1 initial radiological assessment (µSv/y)

Radionuclide	Discharges (Bq/y)	Inhalation dose	External dose	Food dose	Total dose	% Contribution
Tritium	6.0E+12	4.1E+00	0.0E+00	1.6E+00	***5.8E+00***	5.19
Carbon-14	1.4E+12	4.9E+01	9.0E-05	4.6E+01	***9.5E+01***	85.78
Argon-41	1.3E+12	0.0E+00	4.2E+00	0.0E+00	***4.2E+00***	3.77
Cobalt-58	6.1E+07	2.2E-03	1.7E-02	2.7E-04	***1.9E-02***	0.02
Cobalt-60	7.2E+07	1.6E-02	7.9E-01	3.8E-03	***8.1E-01***	0.73
Krypton-85	6.3E+12	0.0E+00	8.1E-02	0.0E+00	***8.1E-02***	0.07
Iodine-131	3.6E+08	1.4E-01	1.4E-02	1.5E+00	***1.6E+00***	1.49
Iodine-133	4.4E+08	4.2E-02	3.3E-03	3.1E-02	***7.7E-02***	0.07
Xenon-133*	2.8E+13	0.0E+00	2.6E+00	0.0E+00	***2.6E+00***	2.36
Caesium-134	5.6E+07	8.4E-03	2.0E-01	2.6E-02	***2.4E-01***	0.21
Caesium-137	5.0E+07	5.0E-03	3.3E-01	1.9E-02	***3.5E-01***	0.32
Total		**5.3E+01**	**8.2E+00**	**4.9E+01**	**1.1E+02**	

**includes discharges of Xe-131m and Xe-135*

Table A3.4. Dose to fisherman from Stage 1 initial radiological assessment (µSv/y)

Radionuclide	Discharge (Bq/y)	External dose	Fish /shellfish dose	Total dose	% Contribution
Tritium	1.50E+14	0.0E+00	4.5E-01	**4.5E-01**	0.12
Carbon-14	1.90E+11	1.0E-04	2.9E+02	**2.9E+02**	79.31
Chromium-51	1.20E+08	1.5E-04	9.2E-05	**2.4E-04**	0.00
Manganese-54	5.40E+08	4.0E-01	9.0E-03	**4.1E-01**	0.11
Cobalt-58	4.14E+09	7.5E-01	2.1E-01	**9.5E-01**	0.26
Cobalt-60	6.00E+09	5.4E+01	1.5E+00	**5.6E+01**	15.25
Nickel-63	1.92E+09	0.0E+00	2.3E-02	**2.3E-02**	0.01
Silver-110m	1.14E+09	4.6E-01	1.5E+01	**1.5E+01**	4.14
Antimony-125	1.6E+09	8.2E-02	8.2E-02	**1.6E-01**	0.04
Iodine-131	1.00E+08	8.3E-07	8.3E-04	**8.3E-04**	0.00
Caesium-134	1.12E+09	3.1E-01	1.5E-01	**4.5E-01**	0.12
Caesium-137	1.89E+09	7.6E-01	1.8E-01	**9.5E-01**	0.26
*Other beta/gamma (Sb-124 & Te-123m)**	*1.50E+09*	6.0E-01	1.4E-01	**7.5E-01**	0.20
Sulphur-35	0	0	0	**0**	0
OBT	0	0	0	**0**	0
Total		***5.8E+01***	***3.1E+02***	**3.7E+02**	

**Cs-137 used as surrogate*

Table A3.5.Dose rate to worst affected terrestrial organism from Stage 1 initial radiological assessment, (µGy/h)

Radionuclide	Discharges (Bq/y)	Surrogate radionuclide	Dose rate	% Contribution
Tritium	6.0E+12	-	3.5E-02	5.71
Carbon-14	1.4E+12	-	5.0E-01	81.32
Argon-41	1.3E+12	-	2.4E-03	0.38
Cobalt-58	6.1E+07	Cobalt-60	1.3E-03	0.22
Cobalt-60	7.2E+07	-	1.6E-03	0.26
Krypton-85	6.3E+12	-	1.1E-03	0.17
Iodine-131	3.6E+08	-	2.6E-04	0.04
Iodine-133	4.4E+08	Iodine-125	5.7E-04	0.09
Xenon-133	2.8E+13	Argon-41	6.7E-02	10.88
Caesium-134	5.6E+07	Caesium-137	3.0E-03	0.49
Caesium-137	5.0E+07	-	2.7E-03	0.44
Total			**6.2E-01**	

Table A3.6. Dose rate to worst affected marine organism from Stage 1 initial radiological assessment (µGy/h)

Radionuclide	Discharges (Bq/y)	Surrogate radionuclide	Dose rate	% Contribution
Tritium	1.50E+14	-	1.6E-03	0.25
Carbon-14	1.90E+11	-	1.1E-01	17.09
Chromium-51	1.20E+08	Cobalt-60	2.5E-03	0.40
Manganese-54	5.40E+08	Cobalt-60	1.1E-02	1.80
Cobalt-58	4.14E+09	Cobalt-60	8.7E-02	13.80
Cobalt-60	6.00E+09	-	1.3E-01	20.00
Nickel-63	1.92E+09	Caesium-137	1.5E-03	0.24
Silver-110m	1.14E+09	Caesium-137	9.1E-04	0.14
Antimony-125	1.6E+09	Ruthenium-106	2.9E-01	45.70
Iodine-131	1.00E+08	-	2.5E-05	0.00
Caesium-134	1.12E+09	Caesium-137	9.0E-04	0.14
Caesium-137	1.89E+09	-	1.5E-03	0.24
Other β/γ-emitting nuclides	*1.5E+09*	Caesium-137	1.2E-03	0.19
Total			**6.3E-01**	

Table A3.7. Dose to local inhabitant from Stage 2 initial radiological assessment (µSv/y) for discharges to atmosphere at the maximum expected discharges

Radionuclide	Discharges (Bq/y)	Inhalation dose	External dose	Food dose	Total dose	% Contribution
Tritium	6.0E+12	1.2E-01	0.0E+00	4.5E-01	***5.8E-01***	3.69
Carbon-14	1.4E+12	1.5E+00	2.7E-06	1.3E+01	***1.4E+01***	91.89
Argon-41	1.3E+12	0.0E+00	1.3E-01	0.0E+00	***1.3E-01***	0.80
Cobalt-58	6.1E+07	6.6E-05	5.0E-04	7.5E-05	***6.4E-04***	0.00
Cobalt-60	7.2E+07	4.8E-04	2.4E-02	1.1E-03	***2.5E-02***	0.16
Krypton-85	6.3E+12	0.0E+00	2.4E-03	0.0E+00	***2.4E-03***	0.02
Iodine-131	3.6E+08	4.3E-03	4.1E-04	4.2E-01	***4.2E-01***	2.70
Iodine-133	4.4E+08	1.3E-03	9.9E-05	8.8E-03	***1.0E-02***	0.06
Xenon-133*	2.8E+13	0.0E+00	7.9E-02	0.0E+00	***7.9E-02***	0.50
Caesium-134	5.6E+07	2.5E-04	6.1E-03	7.4E-03	***1.4E-02***	0.09
Caesium-137	5.0E+07	1.5E-04	9.8E-03	5.4E-03	***1.5E-02***	0.10
Total		***1.6E+00***	***2.5E-01***	***1.4E+01***	***1.6E+01***	

**includes discharges of Xe-131m and Xe-135*

Table A3.8. Dose to fisherman from Stage 2 initial radiological assessment (µSv/y) for liquid discharges to marine environment at the maximum expected discharges

Radionuclide	Discharge (Bq/y)	External dose	Fish /shellfish dose	Total dose	% Contribution
Tritium	1.50E+14	0.0E+00	4.2E-03	***4.2E-03***	0.12
Carbon-14	1.90E+11	9.6E-07	2.8E+00	***2.8E+00***	79.31
Chromium-51	1.20E+08	1.4E-06	8.7E-07	***2.3E-06***	0.00
Manganese-54	5.40E+08	3.7E-03	8.5E-05	***3.9E-03***	0.11
Cobalt-58	4.14E+09	7.1E-03	2.0E-03	***9.0E-03***	0.26
Cobalt-60	6.00E+09	5.1E-01	1.4E-02	***5.3E-01***	15.25
Nickel-63	1.92E+09	0.0E+00	2.2E-04	***2.2E-04***	0.01
Silver-110m	1.14E+09	4.3E-03	1.4E-01	***1.4E-01***	4.14
Antimony-125	1.6E+09	7.74E-04	7.74E-04	***1.5E-03***	0.04
Iodine-131	1.00E+08	7.9E-09	7.9E-06	***7.9E-06***	0.00
Caesium-134	1.12E+09	3.0E-03	1.4E-03	***4.2E-03***	0.12
Caesium-137	1.89E+09	7.2E-03	1.7E-03	***8.9E-03***	0.26
*Other beta/gamma (Sb-124 & Te-123m)**	*1.5E+09*	5.7E-03	1.3E-03	***7.1E-03***	0.20
Sulphur-35	0	0	0	***0***	0
OBT	0	0	0	***0***	0
Total		***5.5E-01***	***2.9E+00***	***3.5E+00***	

**Cs-137 used as surrogate*

Table A3.9. Dose rate to worst affected terrestrial organism from Stage 2 initial radiological assessment (µGy/h) for discharges to atmosphere at the maximum expected discharges

Radionuclide	Discharges (Bq/y)	Surrogate radionuclide	Dose rate	% Contribution
Tritium	6.0E+12	-	1.1E-03	5.71
Carbon-14	1.4E+12	-	1.5E-02	81.32
Argon-41	1.3E+12	-	7.1E-05	0.38
Cobalt-58	6.1E+07	Cobalt-60	4.0E-05	0.22
Cobalt-60	7.2E+07	-	4.8E-05	0.26
Krypton-85	6.3E+12	-	3.2E-05	0.17
Iodine-131	3.6E+08	-	7.9E-06	0.04
Iodine-133	4.4E+08	Iodine-125	1.7E-05	0.09
Xenon-133	3.8E+13	Argon-41	2.1E-03	10.88
Caesium-134	5.6E+07	Caesium-137	9.1E-05	0.49
Caesium-137	5.0E+07	-	8.2E-05	0.44
Total			**1.9E-02**	

Table A3.10. Dose rate to worst affected marine organism from Stage 2 initial radiological assessment (µGy/h) for liquid discharges to marine environment at the maximum expected discharges

Radionuclide	Discharges (Bq/y)	Surrogate radionuclide	Dose rate	% Contribution
Tritium	1.50E+14	-	1.5E-05	0.25
Carbon-14	1.90E+11	-	1.0E-03	17.09
Chromium-51	1.20E+08	Cobalt-60	2.4E-05	0.40
Manganese-54	5.40E+08	Cobalt-60	1.1E-04	1.80
Cobalt-58	4.14E+09	Cobalt-60	8.2E-04	13.80
Cobalt-60	6.00E+09	-	1.2E-03	20.00
Nickel-63	1.92E+09	Caesium-137	1.5E-05	0.24
Silver-110m	1.14E+09	Caesium-137	8.6E-06	0.14
Antimony-125	1.6E+09	Ruthenium-106	2.7E-03	45.70
Iodine-131	1.00E+08	-	2.3E-07	0.00
Caesium-134	1.12E+09	Caesium-137	8.5E-06	0.14
Caesium-137	1.89E+09	-	1.4E-05	0.24
Other β/γ-emitting nuclides	*1.5E+09*	Caesium-137	1.1E-05	0.19
Total			**6.0E-03**	

Table A3.11. Dose to local inhabitant and worst affected organisms from Stage 2 initial radiological assessment (µSv/y and µGy/h) for discharges to atmosphere at NNB GenCo's proposed limits

Radionuclide	Discharges (Bq/y)	Total dose to local inhabitant (µSv/y)	Dose rate to worst affected organism (µGy/h)
Tritium	6.0E+12	5.8E-01	1.1E-03
Carbon-14	1.4E+12	1.4E+01	1.5E-02
Iodine-131	4.0E+08	4.6E-01	8.6E-06
Noble gases	4.5E+13	2.2E-01	2.1E-03
Fission and activation products	2.4E+11	6.5E-02	2.6E-04
Total		**1.6E+01**	**1.9E-02**

Table A3.12. Dose to local fisherman and worst affected organisms from Stage 2 initial radiological assessment (µSv/y and µGy/h) for liquid discharges to the marine environment at NNB GenCo's proposed limits.

Radionuclide	Discharges (Bq/y)	Total dose to local fisherman (µSv/y)	Dose rate to worst affected organism (µGy/h)
Tritium	2.00E+14	4.2E-03	1.5E-05
Carbon-14	1.90E+11	2.8E+00	1.0E-03
Caesium-137	1.90E+09	8.9E-03	1.4E-05
Other fission and activation products	1.8E+10	7.0E-01	4.9E-03
Total		**3.5E+00**	**6.0E-03**

Appendix 4 – Independent Radiological Assessment of Discharges to Atmosphere

Introduction

A4.1 This Appendix presents the assessed radiological doses to local residents due to discharges of radioactive wastes to the atmosphere from the proposed Hinkley Point C Nuclear Power Station. The methodology used to assess doses from the atmospheric releases from the proposed power plant is described.

A4.2 The radiological assessments have been undertaken on the basis of the maximum predicted discharges of the full list of radionuclides for the proposed nuclear power station as presented in the NNB GenCo submission [Ref. A4.1]. This has been reproduced in Table A4.1.The validity of these data has not been assessed. A second assessment was made at NNB GenCo's proposed limits which are slightly different to the maximum predicted discharges (Table A4.1).

A4.3 Radiological doses as a result of discharges to atmosphere from the neighbouring Hinkley Point B and Hinkley A nuclear power stations have also been assessed, based on the current annual discharge limits for these power stations presented in Table A4.1. The assessed radiological doses due to discharges from all three power stations were combined to derive the total site doses.

Discharges to atmosphere

A4.4 According to information provided by NNB GenCo [Ref. A4.1], discharges to atmosphere are assumed to be made from two release points or 'stacks' located within the reactor building of the proposed nuclear power station. The two stacks will have a physical stack height of 70m each and will protrude 10m above the reactor building (60m high) [Ref. A4.1]. The stacks will therefore be in the wake of the reactor building. For the purposes of this assessment, discharges from the two stacks have been modelled as having being released from a single stack with an effective stack height of 23.3m, equivalent to 1/3rd of the physical stack height (70m). This is in accordance with the approach outlined in NPRB-R157 [Ref. A4.2] (Table A4.2).

Receptor points and candidate representative persons

A4.5 For the purposes of this assessment, local residents with a range of observed habit profiles living close to the proposed nuclear power station have been identified as potential candidates for the representative person most likely to be affected by atmospheric discharges (CRP1). The habit profiles data have been obtained from the 2011 CEFAS radiological habits survey report for Hinkley Point [Ref. A4.3]. These data were derived from interviews conducted with members of the public living, working and pursuing recreational activities around the Hinkley Point site and are therefore considered to be representative of those members of the public likely to be the most exposed individuals to atmospheric discharges from the proposed nuclear power station.

A4.6 Hinkley Point is a coastal site and the 2011 CEFAS [Ref. A4.3] radiological habits survey report has indicated that commercial fishing for fish and shellfish takes place along the coast, where liquid discharges from the site are made. Local residents may therefore also receive doses from liquid discharges to the marine environment through ingestion of locally derived seafood.

A4.7 The following candidate for representative person were chosen to reflect the residential, farming and working communities in the area closest to the proposed nuclear power station.

- ***CRP1 Local residents.*** For the purposes of this assessment, it is assumed that families (adults, children (10 years) and infants (1 year)) living in the nearest habitation (assumed to be located at approximately 500 m from the discharge point), are exposed to atmospheric discharges, direct radiation and, to a lesser extent, to liquid discharges in the marine

environment. It is assumed that members of this family spend most of their time at home, some of which is spent outside. They consume green vegetables, root vegetables and fruit from their garden or other local source (500 m from the discharge point) and milk and meat from local farms close to the site, whose livestock graze approximately 500 m from the discharge point. This group is also assumed to consume locally sourced fish and shellfish.

A4.8 Site specific food consumption rates and the proportion of time spent indoors and outdoors based on the 2011 CEFAS report for Hinkley Point have been used to assess radiological doses to each age group in CRP1, in accordance with the recommendation of the National Dose Assessment Working Group (NDAWG) [Ref. A4.4].

Exposure pathways

A4.9 The exposure pathways considered were:

- internal exposure to radionuclides from ingestion of local fruit and vegetable produce (green vegetable and root vegetable) cow milk, cow meat, and sheep meat;
- internal exposure via inhalation of radionuclides from the plume and secondary inhalation of radionuclides deposited on the ground and resuspended; and,
- external doses from exposure to the plume ('cloudshine') and beta and gamma radiation from radionuclides deposited on the ground ('groundshine').

A4.10 Assessment of exposure to direct radiation from the site was taken into account where appropriate (Appendix 8).

Modelling of environmental concentrations

A4.11 Air concentrations and deposition rates at 500m (local residence) and 500m (local farmland) were calculated for unit release rates from the discharge points of the proposed and existing power stations.

A4.12 The Gaussian plume atmospheric dispersion model, PLUME, in PC-CREAM 08 [Ref A4.5] was used to calculate air activity concentrations (dispersion factors) and ground deposition values for each radionuclide [Table A4.3]. Site specific meteorological data based on the average weather condition measured around the Hinkley Point site during the ten year period from 1999 to 2008 was used for the atmospheric dispersion modelling. This information was obtained from the NNB GenCo submission and has been reproduced in Table A4.1.

A4.13 For radionuclides discharged to atmosphere which deposit on the ground (that is all radionuclides except tritium, carbon-14 and noble gases), a deposition velocity of 0.001 m/s was used to calculate the deposition rate with the exception of iodine where a deposition velocity of 0.01 m/s was used [Ref A4.5]. A washout coefficient of 10^{-4} s^{-1} was used to calculate wet deposition.

A4.14 Concentrations in terrestrial foodstuffs and animal products at the nearest allotments and gardens around residences (500 m) and farmland (500 m) were predicted from the air concentrations. For all nuclides, except tritium and carbon-14, food concentrations were derived using deposition velocity and food activity concentration per unit deposition rate factors. For tritium and carbon-14 food concentrations were calculated using factors which relate food activity concentration to unit air activity concentration [Ref A4.5]. The food activity concentration factors are shown in Table A4.4.

Habits data

A4.15 Doses to candidates for the representative person were calculated using the predicted environmental concentrations, generic habits data and observed habit profiles for:

- food intakes
- occupancy at the habitation (500 m from the discharge point) and nearby environment
- time spent indoors and outdoors
- breathing rates.

A4.16 The assessment used information from the 2011 CEFAS habits survey report for Hinkley Point [Ref. A4.3] and NRPB-W41 [Ref. A4.6]. The data used for the assessment of effective doses to adult, child and infant to identify the candidate for representative person for gaseous releases (CRP1) are provided in Table A4.5. These show the habits of the potential candidates for the representative person – who may be most exposed to the discharges. The habits of the candidates for the representative person are prepared from habits profiles. Profile A (Green Veg) is a profile of the average of the top rate consumers of locally produced green vegetables. Profile A also includes information on other habits near the site that may also lead to exposure such as root vegetable consumption and fruit, other foods including marine related foods and other exposure pathways. All the information on habits for profile A is used to calculate the dose to the average person in the group from gaseous discharges. Profile B is the average of the top rate consumers of root vegetables. Included in profile B is information on consumption of green vegetables, fruit etc. There are 11 profiles for adults from which doses to six have been calculated. Each profile is made up from a few to several tens of observations. There are fewer profiles for children and infants because the numbers in these age groups are very low compared to adults and meaningful profiles cannot always be created.

A4.17 The same habits profiles are used in the calculation of doses from liquid discharges and the total dose to each profile is then calculated. The profile giving the highest dose is then the representative person (critical group) for Hinkley Point C.

A4.18 Generic breathing rates were used throughout the assessment, these are presented in Table A3.6 [Ref. A4.6]. It was assumed that candidates for representative person for gaseous releases (CRP1) spent 100% of their time at their homes, but that the time spent indoors is assumed to vary with age group. Adults are assumed to spend 50% of their time indoors while children and infants are assumed to spend 80% and 90% of their time indoors respectively [Ref. A4.6]. Generic habits data used in this assessment are presented in Table A4.6

A4.19 Generic shielding factors were used to modify the external doses for time spent indoors. A shielding factor of 0.1 was used for shielding from material deposited in the ground [Ref A4.6]. A shielding factor of 0.2 was used for shielding of external radiation from material in the plume [Ref A3.7].

Dose to the candidates for representative person (CRP1) for gaseous releases

A4.20 The habits data used have been based on both generic habits data and site specific habits profiles. These are considered to provide a realistic estimate of the doses to CRP1 arising from atmospheric discharges from the proposed nuclear power station.

A4.21 Doses to the infant, child and adult candidates for representative person were calculated using assessment systems based on PC CREAM 08 and customised for the proposed nuclear power station. The dose assessment was performed for individual radionuclides not categories of radionuclides.

A4.22 For internal exposure, inhalation and ingestion dose coefficients [Table A4.7] set out in the Euratom Basic Safety Standards Directive [Ref A4.8] and the predicted concentrations of radionuclides in the environment and foods have been used. For external exposure, cloudshine and groundshine factors have been used and were derived from in the updated version of FGR-12 [Ref A4.9], which is available on the US EPA web site (Table A4.8).

A4.23 The doses associated with the maximum annual radioactive atmospheric discharges predicted by NNB GenCo were calculated from the dose per unit release data for each radionuclide using site specific habits data.

A4.24 The contribution to dose from predicted marine discharges (see Appendix 5), are shown in Table A4.9. The doses to the candidates for representative person from gaseous discharges to atmosphere were found to be around 7 μSv/y for discharges from Hinkley Point C and around 16 μSv/y for the total discharges from all three power stations at Hinkley Point.

A4.25 A breakdown of the highest effective doses to CRP1 (adult milk consumer) arising from the predicted Hinkley Point C discharges are provided in Table A4.10, broken down by radionuclide and pathway.

A4.26 Doses at the NNB GenCo's proposed limits for Hinkley Point C are summarised in Table A4.11. Doses at the proposed limits are very similar to those at the maximum expected discharges.

A4.27 The dose from atmospheric discharges from Hinkley Point C and from all three power stations at Hinkley Point for over 99% of the dose to the representative person from discharges (atmospheric and liquid). Individuals within this group would also receive a contribution from direct radiation, as discussed in Appendix 8.

References

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A4.2 Jones, J A, The Fifth Report of the Working Group on Atmospheric Dispersion: Models to Allow for the Effects of Coastal Sites, Plume Rise and Buildings on Dispersion of Radionuclides and Guidance on the Value of Deposition Velocity and Washout Coefficients, NRPB-R157, NRPB, Chilton, 1983.

A4.3 Clyne, F.C., Garrod, C.J., Rumney, P., Hughes, L.M., and Ly, V.E., 2011. Radiological Habits Survey: Hinkley Point, 2010. RL 01/11. Cefas, Lowestoft

A4.4 NDAWG, Acquisition and Use of Habits Data for Prospective Assessments, NDAWG/2/2009, http://www.ndawg.org/NDAWGpapers.htm

A4.5 Smith, J G and Simmonds, J R (Eds), The methodology for assessing the radiological consequences of routine releases of radionuclides to the environment used in PC-CREAM 08, HPA-RPD-058, HPA, Chilton (2009).

A4.6 Smith, K R and Jones A L, Generalised Habit Data for Radiological Assessments, NRPB-W41, NRPB, Chilton (2003).

A4.7 European Commission (1995). Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment. Radiation Protection 72. EUR 15760 EN.

A4.8 Council Directive 96/29 Euratom of 13 May 1996, Laying Down Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers Arising from Ionising Radiation. Official Journal of the European Communities, L159, Volume 39, 29 June 1996.

A4.9 EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081(Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

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Table A4.1 Predicted discharges and discharge limits used in the assessment for discharges to atmosphere (GBq/y).

Radionuclide	Hinkley Point C (max)$	Hinkley Point B	Hinkley Point A[12]	Hinkley Point C (NNB GenCo's proposed limits)
Ar-41	1.31E+03	1.00E+05	-	-
C-14	1.40E+03	3.70E+03	6.00E+02	1.40E+03
Co-58	6.12E-02	-	-	-
Co-60[13]	7.22E-02	1.10E-01	1.50E-01	-
Cs-134	5.62E-02	-	-	-
Cs-137	5.04E-02	-	-	-
H-3	6.00E+03	1.20E+04	1.50E+03	6.00E+03
I-131	3.64E-01	1.50E+00	-	4.00E-01
I-133	4.36E-01	-	-	-
Kr-85	6.26E+03	-	-	-
S-35		3.50E+02	-	-
Xe-131m	1.35E+02	-	-	-
Xe-133	2.84E+04	-	-	-
Xe-135	8.92E+03	-	-	-
Noble gases*	-	-	-	4.5E+04
Other fission and activation products+	-	-	-	2.4E-01

+ Co-58, Co-60, Cs-134 & Cs-137
* Ar-41, Kr-85, Xe-131m, Xe-133 & Xe-135
$ Used in the dose assessment

Table A4.2 Atmospheric discharge points from the power stations at Hinkley Point

Power station	Discharge position	Effective release height (metres)
Hinkley Point C*	Reactor Building	23
Hinkley Point B	Not specified	21
Hinkley Point A	Not specified	18

* Atmospheric discharges from the proposed nuclear power plant are modelled as being released from a single stack for the purpose of this assessment.

[12] These permit limits for Hinkley Point A presented in this table have been revised subsequent to NNB GenCo's assessments. The new permit limits are 750 GBq for H-3, 50GBq for C-14 and 0.05 GBq for other beta.

[13] Beta radionuclides discharged from Hinkley Point A and B were modelled as Co-60. The value for Co-60 discharges for Hinkley Point B comprises 0.1 GBq of Co-60 and 1GBq of other beta radionuclides. The value for Hinkley Point A is entirely other beta radionuclides.

Table A4.3 Air Concentration factors and ground deposition

Source	Radionuclide	Air concentration (Bq/m3 per TBq/y)		Resuspended air concentration (Bq s/m3 per Bq/m2/s for 1y)	Ground deposition Bq/m2/s per TBq/y	
		at home	at farm		at home	at farm
Hinkley Point C	Ar-41*	5.43E-02	5.43E-02	-	0.00E+00	0.00E+00
	C-14	5.48E-02	5.48E-02	-	0.00E+00	0.00E+00
	Co-58	5.46E-02	5.46E-02	1.68E+07	1.69E-04	1.69E-04
	Co-60	5.46E-02	5.46E-02	2.31E+07	1.69E-04	1.69E-04
	Cs-134	5.46E-02	5.46E-02	2.24E+07	1.69E-04	1.69E-04
	Cs-137	5.46E-02	5.46E-02	2.35E+07	1.69E-04	1.69E-04
	H-3	5.48E-02	5.48E-02	-	0.00E+00	0.00E+00
	I-131	5.42E-02	5.42E-02	9.56E+06	6.55E-04	6.55E-04
	I-133	5.41E-02	5.41E-02	3.27E+06	6.55E-04	6.55E-04
	Kr-85m*	5.48E-02	5.48E-02	-	0.00E+00	0.00E+00
	Xe-131m*	5.48E-02	5.48E-02	-	0.00E+00	0.00E+00
	Xe-133*	5.48E-02	5.48E-02	-	0.00E+00	0.00E+00
	Xe-135*	5.47E-02	5.47E-02	-	0.00E+00	0.00E+00
Hinkley Point B	Ar-41*	1.70E-02	1.70E-02	-	0.00E+00	0.00E+00
	C-14	1.72E-02	1.72E-02	-	0.00E+00	0.00E+00
	Co-60	1.71E-02	1.71E-02	2.31E+07	4.05E-05	4.05E-05
	H-3	1.72E-02	1.72E-02	-	0.00E+00	0.00E+00
	I-131	1.69E-02	1.69E-02	9.56E+06	1.92E-04	1.92E-04
	S-35	1.71E-02	1.71E-02	1.75E+07	4.05E-05	4.05E-05
Hinkley Point A	C-14	1.76E-02	1.76E-02	-	0.00E+00	0.00E+00
	Co-60	1.75E-02	1.75E-02	3.49E+07	3.49E-05	3.49E-05
	H-3	1.76E-02	1.76E-02	-	0.00E+00	0.00E+00

* Noble gases where no deposition to ground occurs

Table A4.4 Terrestrial food concentration factors (Bq/kg per Bq/m2/s)[a]

Radionuclide	Food concentration factors					
	Green Veg	Root Veg	Fruit	Milk	Cow Meat	Sheep Meat
C-14	5.33E+02	5.33E+02	5.33E+02	2.67E+02	8.00E+02	8.00E+02
Co-58	9.13E+04	2.56E+02	1.48E+04	2.56E+03	6.93E+02	1.16E+03
Co-60	1.15E+05	5.10E+03	2.46E+04	3.55E+03	2.92E+03	4.34E+03
Cs-134	1.31E+05	1.19E+05	3.44E+05	1.59E+05	7.93E+05	1.54E+06
Cs-137	1.50E+05	1.33E+05	3.64E+05	1.79E+05	9.15E+05	1.91E+06
H-3	1.00E+02	1.00E+02	1.00E+02	1.13E+02	8.75E+01	8.75E+01
I-131	4.12E+04	8.61E+03	2.92E+04	5.82E+04	2.47E+04	3.17E+04
I-133	6.18E+03	4.66E+01	5.88E+02	3.79E+03	1.11E+03	6.79E+02
S-35	1.23E+05	9.76E+04	2.60E+05	9.78E+05	6.31E+06	1.49E+07

[a] Values for tritium and carbon-14 are quoted in Bq/kg per Bq/m^3.

Table A4.5 Habits Data Profiles for the candidate for representative person in the Hinkley Point area.

Age Group	Profile number	Profile name	Locally produced food consumption (kg/y or l/y)									Handling (h/y)		Occupancy (h/y)			
			Grn veg	Root veg	Fruit	Milk	Cattle meat*	Sheep meat	Fish (sea)	Crust-acea	Moll-usc	Hand-ling fish'g gear	Hand-ling sedim ent	Interti dal occup ancy over mud[c]	Indoor occup ancy (used)	Out door occup ancy (used)	Total plume occup ancy (used)
Adult	A	Green veg[a]	49.1	37.6	25.2	15.6	6.8	1.6	2.3	1.8	0.1	35	1	67	4313	4380	8693
	B	Root veg[b]	39.3	75.6	28.7	43.8	19.5	2.5	-	0.0	-	-	-	52	4328	4380	8708
	C	Fruit	41.1	45.0	40.6	20.8	19.5	2.2	-	0.1	-	-	-	-	4380	4380	8760
	D	Milk	23.0	45.4	14.9	220.4	21.0	-	-	0.1	-	-	-	-	4380	4380	8760
	E	Cattle meat	15.1	55.9	16.5	56.3	44.5	-	0.3	0.1	-	-	-	-	4380	4380	8760
	F	Sheep meat	84.4	61.8	50.4	-	-	15.1	-	-	-	-	-	-	4380	4380	8760
	G	Fish	12	6.8	5.8	-	4.4	-	14.1	5.1	0.1	-	-	-	4380	4380	8760
	H	Crustaceans	36	20.4	10.7	-	-	-	17.2	13.3	0.3	-	-	-	4380	4380	8760
	I	Molluscs	35.5	28.5	6.4	-	-	-	13.7	11.9	0.8	-	-	-	4380	4380	8760
	J	Intertidal – mud[c]	1.9	1.5	0.3	-	-	-	1.0	0.2	0.0	52	1	702	3678	4380	8058
	M	Direct radiation	1.7	1.3	0.3	-	-	-	0.9	0.2	-	-	-	-	0	80	80
10 y Child	A	Green veg[a]	25.6	14.4	20.1	-	-	-	-	-	-	-	-	14.7	7008	1752	8760
	B	Root veg[b]	19.6	24.7	16.2	30.4	4.5	-	-	-	-	-	-	1.5	7008	1752	8760
	C	Fruit	22.3	11.4	23.6			-	-	-	-	-	-	-	7008	1752	8760
	D	Milk	2.3	21.7	0.6	101.6	6.8	-	-	-	-	-	-	-	7008	1752	8760
	E	Cattle meat	2	26.3	1.3	60.8	17.7	-	0.7	-	-	-	-	-	7008	1752	8760
	G	Fish	3.9	5	2.3	-	10.8	-	2.5	-	-	-	-	-	7008	1752	8760
	J	Intertidal - mud[c]	-	-	-	-	-	-	3.6	-	-	-	-	284.0	6724	6724	1752
	M	Direct radiation	5.5	0.7		-	-	-	1.2	-	-	-	-		6708	1752	8460
1y infant	A	Green veg[a]	4.1	4.9	4.7	18.7	-	-	-	-	-	-	-	72.0	7008	1752	8760
	B	Root veg[b]	3.0	8.0	13.5	-	-	-	-	-	-	-	-	-	7008	1752	8760
	C	Fruit	3	8	13.5	-	-	-	-	-	-	-	-	-	7008	1752	8760
	D	Milk	2.1	2.7	0.2	73.6	-	-	-	-	-	-	-	-	7008	1752	8760
	J	Intertidal - mud[c]	1.2	0.3	0.0	-	-	-	-	-	-	-	-	117.0	6891	1752	8643

[a] Combination of green veg. and other domestic veg. profiles data
[b] Combination of root veg. and potato profiles data
[c] Sum time spent in intertidal environments (including salt marsh, sand and rocks).

Table A4.6 Generic habit data

Habit data	Adult	Child	Infant	Units
Breathing rate per y	8100	5600	1900	m3/y
Breathing rate per h	0.92466	0.639	0.217	m3/h
Default fraction of time indoors	0.5	0.8	0.9	-
Default Occupancy	1	1	1	-
Inadvertent ingestion of seawater	0.5	0.5	0.2	l/y
Inadvertent ingestion of sediment	8.30E-03	0.018	0.044	kg/y
Default beach occupancy	300	300	30	h/y

Table A4.7 Internal committed dose rate factors for exposure via inhalation and ingestion (Sv/Bq)

Radionuclide	ICRP lung class	Inhalation			Ingestion		
		A	C	I	A	C	I
Ar-41	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	V	2.00E-09	2.80E-09	6.60E-09	5.80E-10	8.00E-10	1.60E-09
Co-58	M	1.60E-09	2.40E-09	6.50E-09	7.40E-10	1.70E-09	4.40E-09
Co-60	M	1.00E-08	1.50E-08	3.40E-08	3.40E-10	1.10E-08	2.70E-08
Cs-134	F	6.60E-09	5.30E-09	7.30E-09	1.90E-08	1.40E-08	1.60E-08
Cs-137	F	4.60E-09	3.70E-09	5.40E-09	1.30E-08	1.00E-08	1.20E-08
H-3	V	1.80E-11	2.30E-11	4.80E-11	1.80E-11	2.30E-11	4.80E-11
I-131	F	7.40E-09	1.90E-08	7.20E-08	2.20E-08	5.20E-08	1.80E-07
I-133	F	1.50E-09	3.80E-09	1.80E-08	4.30E-09	1.00E-08	4.40E-08
Kr-85	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S-35	M	1.40E-09	2.00E-09	4.50E-09	7.70E-10	1.60E-09	5.40E-09
Xe-131m	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

A = Adult, C = Child, I = Infant. Note – Inhalation factors for noble gases are zero and are not presented

Table A4.8 External effective dose rate factors for exposure to cloudshine and groundshine

Radionuclide	Cloudshine (Sv/h per Bq/m^3)	Groundshine (Sv/h per Bq/m^2/s)
Ar-41	2.34E-10	4.32E-12
C-14	9.40E-15	5.80E-17
Co-58	1.71E-10	3.42E-12
Co-60	4.54E-10	8.46E-12
Cs-134	2.73E-10	5.47E-12
Cs-137	9.93E-11	2.05E-12
H-3	1.19E-15	0.00E+00
I-131	6.55E-11	1.35E-12
I-133	1.06E-10	2.15E-12
Kr-85	4.28E-13	9.50E-15
S-35	8.75E-16	6.05E-17
Xe-131m	1.40E-12	7.42E-14
Xe-133	5.62E-12	1.66E-13
Xe-135	4.28E-11	8.71E-13

All values derived from Ref [A4.9]

Table A4.9 Doses to the candidates for the representative person (CRP1) arising from discharges to the atmosphere from Hinkley Point C and from all three power stations at Hinkley Point (µSv/y)

Profile name	Age group	Hinkley Point C			Hinkley Point A, B & C		
		Terrestrial	Marine	Total	Terrestrial	Marine	Total
A - Green vegetable	Adult	4.78E+00	7.06E-02	4.85E+00	9.08E+00	1.62E-01	9.24E+00
	Child	3.43E+00	3.89E-04	3.43E+00	6.01E+00	8.56E-03	6.02E+00
	Infant	2.77E+00	1.84E-03	2.77E+00	6.52E+00	3.49E-02	6.56E+00
B - Root vegetable	Adult	6.41E+00	1.57E-03	6.41E+00	1.21E+01	2.10E-02	1.21E+01
	Child	4.22E+00	1.11E-04	4.22E+00	8.13E+00	3.95E-03	8.13E+00
	Infant	2.81E+00	0.00E+00	2.81E+00	5.29E+00	0.00E+00	5.29E+00
C - Fruit	Adult	5.70E+00	1.67E-03	5.70E+00	1.11E+01	2.25E-03	1.11E+01
	Child	3.34E+00	0.00E+00	3.34E+00	5.92E+00	0.00E+00	5.92E+00
	Infant	2.81E+00	0.00E+00	2.81E+00	5.29E+00	0.00E+00	5.29E+00
D - Milk	Adult	**7.19E+00**	**1.67E-03**	**7.19E+00**	**1.44E+01**	**2.25E-03**	**1.44E+01**
	Child	4.39E+00	0.00E+00	4.39E+00	1.01E+01	0.00E+00	1.01E+01
	Infant	4.22E+00	0.00E+00	4.22E+00	1.21E+01	0.00E+00	1.21E+01
E - Cow meat	Adult	6.03E+00	6.65E-03	6.03E+00	1.31E+01	1.29E-02	1.31E+01
	Child	4.37E+00	1.60E-02	4.39E+00	1.08E+01	2.60E-02	1.08E+01
	Infant	1.14E+00	0.00E+00	1.14E+00	3.28E+00	0.00E+00	3.28E+00
F - Sheep meat	Adult	6.91E+00	0.00E+00	6.91E+00	1.29E+01	0.00E+00	1.29E+01
	Child	1.39E+00	0.00E+00	1.39E+00	3.76E+00	0.00E+00	3.76E+00
	Infant	1.14E+00	0.00E+00	1.14E+00	3.28E+00	0.00E+00	3.28E+00
L – Indoor occupancy	Adult	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Child	1.35E+00	0.00E+00	1.35E+00	3.65E+00	0.00E+00	3.65E+00
	Infant	1.14E+00	0.00E+00	1.14E+00	3.28E+00	0.00E+00	3.28E+00
M – Outdoor occupancy	Adult	9.63E-02	1.83E-02	1.15E-01	1.43E-01	3.64E-02	1.80E-01
	Child	1.56E+00	2.75E-02	1.59E+00	3.88E+00	4.46E-02	3.93E+00
	Infant	1.14E+00	0.00E+00	1.14E+00	3.28E+00	0.00E+00	3.28E+00

Table A4.10 Dose breakdown for the candidate for the representative person (adult milk consumer) from atmospheric discharges from Hinkley Point C at predicted levels (μSv/y)

Radio nuclide	Terrestrial pathways									Total dose
	Inhalation	Cloud shine	Ground shine	Green vegetables	Root vegetables	Fruit	Milk	Cow meat	Marine pathway	
Ar-41	0.00E+00	8.72E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**8.72E-02**
C-14	1.24E+00	3.25E-07	0.00E+00	5.45E-01	1.08E+00	3.53E-01	2.62E+00	7.48E-01	1.65E-03	**6.59E+00**
Co-58	4.34E-05	3.01E-06	1.70E-10	1.61E-05	8.90E-08	1.69E-06	4.32E-06	1.11E-07	6.16E-07	**6.93E-05**
Co-60	3.20E-04	9.40E-06	4.97E-10	1.10E-04	9.61E-06	1.52E-05	3.25E-05	2.54E-06	4.86E-06	**5.04E-04**
Cs-134	1.64E-04	4.40E-06	2.50E-10	5.44E-04	9.75E-04	9.25E-04	6.32E-03	3.01E-03	4.02E-07	**1.19E-02**
Cs-137	1.03E-04	4.03E-10	4.21E-14	0.00E+00	6.69E-04	6.01E-04	4.37E-03	2.13E-03	4.79E-07	**7.87E-03**
H-3	4.79E-02	2.06E-06	0.00E+00	1.36E-02	2.69E-02	8.82E-03	1.47E-01	1.09E-02	2.84E-06	**2.56E-01**
I-131	1.19E-03	6.79E-06	1.55E-09	4.97E-03	2.05E-03	2.28E-03	6.73E-02	2.72E-03	8.51E-09	**8.05E-02**
I-133	2.87E-04	1.31E-05	2.96E-09	1.75E-04	2.60E-06	1.08E-05	1.03E-03	2.86E-05	0.00E+00	**1.54E-03**
Kr-85	0.00E+00	1.54E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**1.54E-03**
Xe-131m	0.00E+00	5.45E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**5.45E-05**
Xe-133	0.00E+00	4.59E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**4.59E-02**
Xe-135	0.00E+00	1.10E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**1.10E-01**
Grand Total	**1.29E+00**	**2.45E-01**	**5.43E-09**	**5.65E-01**	**1.11E+00**	**3.66E-01**	**2.84E+00**	**7.66E-01**	**1.66E-03**	**7.19E+00**

Table A4.11 Comparison of doses to the candidate for the representative person (CRP1) arising from discharges to the atmosphere from Hinkley Point C at maximum expected discharges and at NNB GenCo's proposed limits (µSv/y)

Profile name	Age group	At maximum expected discharges			At proposed limits		
		Terrestrial	Marine	Total	Terrestrial	Marine	Total
A - Green vegetable	Adult	4.78E+00	7.06E-02	4.85E+00	4.78E+00	7.06E-02	4.85E+00
	Child	3.43E+00	3.89E-04	3.43E+00	3.43E+00	3.96E-04	3.43E+00
	Infant	2.77E+00	1.84E-03	2.77E+00	2.77E+00	1.85E-03	2.77E+00
B - Root vegetable	Adult	6.41E+00	1.57E-03	6.41E+00	6.41E+00	1.57E-03	6.42E+00
	Child	4.22E+00	1.11E-04	4.22E+00	4.22E+00	1.18E-04	4.22E+00
	Infant	2.81E+00	0.00E+00	2.81E+00	2.81E+00	0.00E+00	2.81E+00
C - Fruit	Adult	5.70E+00	1.67E-03	5.70E+00	5.70E+00	1.67E-03	5.71E+00
	Child	3.34E+00	0.00E+00	3.34E+00	3.34E+00	0.00E+00	3.34E+00
	Infant	2.81E+00	0.00E+00	2.81E+00	2.81E+00	0.00E+00	2.81E+00
D - Milk	Adult	**7.19E+00**	**1.67E-03**	**7.19E+00**	7.19E+00	1.67E-03	7.20E+00
	Child	4.39E+00	0.00E+00	4.39E+00	4.40E+00	0.00E+00	4.40E+00
	Infant	4.22E+00	0.00E+00	4.22E+00	4.23E+00	0.00E+00	4.23E+00
E - Cow meat	Adult	6.03E+00	6.65E-03	6.03E+00	6.03E+00	6.66E-03	6.04E+00
	Child	4.37E+00	1.60E-02	4.39E+00	4.38E+00	1.60E-02	4.40E+00
	Infant	1.14E+00	0.00E+00	1.14E+00	1.14E+00	0.00E+00	1.14E+00
F - Sheep meat	Adult	6.91E+00	0.00E+00	6.91E+00	6.91E+00	0.00E+00	6.91E+00
	Child	1.39E+00	0.00E+00	1.39E+00	1.39E+00	0.00E+00	1.39E+00
	Infant	1.14E+00	0.00E+00	1.14E+00	1.14E+00	0.00E+00	1.14E+00

Appendix 5 – Independent Radiological Assessment of Liquid Discharges

Introduction

A5.1 This Appendix presents the assessed radiological doses to representative persons due to discharges of liquid radioactive wastes to the marine environment from the proposed Hinkley Point C Nuclear Power Station. The assessment is based on the predicted maximum annual radioactive discharges to the marine environment as presented by NNB GenCo [Ref A5.1]. The validity of these predictions has not been assessed.

A5.2 Radiological doses due to liquid discharges from the neighbouring Hinkley Point B and Hinkley A nuclear power stations have also been assessed, based on the current permit limits for these power stations [Ref. A5.1].

A5.3 The assessed radiological doses due to discharges from all three power stations were combined to derive the total site doses. The methodology used to undertake these radiological assessments is described further in subsequent sections.

Radioactive liquid discharges to the marine environment

A5.4 According to information presented by NNB GenCo, the proposed nuclear power station is expected to discharge radioactive liquids into the Bristol Channel marine compartment [Ref. A5.1]. These discharges are assumed to be made via a single release point to an offshore location close to the site of the proposed power station. Radioactive liquids from the Hinkley Point B and Hinkley Point A nuclear power stations are assumed to be discharged from the same release point.

A5.5 The radiological assessments have been undertaken on the basis of the maximum predicted discharges of the full list of radionuclides for the proposed nuclear power station [Ref. A5.1], and the current permit limits for the existing power stations [Ref. A5.1]. These have been reproduced in Table A5.1.

Receptor points and candidates for representative person

A5.6 Assumptions about the pattern of coastal land use and commercial and leisure activities around the site were based on observed habits profiles for the Hinkley Point area, as reported in the 2011 CEFAS radiological habits survey report for Hinkley Point [Ref. A5.2]. This is considered to be a realistic representation of the habits of potential candidates for representative person for exposure to liquid discharges from the proposed nuclear power plant.

A5.7 The 2011 CEFAS survey [Ref. A5.2] has identified the presence of commercial fishing in the vicinity of the proposed nuclear power plant such that exposure pathways associated with fisheries and marine food consumption should be assessed.

A5.8 The following candidates for representative person (CRP2) have been chosen to reflect the fishing communities who could be potentially affected by liquid discharges into the marine environment from the proposed nuclear power station:

- ***CRP2 Fisherman and family.*** For the purposes of this assessment, it has been assumed that the fishermen and their families (adults, children (10 years) and infants (1 year)) are exposed to liquid discharges from the site by spending time on the intertidal sediments in the area and consuming locally caught fish and shellfish (crustaceans and molluscs). Doses from atmospheric discharges from the proposed nuclear power station

were also assessed for individuals in this group via the consumption of some locally produced terrestrial foodstuffs.

A5.9 Doses to the candidates for representative person most exposed to gaseous discharge to atmosphere (CRP1) were assessed as described in Appendix 4.

Exposure pathways

A5.10 The exposure pathways considered were:

- internal exposure to radionuclides from ingestion of sea fish and marine shellfish (crustaceans and molluscs) caught from the local coastal waters;
- external doses from exposure to radionuclides incorporated into coastal sediment; and,
- Other exposure pathways such as external exposure from handling fishing gear (adults only) and inhalation of sea spray, inadvertent ingestion of sediment and inadvertent ingestion of seawater.

Modelling of environmental concentrations

A5.11 The assessment of environmental concentrations per unit release rate in the local and regional coastal area has been performed using the DORIS Model, which is part of the PC CREAM (08 version) software suite of radiological assessment models [Ref A5.4].

A5.12 Activity concentrations per unit release rate of radionuclides in filtered seawater (Bq/l per TBq/y), unfiltered seawater (Bq/l per TBq/y) and marine sediment (Bq/kg per TBq/y) have been predicted using DORIS assuming continuous discharges for a period of 50 years.

A5.13 DORIS calculates the activity concentration values in local coastal waters, ('Local Compartment'). For this assessment, the Hinkley Point Local Compartment has been chosen. The pre-defined characteristics for this box have been used [Ref A5.4], and are shown in Table A5.2. This marine compartment has been chosen on the basis that it is the body of water into which liquid discharges from the proposed power plant will be made and therefore appropriate for the assessment of doses to CRP 2. The local compartment is set to exchange water with the Bristol Channel marine compartment of the model. The sediment concentration factors used in DORIS for the calculation of environmental concentrations are shown in Table A5.3. The environmental activity concentrations per unit release rate (per Bq/y) for the Hinkley Point local compartment are shown in Table A5.4.

A5.14 Concentration factors for sea fish, marine crustacea and marine molluscs are shown in Table A5.5. The concentration factors and the filtered seawater activity concentration per unit release rate factors have been used to calculate the local sea fish, and shellfish activity concentration per unit release rate values [Table A5.6].

A5.15 The internal dose rates per unit concentration arising from internal exposure to radionuclides through ingestion of foodstuffs or inhalation are given in Table A5.7 [Ref A5.4].

A5.16 External effective dose rates per unit concentration arising from exposure to radionuclides from occupancy on marine sediment (Sv/h per Bq/kg) have been derived from Reference A5.6 for all radionuclides. These data are based on a semi-infinite plane of contaminated material. In this case, it is appropriate to apply a modifying factor of 0.5 [Ref A5.6] for exposure to radionuclides in marine sediment to take account of the fact that the beach is not a semi-infinite source. A sediment density of 1600 kg/m^3 was assumed in the derivation of the values as recommended in Reference A5.6. The external effective dose rate factors used in the assessment are provided in Table A5.6.

A5.17 The inadvertent ingestion of sediment and seawater during beach activities has been included in the assessment. High rates of ingestion have been used [Ref A5.3]. The doses have been calculated by determining the radionuclide intake from the appropriate environmental

concentration and the level of intake. The radionuclide intake has been multiplied by the ingestion dose coefficient [Ref A5.4] to determine the doses.

A5.18 The inhalation of sea-spray has also been taken into account in the assessment. PC CREAM [Ref. 5.4] has been used to determine sea-spray concentrations. This output has been used to calculate inhalation doses based on the appropriate age group inhalation rates and occupancy over the inter-tidal sediments.

A5.19 External skin equivalent dose rates have also been calculated, using the external beta skin dose rate factors (Sv/h per Bq/cm^2) [Ref A5.7]. The exposure pathway is handling fishing gear, which had come into contact with marine sediment incorporating radionuclides. The majority of skin dose arises from radionuclides emitting beta radiation. Beta skin dose rates have been calculated using the simple Hunt model [Ref A5.7].

Habits data

A5.20 Doses to the candidates for the representative person have been calculated using the predicted environmental and seafood concentrations and habits data, including information concerning seafood intakes and occupancy of the coastal environment in the Hinkley Point area.

A5.21 Site specific habits data from the 2011 CEFAS report [Ref A5.2] were used to identify a range of habit profiles typical of potential candidates for the representative person for discharges to the Hinkley Point marine environment. These are:

- **Fish consumer.** These are assumed to be individuals with the top consumption of locally caught fish. They also consume fruit and vegetables, and shellfish and have high occupancy over intertidal sand and mud and spend some time handling fishing gear.
- **Crustaceans consumer.** These are assumed to be individuals with the top consumption of locally caught crustaceans. They also eat fish and molluscs, but locally produced vegetable, fruit or dairy products are not consumed. They have high occupancy over intertidal mud and sands and a high amount of time handing sediment and fishing gear.
- **Molluscs consumer.** These are assumed to be individuals with the top consumption of locally caught mollusc. They also eat fish and crustaceans, but locally produced vegetable, fruit or dairy products are not consumed. They have high occupancy over intertidal mud and sands and a high amount of time handing sediment and fishing gear.
- **Intertidal – mud occupancy.** These are individuals with the highest occupancy over intertidal mud and sand. They also spend a high amount of time handling sediment and fishing gear. They also eat fish and shellfish, but locally produced vegetable, fruit or dairy products are not consumed.
- **Intertidal - salt marsh occupancy.** These are individuals with the highest occupancy over intertidal salt marshes. They also spend a high amount of time handling sediment. They also eat fish and shellfish, but locally produced vegetable, fruit or dairy products are not consumed.

A5.22 Some generic data such as inhalation rates and inadvertent ingestion rates have been derived from NRPB-W41 [Ref. A5.3]. .

A5.23 The assessment used information from the 2011 CEFAS habits survey report for Hinkley Point [Ref. A4.3] and NRPB-W41 [Ref. A4.6]. The data used for the assessment of effective doses to adult, child and infant to identify the candidate for representative person for liquid releases (CRP2) are provided in Table A5.9. These show the habits of the potential candidates for the representative person – who may be most exposed to the discharges. The habits of the candidates for the representative person are prepared from habits profiles. Profile G (Fish) is a profile of the average of the top rate consumers of locally caught fish. Profile G also includes information on other habits near the site that may also lead to exposure such as mollusc consumption, crustacean consumption and other foods including terrestrial foods affected by gaseous discharges. All the information on habits for profile G is used to calculate the dose to the average person in the group from liquid discharges. Profile H

is the average of the top rate consumers of shellfish and it includes information on consumption of fish and terrestrial foods. There are 12 profiles for adults for which doses have been calculated. Five of the profiles are affected more by liquid discharges and these are shown in this appendix. Each profile is made up from a few to several tens of observations. There are fewer profiles for children and infants because the numbers in these age groups are very low compared to adults and meaningful profiles cannot always be created.

A5.24 The same habits profiles are used in the calculation of doses from gaseous discharges and the total dose to each profile is then calculated. The profile giving the highest dose is then the representative person (critical group) for Hinkley Point C.

A5.25 Habit profiles applied for CRP2 are presented in Table A5.9. Generic habits data is provided in Table A5.10.

A5.26 It has been assumed that all occupancy and all seafood consumption are associated with the local marine environment (Hinkley Point local compartment).

Doses to the candidates for the representative person

A5.27 Effective doses to the infant, child and adult candidates for the representative person CRP2 have been calculated using ingestion and inhalation dose coefficients from the Euratom Basic Safety Standards Directive as applied in [Ref A5.4], generic and site-specific habits data representative of the fishing communities around the Hinkley Point site, predicted dose rate data and predicted concentrations of radionuclides in foods and the environment. Doses to CRP2 from liquid discharges, plus the contribution from predicted atmospheric discharges are shown in Table A5.11. Doses from Hinkley Point C for the 5 profiles range from 1 to 4 µSv/y and doses from liquid discharges from all three power stations range from 3 to 7µSv/y .

A5.28 A breakdown of the doses to candidates for the representative person arising from liquid discharges by radionuclide and pathway to the fisherman at the predicted levels is provided in Tables A5.12 and A5.13. The majority of the dose is due to the intake of carbon-14 in fish.

A5.29 Doses at the NNB GenCo's proposed limits for Hinkley Point C are summarised in Table A5.14. Doses at the proposed limits are very similar to those at the maximum expected discharges.

References

A5.1 NNB GenCo, UK EPR Hinkley Point C, Radioactive Substances Regulation Environmental Permit Application, NNB-OSL-REP-000155 (2011).

A5.2 Clyne, F.C., Garrod, C.J., Rumney, P., Hughes, L.M., and Ly, V.E., 2011. Radiological Habits Survey: Hinkley Point, 2010. RL 01/11. Cefas, Lowestoft

A5.3 Smith, K R and Jones A L, Generalised Habit Data for Radiological Assessments, NRPB-W41, NRPB, Chilton (2003).

A5.4 Smith, J G and Simmonds, J R (Eds), The methodology for assessing the radiological consequences of routine releases of radionuclides to the environment used in PC-CREAM 08, HPA-RPD-058, HPA, Chilton (2009)..

A5.5 Simmonds. J.R., Lawson, G. and Mayall, A., Methodology For Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment. Radiation Protection 72, Report EUR 15760, 1995.

A5.7 EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081 (Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

A5.8 Hunt G, Simple models for prediction of external radiation exposure from aquatic pathways, 1984, Radiation Protection Dosimetry Vol. 8 No. 4 p 215-224

Table A5.1 Predicted discharges and discharge limits used in the assessment for liquid discharges to Sea (GBq/y)

Radionuclide	Predicted marine discharges			
	Hinkley Point C	Hinkley Point B	Hinkley Point A	Hinkley Point C (NNB GenCo's proposed limits)
Ag-110m	1.14E+00	-	-	
C-14	1.90E+02	-	-	1.90E+02
Co-58	4.14E+00	-	-	
Co-60	6.00E+00	1.00E+01	-	
Cr-51	1.20E-01	-	-	
Cs-134[14]	1.12E+00	8.00E+01	7.00E+02	
Cs-137	1.89E+00	1.00E+02	1.00E+03	1.90E+00
H-3	1.50E+05	6.50E+05	1.00E+03	2.00E+05
I-131	1.00E-01	-	-	
Mn-54	5.40E-01	-	-	
Ni-63	1.92E+00	-	-	
S-35	0.00E+00	2.00E+03	-	
Sb-124	9.80E-01	-	-	
Sb-125	1.63E+00	-	-	
Te-123m	5.20E-01	-	-	
Other fission and activation products+				1.81E+01

+ Ag-110m, Co-58, Co-60, Cr-51, Cs-134, Mn-54, Ni-63, Sb-124, Sb-125 and Te-123m

Table A5.2 Hinkley Point local compartment parameters

Parameter	Value	Source of data/ Comments
Volume (m3)	5.00E+09	PC CREAM 08 default values for Hinkley Point local compartment
Depth (m)	2.00E+01	
Coastline length (m)	3.00E+04	
Volumetric exchange rate (m3/y)	1.00E+11	
Suspended sediment load (t/m3)	2.00E-04	
Sedimentation Rate (t/m2/y)	1.00E-04	
Sediment density (t/m3)	2.60E+00	
Diffusion rate (m2/y)	3.15E-02	

[14] For Hinkley Point A and B, 'other radionuclides' were modelled as Cs-134

Table A5.3 Marine sediment concentration factors (Bq/t per Bq/m^3)

Radionuclide	Marine sediment concentration factors[a]
Ag-110m	1.00E+03
C-14	2.00E+03
Co-58	2.00E+05
Co-60	2.00E+05
Cr-51	5.00E+04
Cs-134	3.00E+03
Cs-137	3.00E+03
H-3	1.00E+00
I-131	2.00E+01
Mn-54	2.00E+05
Ni-63	1.00E+05
Sb-124	1.00E+03
Sb-125	1.00E+03
S-35	5.00E-01
Te-123m	1.00E+03

[a] Default values from PC DORIS input file.

Table A5.4 Environmental concentrations per unit release rate to the Hinkley Point local compartment

Radionuclide	Unfiltered seawater (Bq/l per TBq/y)	Filtered seawater (Bq/l per TBq/y)	Seaspray (Bq/m3 per TBq/y)	Sea bed sediment (Bq/kg per TBq/y)
Ag-110m	9.74E-03	8.12E-03	0.00E+00	4.35E-01
C-14	1.05E-02	7.49E-03	0.00E+00	1.36E+01
Co-58	8.24E-03	2.01E-04	0.00E+00	5.72E-01
Co-60	9.74E-03	2.38E-04	0.00E+00	1.34E+01
Cr-51	6.72E-03	6.11E-04	0.00E+00	1.72E-01
Cs-134	1.01E-02	6.30E-03	0.00E+00	2.59E+00
Cs-137	1.04E-02	6.50E-03	0.00E+00	1.31E+01
H-3	1.05E-02	1.05E-02	0.00E+00	1.80E-02
I-131	3.89E-03	3.87E-03	0.00E+00	8.52E-04
Mn-54	9.33E-03	2.28E-04	0.00E+00	2.73E+00
Ni-63	1.02E-02	4.85E-04	0.00E+00	4.00E+01
S-35	8.89E-03	8.89E-03	0.00E+00	6.19E-03
Sb-124	8.32E-03	6.93E-03	0.00E+00	9.36E-02
Sb-125	1.02E-02	8.53E-03	0.00E+00	1.58E+00
Te-123m	9.18E-03	7.65E-03	0.00E+00	2.02E-01

Table A5.5 Fish and shellfish concentration factors (Bq/kg per Bq/l)[a]

Radionuclide	Concentration factors		
	Sea fish	Crustacea	Mollusca
Ag-110m	5.00E+02	5.00E+03	1.00E+04
C-14	2.00E+04	2.00E+04	2.00E+04
Co-58	1.00E+03	1.00E+04	5.00E+03
Co-60	1.00E+03	1.00E+04	5.00E+03
Cr-51	2.00E+02	5.00E+02	8.00E+02
Cs-134	1.00E+02	3.00E+01	3.00E+01
Cs-137	1.00E+02	3.00E+01	3.00E+01
H-3	1.00E+00	1.00E+00	1.00E+00
I-131	1.00E+01	1.00E+01	1.00E+01
Mn-54	4.00E+02	5.00E+02	5.00E+04
Ni-63	1.00E+03	1.00E+03	2.00E+03
Sb-124	4.00E+02	2.50E+01	2.00E+01
Sb-125	4.00E+02	2.50E+01	2.00E+01
S-35	2.00E+00	1.00E+00	4.00E+00
Te-123m	1.00E+03	1.00E+03	1.00E+03

[a] Default values taken from PC CREAM and are relative to filtered seawater.

Table A5.6 Fish and shellfish concentrations per unit release to the Hinkley Point local compartment (Bq/kg per TBq/y)[a]

Radionuclide	Fish and Shellfish concentrations per unit release		
	Sea fish	Crustacea	Mollusca
Ag-110m	4.06E+00	4.06E+01	8.12E+01
C-14	1.50E+02	1.50E+02	1.50E+02
Co-58	2.01E-01	2.01E+00	1.01E+00
Co-60	2.38E-01	2.38E+00	1.19E+00
Cr-51	1.22E-01	3.06E-01	4.89E-01
Cs-134	6.30E-01	1.89E-01	1.89E-01
Cs-137	6.50E-01	1.95E-01	1.95E-01
H-3	1.05E-02	1.05E-02	1.05E-02
I-131	3.87E-02	3.87E-02	3.87E-02
Mn-54	9.12E-02	1.14E-01	1.14E+01
Ni-63	4.85E-01	4.85E-01	9.70E-01
S-35	1.78E-02	8.89E-03	3.56E-02
Sb-124	2.77E+00	1.73E-01	1.39E-01
Sb-125	3.41E+00	2.13E-01	1.71E-01
Te-123m	7.65E+00	7.65E+00	7.65E+00

[a] Calculated using data in Table A4.4 and Table A4.5.

Table A5.7 Internal committed dose rate factors for expose via inhalation and ingestion (Sv/Bq)

Radionuclide	ICRP lung class	Inhalation			Ingestion		
		A	C	I	A	C	I
Ag-110m	M	7.60E-09	1.20E-08	2.80E-08	2.80E-09	5.20E-09	1.40E-08
C-14	V	2.00E-09	2.80E-09	6.60E-09	5.80E-10	8.00E-10	1.60E-09
Co-58	M	1.60E-09	2.40E-09	6.50E-09	7.40E-10	1.70E-09	4.40E-09
Co-60	M	1.00E-08	1.50E-08	3.40E-08	3.40E-09	1.10E-08	2.70E-08
Cr-51	S	3.70E-11	6.60E-11	2.10E-10	3.80E-11	7.80E-11	2.30E-10
Cs-134	F	6.60E-09	5.30E-09	7.30E-09	1.90E-08	1.40E-08	1.60E-08
Cs-137	F	4.60E-09	3.70E-09	5.40E-09	1.30E-08	1.00E-08	1.20E-08
H-3	V	1.80E-11	2.30E-11	4.80E-11	1.80E-11	2.30E-11	4.80E-11
I-131	F	7.40E-09	1.90E-08	7.20E-08	2.20E-08	5.20E-08	1.80E-07
Mn-54	M	1.50E-09	2.40E-09	6.20E-09	7.10E-10	1.30E-09	3.10E-09
Ni-63	M	4.80E-10	7.00E-10	1.90E-09	1.50E-10	2.80E-10	8.40E-10
Sb-124	M	6.40E-09	9.60E-09	2.40E-08	2.50E-09	5.20E-09	1.60E-08
Sb-125	M	4.80E-09	6.80E-09	1.60E-08	1.10E-09	2.10E-09	6.10E-09
S-35	M	1.40E-09	2.00E-09	4.50E-09	7.70E-10	1.60E-09	5.40E-09
Te-123m	M	4.00E-09	5.70E-09	1.30E-08	1.40E-09	2.80E-09	8.80E-09

A = Adult, C = Child, I = Infant

Table A5.8 External effective dose rate factors for occupancy over marine sediment (µSv/h per TBq/y)

Radionuclide	External Effective Dose Rate Factor for Exposure over Sediment[a,b,c]	Gamma fishing gear	Beta skin dose from handling gear
Ag-110m	1.15E-04	3.02E-06	0.00E+00
C-14	2.82E-09	0.00E+00	0.00E+00
Co-58	5.26E-05	1.41E-06	0.00E+00
Co-60	3.35E-03	8.49E-05	0.00E+00
Cr-51	4.63E-07	1.42E-08	0.00E+00
Cs-134	3.78E-04	1.02E-05	3.65E-05
Cs-137	1.52E-07	1.98E-05	2.85E-04
H-3	0.00E+00	0.00E+00	0.00E+00
I-131	2.85E-08	8.21E-10	1.40E-08
Mn-54	2.17E-04	5.78E-06	0.00E+00
Ni-63	0.00E+00	0.00E+00	0.00E+00
S-35	2.62E-07	0.00E+00	0.00E+00
Sb-124	1.69E-05	4.27E-07	3.11E-06
Sb-125	5.96E-05	1.72E-06	0.00E+00
Te-123m	1.95E-06	7.58E-08	0.00E+00

[a] Derived from data in FGR-12 [Ref A3.7]
[b] Assuming a sediment density of 1600 kg/m^3,
[C] After applying a modifying factor of 0.5 to take account for time spent on the shoreline or top of beach

Table A5.9 Habit data profiles for candidates for the representative person for liquid discharges (same profiles as used in gaseous releases).

Age group	Profile number	Profile name	Locally produced food consumption (kg/y or l/y)									Handling (h/y)		Occupancy (h/y)			
			Grn veg	Root veg	Fruit	Milk	Cattle meat	Sheep meat	Fish (sea)	Crust-acea	Moll-usc	Hand-ling fish'g gear	Hand-ling sedi-ment	Inter-tidal occup ancy over mud[c]	Indoor occu-pancy (used)	Out door occu-pancy (used)	Total plume occu-pancy (used)
Adult	A	Green veg[a]	49.1	37.6	25.2	15.6	6.8	1.6	2.3	1.8	0.1	35	1	67	4313	4380	8693
	B	Root veg[b]	39.3	75.6	28.7	43.8	19.5	2.5	-	0.0	-	-	-	52	4328	4380	8708
	C	Fruit	41.1	45.0	40.6	20.8	19.5	2.2	-	0.1	-	-	-	-	4380	4380	8760
	D	Milk	23.0	45.4	14.9	220.4	21.0	-	-	0.1	-	-	-	-	4380	4380	8760
	E	Cattle meat	15.1	55.9	16.5	56.3	44.5	-	0.3	0.1	-	-	-	-	4380	4380	8760
	F	Sheep meat	84.4	61.8	50.4	-	-	15.1	-	-	-	-	-	-	4380	4380	8760
	G	Fish	12	6.8	5.8	-	4.4	-	14.1	5.1	0.1	-	-	-	4380	4380	8760
	H	Crustaceans	36	20.4	10.7	-	-	-	17.2	13.3	0.3	-	-	-	4380	4380	8760
	I	Molluscs	35.5	28.5	6.4	-	-	-	13.7	11.9	0.8	-	-	-	4380	4380	8760
	J	Intertidal – mud[c]	1.9	1.5	0.3	-	-	-	1.0	0.2	0.0	52	1	702	3678	4380	8058
	K	Direct radiation	1.7	1.3	0.3	-	-	-	0.9	0.2	-	-	-	-	0	80	80
10 y Child	A	Green veg[a]	25.6	14.4	20.1	-	-	-	-	-	-	-	-	14.7	7008	1752	8760
	B	Root veg[b]	19.6	24.7	16.2	30.4	4.5	-	-	-	-	-	-	1.5	7008	1752	8760
	C	Fruit	22.3	11.4	23.6			-	-	-	-	-	-	-	7008	1752	8760
	D	Milk	2.3	21.7	0.6	101.6	6.8	-	-	-	-	-	-	-	7008	1752	8760
	E	Cattle meat	2	26.3	1.3	60.8	17.7	-	0.7	-	-	-	-	-	7008	1752	8760
	G	Fish	3.9	5	2.3	-	10.8	-	2.5	-	-	-	-	-	7008	1752	8760
	J	Intertidal - mud[c]	-	-	-	-	-	-	3.6	-	-	-	-	284.0	6724	6724	1752
	M	Direct radiation	5.5	0.7		-	-	-	1.2	-	-	-	-		6708	1752	8460
1y infant	A	Green veg[a]	4.1	4.9	4.7	18.7	-	-	-	-	-	-	-	72.0	7008	1752	8760
	B	Root veg[b]	3.0	8.0	13.5	-	-	-	-	-	-	-	-	-	7008	1752	8760
	C	Fruit	3	8	13.5	-	-	-	-	-	-	-	-	-	7008	1752	8760
	D	Milk	2.1	2.7	0.2	73.6	-	-	-	-	-	-	-	-	7008	1752	8760
	J	Intertidal - mud[c]	1.2	0.3	0.0	-	-	-	-	-	-	-	-	117.0	6891	1752	8643

[a] Combination of green veg. and other domestic veg. profiles data
[b] Combination of root veg. and potato profiles data
[c] Sum time spent in intertidal environments (including salt marsh, sand and rocks).

Table A5.10 Generic habit data

Habit data	Adult	Child	Infant	Units
Breathing rate per y	8100	5600	1900	m3/y
Breathing rate per h	0.92466	0.639	0.217	m3/h
default fraction of time indoors	0.5	0.8	0.9	-
Default Occupancy	1	1	1	-
Inadvertent ingestion of seawater	0.5	0.5	0.2	l/y
Inadvertent ingestion of sediment	8.30E-03	0.018	0.044	kg/y
Default beach occupancy	300	300	30	h/y

Table A5.11 Doses to the candidates for the representative person 2 (fisherman family) arising from maximum atmospheric and liquid discharges from Hinkley Point C and from all three power stations at Hinkley Point (µSv/y)

Profile name	Age group	Hinkley Point C			Hinkley Point A, B & C		
		Marine	Terrestrial	Total	Marine	Terrestrial	Total
G - Fish	Adult	3.21E-01	2.30E+00	2.62E+00	6.16E-01	5.88E+00	6.50E+00
	Child	**5.73E-02**	2.32E+00	2.37E+00	9.30E-02	6.27E+00	6.36E+00
	Infant	0.00E+00	1.14E+00	1.14E+00	0.00E+00	3.28E+00	3.28E+00
H - Crustaceans	Adult	5.13E-01	3.18E+00	3.70E+00	9.15E-01	6.52E+00	7.44E+00
	Child	0.00E+00	1.40E+00	1.40E+00	0.00E+00	3.76E+00	3.76E+00
	Infant	0.00E+00	1.14E+00	1.14E+00	0.00E+00	3.28E+00	3.28E+00
I - Molluscs	Adult	4.40E-01	3.26E+00	3.70E+00	7.71E-01	6.60E+00	7.37E+00
	Child	0.00E+00	1.40E+00	1.40E+00	0.00E+00	3.76E+00	3.76E+00
	Infant	0.00E+00	1.14E+00	1.14E+00	0.00E+00	3.28E+00	3.28E+00
J – Intertidal mud	Adult	3.49E-02	1.52E+00	1.55E+00	3.08E-01	4.61E+00	4.92E+00
	Child	8.85E-02	1.35E+00	1.44E+00	2.37E-01	3.66E+00	3.90E+00
	Infant	2.79E-03	1.24E+00	1.24E+00	5.07E-02	3.37E+00	3.42E+00
K – Intertidal salt marsh	Adult	0.00E+00	1.54E+00	1.54E+00	0.00E+00	4.78E+00	4.78E+00
	Child	0.00E+00	1.40E+00	1.40E+00	0.00E+00	3.76E+00	3.76E+00
	Infant	0.00E+00	1.14E+00	1.14E+00	0.00E+00	3.28E+00	3.28E+00

Table A5.12 Dose breakdown for the candidate for the representative person (adult crustacean consumer) arising from liquid discharges from Hinkley Point C at predicted levels[15] (µSv/y)

Radio nuclide	Marine pathways					Total dose
	Ingestion of Fish	Ingestion of Crustaceans	Ingestion of Molluscs	External sediments	Other marine pathways	
Ag-110m	2.23E-04	1.72E-03	7.78E-05	0.00E+00	0.00E+00	**2.02E-03**
C-14	2.84E-01	2.20E-01	4.95E-03	0.00E+00	0.00E+00	**5.08E-01**
Co-58	1.06E-05	8.19E-05	9.24E-07	0.00E+00	0.00E+00	**9.34E-05**
Co-60	8.35E-05	6.46E-04	7.28E-06	0.00E+00	0.00E+00	**7.37E-04**
Cr-51	9.58E-09	1.85E-08	6.69E-10	0.00E+00	0.00E+00	**2.88E-08**
Cs-134	2.31E-04	5.35E-05	1.21E-06	0.00E+00	0.00E+00	**2.85E-04**
Cs-137	2.75E-04	6.37E-05	1.44E-06	0.00E+00	0.00E+00	**3.40E-04**
H-3	4.88E-04	3.77E-04	8.51E-06	0.00E+00	0.00E+00	**8.73E-04**
I-131	1.46E-06	1.13E-06	2.55E-08	0.00E+00	0.00E+00	**2.62E-06**
I-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**
S-35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**
Sb-124	1.17E-04	5.65E-06	1.02E-07	0.00E+00	0.00E+00	**1.23E-04**
Sb-125	1.05E-04	5.09E-06	9.18E-08	0.00E+00	0.00E+00	**1.10E-04**
Te-123m	9.58E-05	7.41E-05	1.67E-06	0.00E+00	0.00E+00	**1.72E-04**
Grand total	**2.86E-01**	**2.23E-01**	**5.05E-03**	**0.00E+00**	**0.00E+00**	**5.13E-01**

Table A5.13 Dose breakdown for the candidate for the representative person (adult crustacean consumer) arising from liquid discharges from all three power stations at Hinkley Point[16] (µSv/y)

Radio nuclide	Marine pathways					Total dose
	Ingestion of Fish	Ingestion of Crustaceans	Ingestion of Molluscs	External sediments	Other marine pathways	
Ag-110m	2.23E-04	1.72E-03	7.78E-05	0.00E+00	0.00E+00	**2.02E-03**
C-14	2.84E-01	2.20E-01	4.95E-03	0.00E+00	0.00E+00	**5.08E-01**
Co-58	1.06E-05	8.19E-05	9.24E-07	0.00E+00	0.00E+00	**9.34E-05**
Co-60	2.23E-04	1.72E-03	1.94E-05	0.00E+00	0.00E+00	**1.96E-03**
Cr-51	9.58E-09	1.85E-08	6.69E-10	0.00E+00	0.00E+00	**2.88E-08**
Cs-134	1.61E-01	3.73E-02	8.42E-04	0.00E+00	0.00E+00	**1.99E-01**
Cs-137	1.60E-01	3.72E-02	8.38E-04	0.00E+00	0.00E+00	**1.98E-01**
H-3	2.60E-03	2.01E-03	4.54E-05	0.00E+00	0.00E+00	**4.66E-03**
I-131	1.46E-06	1.13E-06	2.55E-08	0.00E+00	0.00E+00	**2.62E-06**
I-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**
S-35	4.71E-04	1.82E-04	1.64E-05	0.00E+00	0.00E+00	**6.69E-04**
Sb-124	1.17E-04	5.65E-06	1.02E-07	0.00E+00	0.00E+00	**1.23E-04**
Sb-125	1.05E-04	5.09E-06	9.18E-08	0.00E+00	0.00E+00	**1.10E-04**
Te-123m	9.58E-05	7.41E-05	1.67E-06	0.00E+00	0.00E+00	**1.72E-04**
Grand total	**6.09E-01**	**3.00E-01**	**6.79E-03**	**0.00E+00**	**0.00E+00**	**9.15E-01**

[15] Contribution from Terrestrial discharges not included.
[16] Contribution from Terrestrial discharges not included.

Table A5.14 Comparison of doses to the candidate for the representative person (CRP2) (most exposed to liquid discharges) arising from gaseous and liquid discharges to the marine environment from Hinkley Point C at maximum expected discharges and at NNB GenCo's proposed limits (µSv/y).

Profile name	Age group	Dose from maximum expected discharges			Dose from proposed limits		
		Marine	Terrestrial	Total	Marine	Terrestrial	Total
G - Fish	Adult	3.21E-01	2.30E+00	2.62E+00	3.21E-01	2.30E+00	2.62E+00
	Child	5.73E-02	2.32E+00	2.37E+00	5.73E-02	2.32E+00	2.37E+00
	Infant	0.00E+00	1.14E+00	1.14E+00	0.00E+00	1.14E+00	1.14E+00
H - Crustaceans	Adult	5.13E-01	3.18E+00	3.70E+00	5.14E-01	3.18E+00	3.70E+00
	Child	0.00E+00	1.40E+00	1.40E+00	0.00E+00	1.39E+00	1.39E+00
	Infant	0.00E+00	1.14E+00	1.14E+00	0.00E+00	1.14E+00	1.14E+00
I - Molluscs	Adult	4.40E-01	3.26E+00	3.70E+00	4.40E-01	3.26E+00	3.70E+00
	Child	0.00E+00	1.40E+00	1.40E+00	0.00E+00	1.39E+00	1.39E+00
	Infant	0.00E+00	1.14E+00	1.14E+00	0.00E+00	1.14E+00	1.14E+00
J – Intertidal mud	Adult	3.49E-02	1.52E+00	1.55E+00	3.49E-02	1.52E+00	1.55E+00
	Child	8.85E-02	1.35E+00	1.44E+00	8.86E-02	1.35E+00	1.44E+00
	Infant	2.79E-03	1.24E+00	1.24E+00	2.80E-03	1.24E+00	1.24E+00
K – Intertidal salt marsh	Adult	0.00E+00	1.54E+00	1.54E+00	0.00E+00	1.54E+00	1.54E+00
	Child	0.00E+00	1.40E+00	1.40E+00	0.00E+00	1.39E+00	1.39E+00
	Infant	0.00E+00	1.14E+00	1.14E+00	0.00E+00	1.14E+00	1.14E+00

Appendix 6 – Independent Radiological Assessment of Collective Doses

A6.1 Collective dose provides an assessment of the radiation exposure in a population. It is the time integral of doses across a population. It is dependent on how far the discharged radionuclides spread with time; the concentrations in particular in foods; the radioactive half life; the size of the populations exposed and time integration period. It has been agreed that the collective doses to the populations of the UK, Europe[17] and the World, truncated at 500 years, should be estimated for authorisation purposes [Ref. A6.1]. An estimate of collective dose is identified as a requirement in the Environment Agency's guidance notes on how to apply for an environmental permit - part RSR-B3 [Ref. A6.2].

Calculation of collective doses

A6.2 Collective doses have been calculated for the UK, European (EU-12) and World populations, truncated at 500 years, in accordance with guidance identified above and from Defra [Ref A6.3] for discharges to atmosphere and from discharges to the marine environment. The assessment was made using PC CREAM 08 [Ref. A6.4].

A6.3 The annual maximum discharges to atmosphere and to the marine environment shown in Table 1 and Table 3 were used in the calculations. Calculations were also performed for discharges at the NNB GenCo proposed limits also presented in Tables 1 and 3.Collective doses are dependent on the release point. The assessment was made for discharges from the proposed Hinkley Point Nuclear Power Station and the existing Hinkley Point B and Hinkley Point A Power Stations. Collective doses arising from atmospheric and liquid discharges for the predicted maximum annual discharges for Hinkley Point C and current permit limits for Hinkley Point A and B were calculated.

A6.4 The collective doses arising from atmospheric and liquid discharges at the predicted maximum annual discharge rates from the proposed Hinkley Point C power station and the existing Hinkley Point B and Hinkley Point A power stations are presented in Tables A6.1 to A6.4. Table A6.5 compares collective doses arising from the predicted annual maximum discharges from Hinkley Point C and discharges at the NNB GenCo's proposed limits.

Assessed collective doses

A6.5 A summary of collective doses due predicted maximum annual discharges from Hinkley Point C and are given in Table A6.5.

A6.6 Collective doses from predicted maximum annual discharges to atmosphere from the proposed nuclear power station at Hinkley Point C were estimated to be: 0.37 manSv/y to the UK population, 2.2 manSv/y to European population and 24.7 manSv/y to the World . The majority of the collective doses arising from atmospheric discharges have been predicted to arise from carbon -14.

A6.7 The collective doses from predicted maximum annual discharges of liquid waste to sea from the proposed nuclear power station have been estimated to be: 0.02 manSv/y to UK, 0.09 manSv/y to Europe and 2.14 manSv/y to the world. The majority of the marine collective doses have been predicted to arise from carbon -14.

A6.8 The collective doses from the sum of the maximum annual atmospheric discharges and discharges to sea from the proposed nuclear power station at Hinkley Point C have been estimated to be: 0.39 manSv/y to the UK, 2.3 manSv/y to Europe and 26.8 manSv/y to the World. The majority of the collective doses have been predicted to arise from carbon-14.

[17] Only the EU-12 population profile was available for assessing collective doses due to atmospheric discharges in PC CREAM 08.

A6.9 Collective doses from the combined discharges from all three power stations have been estimated to be: to the UK - 1.9 manSv per year of discharge, to Europe - 10.2 manSv/y, and to the world - 102 manSv/y. The majority of the collective dose is from atmospheric discharges, which in turn are dominated by carbon-14. Summaries of collective doses to UK, Europe and the World populations are shown in Table A6.6.

A6.10 Average per caput doses (i.e. average individual doses derived from collective dose) were calculated for UK, European and World populations. The population data for UK, Europe and the World from which the per caput doses were derived are shown in Table A6.7. The average per caput doses due to discharges from both the proposed and existing power stations are presented in Tables A6.8 and A6.9 respectively (truncated at 500 years). At predicted levels, the average per caput dose to the UK, EU and World populations from the proposed nuclear power station at Hinkley Point C were between 3 and 6.5 nSv and for all three power stations were between 10 and 32 nSv.

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A6.11 The UK regulatory and advisory agencies have agreed that the risks associated with annual average per caput doses in the nSv range may be considered to be miniscule and should be ignored in the authorisation decision making processes [Ref A5.1]. The results of this study show that the per-caput doses from the proposed nuclear power station are of the order of a few nSv and therefore within the range that might be considered trivial.

Comparison with NNB GenCo collective doses

A6.12 Collective doses calculated in the independent assessment and by NNB GenCo were compared. The independent assessment found collective doses that were higher for the UK, by 30%, lower by 25% than those calculated by NNB GenCo for Europe and were the same for the world. The main difference for Europe is the population used PC CREAM-08 which is for 12 European countries and PC-CREAM-98 considers more European countries with a bigger total population.

References

A6.1 Joint Environment Agencies, Principles for the Assessment of Prospective Public Doses (Interim Guidance), (December 2002).

A6.2 Environment Agency. Form Guidance EP-RSR: How to apply for an environmental permit – Part RSR-B3, Guidance Notes.http://publications.environment-agency.gov.uk/PDF/GEHO0410BSFS-E-E.pdf

A6.3 Defra, The Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000. Defra (May 2000).

A6.4 Mayall A, Cabianca T, Attwood C, Fayers CA, Smith JG, Penfold J, Steadman D, Martin G, Morris TP and Simmonds JR. PC CREAM-97 (PC CREAM-98 code update) NRPB Chilton NRPB-SR-296 (EUR 17791) (1997).

Table A6.1 Collective dose to UK, EU-12 and World populations from atmospheric discharges at the maximum predicted discharges from Hinkley Point C (manSv per year of discharge)

Radionuclide	UK population			EU population			World population
	1st pass	Global pass	Total	1st pass	Global pass	Total	Global pass*
Ar-41	5.56E-05	0.00E+00	5.56E-05	5.75E-05	0.00E+00	5.75E-05	0.00E+00
C-14	2.14E-01	1.47E-01	3.61E-01	1.28E+00	8.87E-01	2.17E+00	2.47E+01
Co-58	5.59E-06	0.00E+00	5.59E-06	7.37E-06	0.00E+00	7.37E-06	0.00E+00
Co-60	2.31E-04	0.00E+00	2.31E-04	2.90E-04	0.00E+00	2.90E-04	0.00E+00
Cs-134	4.14E-04	0.00E+00	4.14E-04	1.56E-03	0.00E+00	1.56E-03	0.00E+00
Cs-137	3.58E-04	0.00E+00	3.58E-04	1.23E-03	0.00E+00	1.23E-03	0.00E+00
H-3	4.50E-03	1.17E-05	4.51E-03	1.01E-02	7.06E-05	1.02E-02	1.96E-03
I-131	7.12E-04	0.00E+00	7.12E-04	4.06E-04	0.00E+00	4.06E-04	0.00E+00
I-133	9.58E-05	0.00E+00	9.58E-05	1.06E-04	0.00E+00	1.06E-04	0.00E+00
Kr-85	1.86E-05	9.63E-06	2.82E-05	5.11E-05	5.81E-05	1.09E-04	1.58E-03
S-35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-131m	2.85E-07	0.00E+00	2.85E-07	7.19E-07	0.00E+00	7.19E-07	0.00E+00
Xe-133	2.04E-04	0.00E+00	2.04E-04	4.70E-04	0.00E+00	4.70E-04	0.00E+00
Xe-135	2.48E-04	0.00E+00	2.48E-04	2.92E-04	0.00E+00	2.92E-04	0.00E+00
Total	2.21E-01	1.47E-01	**3.68E-01**	1.29E+00	8.87E-01	2.18E+00	**2.47E+01**

*** Only the global pass is calculated for the World collective dose**

Table A6.2 Collective dose to UK, EU-12 and World populations from atmospheric discharges from all three power stations at Hinkley Point at current or proposed limits (manSv per year of discharge)

Radionuclide	UK population			EU population			World population
	1st pass	Global pass	Total	1st pass	Global pass	Total	Global pass*
Ar-41	4.29E-03	0.00E+00	4.29E-03	4.44E-03	0.00E+00	4.44E-03	0.00E+00
C-14	8.71E-01	5.98E-01	1.47E+00	5.23E+00	3.61E+00	8.84E+00	1.00E+02
Co-58	5.59E-06	0.00E+00	5.59E-06	7.37E-06	0.00E+00	7.37E-06	0.00E+00
Co-60	4.23E-03	0.00E+00	4.23E-03	5.30E-03	0.00E+00	5.30E-03	0.00E+00
Cs-134	4.14E-04	0.00E+00	4.14E-04	1.56E-03	0.00E+00	1.56E-03	0.00E+00
Cs-137	3.58E-04	0.00E+00	3.58E-04	1.23E-03	0.00E+00	1.23E-03	0.00E+00
H-3	1.46E-02	3.80E-05	1.46E-02	3.29E-02	2.29E-04	3.31E-02	6.38E-03
I-131	7.12E-04	0.00E+00	7.12E-04	4.06E-04	0.00E+00	4.06E-04	0.00E+00
I-133	9.58E-05	0.00E+00	9.58E-05	1.06E-04	0.00E+00	1.06E-04	0.00E+00
Kr-85	1.86E-05	9.63E-06	2.82E-05	5.11E-05	5.81E-05	1.09E-04	1.58E-03
S-35	4.24E-01	0.00E+00	4.24E-01	1.22E+00	0.00E+00	1.22E+00	0.00E+00
Xe-131m	2.85E-07	0.00E+00	2.85E-07	7.19E-07	0.00E+00	7.19E-07	0.00E+00
Xe-133	2.04E-04	0.00E+00	2.04E-04	4.70E-04	0.00E+00	4.70E-04	0.00E+00
Xe-135	2.48E-04	0.00E+00	2.48E-04	2.92E-04	0.00E+00	2.92E-04	0.00E+00
Total	**1.32E+00**	**5.98E-01**	**1.92E+00**	**6.50E+00**	**3.61E+00**	**1.01E+01**	**1.00E+02**

*** Only the global pass is calculated for the World collective dose**

Table A6.3 Collective dose to UK, EU-12 and World populations from liquid discharges at the maximum expected discharges from Hinkley Point C (manSv per year of discharge)

Radio nuclide	UK population			EU population			World population		
	1st pass	GC	Total	1st pass	GC	Total	1st pass	GC	Total
Ag-110m	1.65E-05	0.00E+00	1.65E-05	3.00E-05	0.00E+00	3.00E-05	3.16E-05	0.00E+00	3.16E-05
C-14	4.74E-03	1.26E-02	1.74E-02	1.59E-02	7.62E-02	9.21E-02	2.31E-02	2.11E+00	2.14E+00
Co-58	8.78E-07	0.00E+00	8.78E-07	1.90E-06	0.00E+00	1.90E-06	2.12E-06	0.00E+00	2.12E-06
Co-60	1.25E-05	0.00E+00	1.25E-05	2.55E-05	0.00E+00	2.55E-05	2.87E-05	0.00E+00	2.87E-05
Cr-51	2.63E-10	0.00E+00	2.63E-10	5.50E-10	0.00E+00	5.50E-10	6.01E-10	0.00E+00	6.01E-10
Cs-134	2.05E-06	0.00E+00	2.05E-06	6.40E-06	0.00E+00	6.40E-06	7.83E-06	0.00E+00	7.83E-06
Cs-137	3.33E-06	0.00E+00	3.33E-06	1.11E-05	0.00E+00	1.11E-05	1.51E-05	0.00E+00	1.51E-05
H-3	5.25E-06	3.03E-05	3.56E-05	1.50E-05	1.83E-04	1.98E-04	1.50E-05	5.09E-03	5.10E-03
I-131	4.39E-09	0.00E+00	4.39E-09	9.14E-09	0.00E+00	9.14E-09	1.00E-08	0.00E+00	1.00E-08
Mn-54	8.53E-07	0.00E+00	8.53E-07	1.38E-06	0.00E+00	1.38E-06	1.40E-06	0.00E+00	1.40E-06
Ni-63	3.15E-07	0.00E+00	3.15E-07	8.72E-07	0.00E+00	8.72E-07	1.07E-06	0.00E+00	1.07E-06
S-35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-124	2.98E-07	0.00E+00	2.98E-07	9.16E-07	0.00E+00	9.16E-07	1.07E-06	0.00E+00	1.07E-06
Sb-125	6.89E-07	0.00E+00	6.89E-07	2.30E-06	0.00E+00	2.30E-06	2.89E-06	0.00E+00	2.89E-06
Te-123m	6.40E-07	0.00E+00	6.40E-07	1.60E-06	0.00E+00	1.60E-06	1.83E-06	0.00E+00	1.83E-06
Total	**4.79E-03**	**1.27E-02**	**1.75E-02**	**1.59E-02**	**7.64E-02**	**9.23E-02**	**2.33E-02**	**2.12E+00**	**2.14E+00**

Table A6.4 Collective dose to UK, EU-12 and World populations from liquid discharges - from all three power stations at Hinkley Point at proposed or current limits (manSv per year of discharge)

Radio nuclide	UK population			EU population			World population		
	1st pass	GC	Total	1st pass	GC	Total	1st pass	GC	Total
Ag-110m	1.65E-05	0.00E+00	1.65E-05	3.00E-05	0.00E+00	3.00E-05	3.17E-05	0.00E+00	3.16E-05
C-14	4.74E-03	1.26E-02	1.74E-02	1.59E-02	7.62E-02	9.21E-02	2.31E-02	2.11E+00	2.14E+00
Co-58	8.78E-07	0.00E+00	8.78E-07	1.90E-06	0.00E+00	1.90E-06	1.92E-06	0.00E+00	2.12E-06
Co-60	3.34E-05	0.00E+00	3.33E-05	6.80E-05	0.00E+00	6.80E-05	7.36E-05	0.00E+00	7.66E-05
Cr-51	2.63E-10	0.00E+00	2.63E-10	5.48E-10	0.00E+00	5.50E-10	5.52E-10	0.00E+00	6.01E-10
Cs-134	1.43E-03	0.00E+00	1.43E-03	4.46E-03	0.00E+00	4.46E-03	4.47E-03	0.00E+00	5.46E-03
Cs-137	1.94E-03	0.00E+00	1.94E-03	6.46E-03	0.00E+00	6.46E-03	6.49E-03	0.00E+00	8.79E-03
H-3	2.81E-05	1.62E-04	1.90E-04	8.11E-05	9.77E-04	1.06E-03	2.03E-03	2.72E-02	2.72E-02
I-131	4.40E-09	0.00E+00	4.39E-09	9.14E-09	0.00E+00	9.14E-09	9.14E-09	0.00E+00	1.00E-08
Mn-54	8.53E-07	0.00E+00	8.53E-07	1.38E-06	0.00E+00	1.38E-06	1.39E-06	0.00E+00	1.40E-06
Ni-63	3.15E-07	0.00E+00	3.15E-07	8.72E-07	0.00E+00	8.72E-07	8.72E-07	0.00E+00	1.07E-06
S-35	3.67E-06	0.00E+00	3.68E-06	7.89E-06	0.00E+00	7.88E-06	7.88E-06	0.00E+00	8.66E-06
Sb-124	2.98E-07	0.00E+00	2.98E-07	9.16E-07	0.00E+00	9.16E-07	9.17E-07	0.00E+00	1.07E-06
Sb-125	6.90E-07	0.00E+00	6.89E-07	2.30E-06	0.00E+00	2.30E-06	2.30E-06	0.00E+00	2.89E-06
Te-123m	6.40E-07	0.00E+00	6.40E-07	1.60E-06	0.00E+00	1.60E-06	1.60E-06	0.00E+00	1.83E-06
Total	**8.20E-03**	**1.28E-02**	**2.10E-02**	**2.70E-02**	**7.72E-02**	**1.04E-01**	**3.76E-02**	**2.14E+00**	**2.18E+00**

GC - Global Circulation. All values derived from PC CREAM [Ref. 14.4]

Table A6.5 Collective dose (man Sv per year of discharge) for predicted discharges from Hinkley Point C

Release	Maximum expected discharges			NNB GenCo's proposed limits		
	UK	Europe	World	UK	Europe	World
Atmospheric (1st pass)	0.22	1.30	-	0.22	1.30	-
Atmospheric (GC)	0.15	0.89	24.7	0.15	0.89	24.7
Atmospheric (total)	***0.37***	***2.2***	***24.7***	***0.37***	***2.2***	***24.7***
Marine (1st Pass)	0.005	0.02	0.02	0.005	0.02	0.02
Marine (GC)	0.01	0.08	2.1	0.01	0.08	2.1
Marine (total)	***0.02***	***0.09***	***2.1***	***0.02***	***0.09***	***2.1***
Total	**0.39**	**2.3**	**26.8**	**0.39**	**2.3**	**26.8**

Table A6.6 Collective dose for predicted discharges from all three power stations at Hinkley Point at proposed or current limits (manSv per year of discharge)

Release	UK	Europe	World
Atmospheric (1st pass)	1.3	6.5	-
Atmospheric (GC)	0.60	3.6	100
Atmospheric (total)	***1.9***	***10.1***	***100***
Marine (1st Pass)	0.008	0.03	0.04
Marine (GC)	0.01	0.08	2.1
Marine (total)	***0.02***	***0.1***	***2.2***
Total	**1.9**	**10.2**	**102**

Table A6.7 Population data

Region	Population
UK	5.96E+07
Europe (EU-12)	3.60E+08
World	1.00E+10

Table A6.8 Average per caput doses at NNB GenCo's proposed limits for Hinkley Point C (nSv/y)

Pathway	Dose per person		
	UK	Europe	World
Atmospheric discharges	6.2	6.1	2.5
Marine discharges	0.3	0.3	0.2
Total	**6.5**	**6.4**	**2.7**

Table A6.9 Average per caput doses from all three power stations at Hinkley Point at proposed or current limits truncated to 500 years (nSv/y)

Pathway	Dose population		
	UK	Europe	World
Atmospheric discharges	31.9	28.1	10.0
Marine discharges	0.35	0.3	0.2
Total	**32.3**	**28.4**	**10.2**

Appendix 7 – Independent Radiological Assessment of Doses from Potential Short-term Releases

Introduction

A7.1 This Appendix presents the assessed radiological doses to the most exposed members of the public due to planned short-term discharges of radioactive wastes to the atmosphere from the proposed Hinkley Point C power station. The methodology used to assess these doses is also described in this appendix.

A7.2 The information provided by NNB GenCo [RefA7.1] includes an assessment of the potential short-term gaseous discharges that may arise, e.g. during routine maintenance operations of the plant. The objective was to determine the potential for higher doses if short duration peak activity concentrations in air and foodstuffs coincide with particular agricultural or other seasonal variations leading to peaks levels in harvested foodstuffs.

A7.3 The radiological assessments undertaken by NNB GenCo and in this independent assessment are based on the methods outlined in Reference A7.2 and use the ADMS atmospheric dispersion model [Ref. A7.3].

A7.4 Two assessments have been made, one is based on the predicted maximal monthly discharge values, as presented by NNB GenCo – which were assumed to be released over 6 hours.. The second assessment is based on the assumption that the maximum annual discharge is made over 6 hours. This will provide a bounding assessment of the radiological impact in the unlikely event that such a discharge were to occur. These assessments will give an indication of whether there is a need for notification levels for short duration releases.

Short-term discharges to atmosphere

A7.5 For our assessment we assumed NNB GenCo predicted short-term discharges were discharged over a six hour period, the discharge and emission rate are presented in Table A7.1. In accordance with information provided by NNB GenCo, the short-term releases have been assumed to occur from a 70 m high stack located adjacent to a reactor building and other ancillary buildings as described in the NNB GenCo report. The assessment was carried out for the West Stack, as this was shown to lead to the highest ground level activity concentrations in the NNB GenCo assessment.

A7.6 The ADMS 4.2 dispersion model has been used to estimate activity concentrations in the air and deposited on the ground at a potential receptor location of 500 m. This distance has been chosen to maintain consistency with those used in the assessment of continuous discharges, as outlined in Appendix 4. Dry and wet deposition has been modelled simultaneously, using the same deposition parameters as the NNB GenCo assessment. The deposition parameters are set out in Table A7.2.

A7.7 Site specific meteorological data was obtained from the Meteorological Office. The dataset was based on the Numerical Weather Prediction (NWP) model which calculates the weather conditions for each hour at a specific location based on measurements recorded at nearby weather stations. The NWP dataset obtained from the Meteorological Office provided hourly weather conditions at the Hinkley Point area for the ten year period from 1999 to 2008 inclusive. The period of 1 June – 31 August for each of the ten years of

meteorological data was used for the atmospheric dispersion modelling of short-term discharges to atmosphere.

A7.8 The period of 1 June – 31 August was selected because it is the peak growing season for most foodstuffs and animal feed (pasture and hay). It is therefore considered to be representative of conservative approach for ingestion pathways

A7.9 As the wind direction at the Hinkley C site is variable, it was necessary to specify receptor locations at 500m distance from the West stack at 10 degree intervals (i.e. a total of 36 receptor locations from 0 – 350 degrees were required for each receptor distance to ensure the range of wind directions were considered).

A7.10 The modelled concentrations utilised for the short-term dose assessment was based on the 95th percentile of the 6-hour rolling average. The 6-hour rolling average was utilised as the precise timing of any planned short-term discharges from the Hinkley C site is not known and therefore could occur during any 6 hour period within the assessed period of 1 June – 31 August. The 95th percentile of the generated 6 hour averages was selected to provide a conservative assessment.

Food concentration factors for short term deposit

A7.11 Food concentrations per unit deposit from a short duration release were taken from an NDAWG report (Ref A7.4 for the purpose of the independent assessment doses from short term releases. The NDAWG report did not contain food concentration factors for Co-58, Cs-134 and I-133; therefore the concentration factors for Co-60, Cs-137 and I-131 have been adopted for these radionuclides respectively. The food concentration factors for all radionuclides except C-14 and S-35 were derived from HPA's FARMLAND model (part of PC-CREAM) – the food concentration factors for `C-14 and S-35 were derived from FSA's SPADE model.

A7.12 The calculation of concentration of carbon-14 in food was modelled by direct uptake from air. This modelling is different to the other radionuclides which predict concentration by modelling activity deposited on the ground and plant surfaces followed by uptake by root and direct from leaves.

Receptor points and habit data

A7.13 The most exposed members of the public from short-term discharges have been assumed to live at the habitation at 500 m from the point of release, as assumed for the continuous release assessment, which has been assumed to be the location of the candidates for the representative person from continuous atmospheric discharges, as outlined in Appendix 2.

A7.14 Activity concentrations have been determined at ground level 500 m downwind of the release point. The activity concentrations in air, related to the defined release rates, and the deposition rate and cumulative deposition have been determined using ADMS 4.2, and are presented in Table A7.3.

A7.15 It has been assumed that the most exposed members of the public remain at this location throughout the duration of passage of the short-term release plume (6 hours) and that 100% of that time was spent outdoors.

A7.16 Doses from ingestion pathways have been based on food concentration factors provided in NDAWG 2011 [Ref. A7.4]. Exposed members of the public are assumed to consume green

vegetables, root vegetables and fruit from their garden or other local source (500 m from the discharge point) and milk and meat from local farms close to the site, whose livestock graze approximately 500 m from the discharge point. Site specific food consumption rates based on the habit profile of milk consumers [Ref. A7.5] have been used for this assessment.

Exposure pathways

A7.17 The exposure pathways considered were:

- Internal exposure from inhalation of radionuclides from the plume. The secondary inhalation of radionuclides which have been deposited on the ground and resuspended was not included, since the release did not include radionuclides for which this pathway is likely to provide a significant contribution to dose [Ref. A7.2];
- External dose from exposure to radionuclides in the short-term release plume ('cloudshine') and gamma radiation from radionuclides deposited on the ground ('groundshine');
- Internal dose from radionuclides from ingestion of local fruit and vegetable produce, cow and sheep meat and cow milk.

Doses from short-term releases

A7.18 Doses arising from the inhalation of plume have been based on inhalation rates for adults, children and infants derived from NRPB-W41 [Ref. A7.6] and activity concentrations in air at 500 m from the release point. Exposed members of the public are assumed to be outside during the period of passage of the plume (6 hours); outdoor breathing rates have therefore been used and indoor reduction factors have not been applied. Dose coefficients for inhalation have been taken from the PC CREAM 08 documentation [Ref. A7.7].

A7.19 External doses arising from immersion in plume ('cloudshine') and from deposited activity ('groundshine') have been estimated using ADMS 4.2 derived activity concentrations in air and deposited activity at 500 m for a 6 hour release period, and dose coefficients obtained from FGR-12 [Ref. A6.8]. The dose coefficient values are presented in Tables A7.4 and A7.5. The external doses arising from deposition have been based on the integrated effective doses over 1 year and the total activity deposited at 500 m.

A7.20 Doses arising from terrestrial food pathways have been estimated by applying food concentration factors derived from NDAWG 2011 [Ref. A7.4], habits data for milk consumer profiles [Ref. A7.5] and ingestion dose coefficients [Ref. A7.7] to the total deposited activity for a 6 hour release estimated using the ADMS dispersion model. The relevant foodstuffs are assumed to be produced at 500 m from the release point as described earlier. The NDAWG food concentration factors are presented in Table A7.6.

A7.21 Assumptions regarding the duration of short term releases, food source location and use of NDAWG food factors are likely to have resulted in overestimation of the doses arising from short term releases. Conversely, simplifications in the timing of agricultural practices, processing delays and radioactive decay would result in slight underestimation of doses from ingestion pathways for PC CREAM derived food factors. In both cases, the use of habit profiles (milk consumer) would result in lower doses than if top 2 approach has been used.

A7.22 The estimated doses arising from a single short-term release using the NDAWG derived `food concentration factors, from the exposure pathways described above, are shown in

Table A7.7. Doses have been calculated using the NNB GenCo assumptions about short duration releases and also assuming the maximum expected annual discharge occurs over 6 hours. This latter calculation gives an upper bound on the expected doses and possible peak concentrations in food. For the NNB GenCo assumptions doses were estimated to be in the order of 2.7 to 5.2 µSv, primarily due to C-14 ingested from terrestrial foods (root vegetables and milk). For the assumption of the maximum expected annual discharges over 6 hours, doses ranged from 36 to 72µSv – again primarily due to C-14 in terrestrial foods. Additional breakdown of the doses by pathway and by nuclide and pathway are shown in Table A7.9 and Table A7.10.

A7.23 Reference A7.2 recommends that a first order approximation of the impact of multiple releases may be made by multiplying the dose estimated for a single release by a factor of 10. This could be applied to the NNB GenCo predicted short term discharges and would give doses of 27 to 52 µSv. However it is not appropriate to apply a factor of 10 to the assessment based on maximum expected annual discharges as this latter calculation is a bounding worst case.

Radionuclide concentrations in food

A7.24 The EC has laid down the maximum permitted concentration of radionuclides in food in Council Regulation (EURATOM) 3954/87 (as amended) following the Chernobyl accident for application in the event of accident or radiological emergency [Ref. A7.9]. The regulations set maximum activity concentrations for 5 categories of radionuclides for 5 broad groups of foodstuff as shown in Table A7.10, referred to as community food intervention level (CFILS) [Ref. A7.10].

A7.25 The concentration of radionuclides in selected terrestrial foodstuff over one year following a single short-term release from Hinkley Point C has been determined. The radionuclide concentrations were back-calculated from the food ingestion doses derived using the NDAWG food concentration factors, in accordance with the approach described in RP 105 guidance document [Ref. A7.10]. The default correction factors provided in RP 105 were used.

$$Cf = E/(f \times D \times I \times C)$$

Where

Cf = activity concentration in food

E = reference individual effective dose arising from ingestion of contaminated food in a year subsequent to the accident

f = a factor representing the fraction of ingested food that is contaminated

D = ingestion dose coefficient (Sv/Bq)

I = annual food intake (kg)

C = a correction factor to allow for the additivity of foods within the category ‘other foods’: taken as 5 for radionuclides with half lives greater than a few weeks and 1 for radionuclides with half lives of a few days or less e.g. isotopes of iodine.

A7.26 Activity concentration in food were back calculated using the above formula from predicted doses estimated from three sets of assumptions about the discharges over the short duration. These were - short term discharges at NNB GenCo assumptions; at 1 GBq; and at the maximum expected discharge in one year. The predicted concentrations were compared with the EC recommended community food intervention levels (CFILs). Predicted

milk concentrations were compared against the CFILs for dairy produce and root vegetables were compared against the CFILs for 'other foods'. Green vegetables, fruit, cow meat and sheep meat were compared against the CFILs for 'minor foods'. No CFIL values were available for isotopes of cobalt – the CFIL values for caesium were used to compare with the predicted values for cobalt. The concentration of the assessed radionuclides in food was found to be orders of magnitude below the CFILs at NNB GenCo's predicted short term discharge rates (Table A7.11). Assuming the maximum annual discharge was released over 6 hours, the predicted concentrations were 10-100 times lower than the CFILs (Table A7.12).

A7.27 To make any future assessments more straightforward easier, food concentrations per GBq discharge are presented in Table A7.13.

References

A7.1 NNB GenCo, UK EPR Hinkley Point C, Radioactive Substances Regulation Environmental Permit Application, NNB-OSL-REP-000155 (2011)

A7.2 Smith, J G, Bedwell, P, Walsh C and Haywood, S M, A Methodology for Assessing Doses from Short-term Planned Discharges to Atmosphere, NRPB-W54, NRPB, Chilton (Issue 5, 2006).

A7.3 ADMS 4, Industrial Air Pollution Model, http://www.cerc.co.uk/software/adms4.htm

A7.4 National Dose Assessment Working Group (2011) Short-term Releases to the Atmosphere, NDAWG/2/2011 (Updated version of NDAWG/1/2010). http://www.ndawg.org/documents/NDAWG-2-2011_000.pdf

A7.5 Clyne, F.C., Garrod, C.J., Rumney, P., Hughes, L.M., and Ly, V.E., 2011. Radiological Habits Survey: Hinkley Point, 2010. RL 01/11. Cefas, Lowestoft

A7.6 Smith, K R and Jones A L, Generalised Habit Data for Radiological Assessments, NRPB-W41, NRPB, Chilton (2003).

A7.7 Smith, J G and Simmonds, J R (Eds), The methodology for assessing the radiological consequences of routine releases of radionuclides to the environment used in PC-CREAM 08, HPA-RPD-058, HPA, Chilton (2009).

A7.8 EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081 (Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

A7.9 European Commission, Council Regulation (EURATOM) No 3954/87 of 22 December 1987 laying down maximum permitted levels of radioactive contamination of foodstuffs and of feedingstuffs following a nuclear accident or any other case of radiological emergency.

A7.10 European Commission (1998), Radiation Protection 105, EU Food Restriction Criteria For Application After an Accident.

Table A7.1 Short-term discharges to atmosphere from Hinkley Point C assumed in the assessments.

Radionuclide	Released over 6 hours (GBq)	
	NNB GenCo short duration release assumptions	Maximum expected annual discharges
Ar-41	1.45E+02	1.31E+03
C-14	1.00E+02	1.40E+03
Co-58	1.53E-02	6.12E-02
Co-60	1.81E-02	7.22E-02
Cs-134	1.40E-02	5.62E-02
Cs-137	1.26E-02	5.04E-02
H-3	3.00E+02	6.00E+03
I-131	1.37E-01	3.64E-01
I-133	1.63E-01	4.36E-01
Kr-85	6.95E+02	6.26E+03
Xe-131m	1.50E+01	1.35E+02
Xe-133	3.16E+03	2.84E+04
Xe-135	9.90E+02	8.92E+03

Table A7.2 Deposition velocity and washout coefficients

Radionuclide	Deposition velocity (m/s)	Washout coefficient
Ar-41	0	0
C-14	0	0
Co-58	1.00E-03	ARB[18]
Co-60	1.00E-03	ARB
Cs-134	1.00E-03	ARB
Cs-137	1.00E-03	ARB
H-3	5.00E-03	ARB
I-131	1.00E-02	ARB
I-133	1.00E-02	ARB
Kr-85	0	0
Xe-131m	0	0
Xe-133	0	0
Xe-135	0	0

[18]Where $A = 10^{-4}$, B=0.64 and R= rain fall rate (mm/h)

Table A7.3 Activity concentrations from predicted 6 hour short-term discharges to atmosphere from Hinkley Point C

Nuclide	Based on NNB GenCo's predicted discharges		Based on maximum expected annual discharges	
	Air concentration (Bq/m^3)	Total deposition (Bq/m^2)	Air concentration (Bq/m^3)	Total deposition (Bq/m^2)
Ar-41	8.54E+00	-	7.69E+01	-
C-14	5.89E+00	-	8.25E+01	-
Co-58	8.92E-04	8.61E-06	3.57E-03	3.44E-05
Co-60	1.06E-03	1.02E-05	4.21E-03	4.06E-05
Cs-134	8.16E-04	7.88E-06	3.28E-03	3.16E-05
Cs-137	7.35E-04	7.09E-06	2.94E-03	2.84E-05
H-3	1.68E+01	3.64E-01	3.37E+02	7.28E+00
I-131	7.38E-03	2.96E-04	1.96E-02	7.87E-04
I-133	8.78E-03	3.52E-04	2.35E-02	9.43E-04
Kr-85	4.09E+01	-	3.69E+02	-
Xe-131m	8.84E-01	-	7.95E+00	-
Xe-133	1.86E+02	-	1.67E+03	-
Xe-135	5.83E+01	-	5.25E+02	-

Table A7.4 Inhalation dose coefficients

Age group	Radionuclide	ICRP lung class	Inhalation	Ingestion
			Sv/Bq	Sv/Bq
Adult	Ar-41	g	0.00E+00	0.00E+00
	C-14	m	2.00E-09	5.80E-10
	Co-58	m	1.60E-09	7.40E-10
	Co-60	m	1.00E-08	3.40E-09
	Cs-134	f	6.60E-09	1.90E-08
	Cs-137	f	4.60E-09	1.30E-08
	H-3	v	1.80E-11	1.80E-11
	I-131	f	7.40E-09	2.20E-08
	I-133	f	1.50E-09	4.30E-09
	Kr-85	g	0.00E+00	0.00E+00
	Xe-131m	g	0.00E+00	0.00E+00
	Xe-133	g	0.00E+00	0.00E+00
	Xe-135	g	0.00E+00	0.00E+00
Child	Ar-41	g	0.00E+00	0.00E+00
	C-14	m	2.80E-09	8.00E-10
	Co-58	m	2.40E-09	1.70E-09
	Co-60	m	1.50E-08	1.10E-08
	Cs-134	f	5.30E-09	1.40E-08
	Cs-137	f	3.70E-09	1.00E-08
	H-3	v	2.30E-11	2.30E-11
	I-131	f	1.90E-08	5.20E-08
	I-133	f	3.80E-09	1.00E-08
	Kr-85	g	0.00E+00	0.00E+00
	Xe-131m	g	0.00E+00	0.00E+00
	Xe-133	g	0.00E+00	0.00E+00
	Xe-135	g	0.00E+00	0.00E+00
Infant	Ar-41	g	0.00E+00	0.00E+00
	C-14	m	6.60E-09	1.60E-09
	Co-58	m	6.50E-09	4.40E-09
	Co-60	m	3.40E-08	2.70E-08
	Cs-134	f	7.30E-09	1.60E-08
	Cs-137	f	5.40E-09	1.20E-08
	H-3	v	4.80E-11	4.80E-11
	I-131	f	7.20E-08	1.80E-07
	I-133	f	1.80E-08	4.40E-08
	Kr-85	g	0.00E+00	0.00E+00
	Xe-131m	g	0.00E+00	0.00E+00
	Xe-133	g	0.00E+00	0.00E+00
	Xe-135	g	0.00E+00	0.00E+00

Table A7.5 External dose coefficients used

Radionuclide	Effective cloud dose (cloudshine) Sv/ Bq per m^3/s	Effective deposit dose (groundshine) Bq per m^2/s
Ar-41	6.14E-14	1.22E-15
C-14	2.60E-18	0.00E+00
Co-58	4.44E-14	9.25E-16
Co-60	1.19E-13	2.30E-15
Cs-134	7.06E-14	1.48E-15
Cs-137	2.55E-14	5.51E-16
H-3	0.00E+00	0.00E+00
I-131	1.69E-14	3.64E-16
I-133	2.89E-14	6.56E-16
Kr-85	2.40E-16	1.05E-17
Xe-131m	3.49E-16	1.60E-17
Xe-133	1.33E-15	3.95E-17
Xe-135	1.10E-14	2.50E-16

Table A7.6 Food concentration factors for unit deposition (Bq y/kg per Bq/m2) (NDAWG 2011)

Radionuclide	Green vegetables	Root vegetables	Fruit	Cow milk	Cow meat	Sheep meat
C-14 (units)	2.63E+00	6.59E+00	6.33E+00	3.30E+00	1.57E+01	2.01E+01
Co-58*	3.17E-03	4.05E-05	1.87E-03	4.23E-03	1.12E-03	9.66E-04
Co-60	3.17E-03	4.05E-05	1.87E-03	4.23E-03	1.12E-03	9.66E-04
Cs-134*	3.73E-03	9.53E-03	3.72E-02	1.10E-02	5.49E-02	4.60E-02
Cs-137	3.73E-03	9.53E-03	3.72E-02	1.10E-02	5.49E-02	4.60E-02
H-3	1.95E-03	1.95E-03	1.95E-03	9.06E-04	7.83E-04	1.19E-03
I-131	1.25E-03	2.73E-04	2.99E-03	1.84E-03	7.84E-04	1.01E-03
I-133*	1.25E-03	2.73E-04	2.99E-03	1.84E-03	7.84E-04	1.01E-03

*Data for Co-58, Cs-134 and I-133 were not provided in NDAWG 2011. The data for Co-60, Cs-137 and I-131 have been used in their place, respectively.

Units for carbon-14 concentration factors are Bq y/kg per Bq d/m^3

Table A7.7 Summary of estimated doses to all age groups from a NNB GenCo predicted maximum short-term release and assuming maximum predicted annual discharge are released over 6 hours from Hinkley Point C (µSv)

	NNB GenCo's predicted short-term discharges			Maximum predicted annual discharges		
Radionuclide	**Adult**	**Child**	**Infant**	**Adult**	**Child**	**Infant**
Ar-41	1.10E-02	1.10E-02	1.10E-02	1.02E-01	1.02E-01	1.02E-01
C-14	5.10E+00	2.90E+00	2.60E+00	7.17E+01	4.01E+01	3.57E+01
Co-58	3.50E-04	1.80E-04	1.30E-04	1.38E-03	7.19E-04	5.02E-04
Co-60	3.40E-03	1.80E-03	1.20E-03	1.38E-02	7.12E-03	4.87E-03
Cs-134	1.60E-03	7.90E-04	5.30E-04	6.28E-03	3.17E-03	2.14E-03
Cs-137	6.20E-04	3.10E-04	2.10E-04	2.49E-03	1.25E-03	8.43E-04
H-3	3.20E-03	2.00E-03	1.50E-03	6.37E-02	4.05E-02	3.01E-02
I-131	1.10E-03	1.00E-03	1.20E-03	2.92E-03	2.66E-03	3.13E-03
I-133	2.60E-04	2.40E-04	3.40E-04	7.08E-04	6.46E-04	9.17E-04
Kr-85	2.10E-04	2.10E-04	2.10E-04	1.91E-03	1.91E-03	1.91E-03
Xe-131m	6.70E-06	6.70E-06	6.70E-06	5.99E-05	5.99E-05	5.99E-05
Xe-133	5.30E-03	5.30E-03	5.30E-03	4.81E-02	4.81E-02	4.81E-02
Xe-135	1.40E-02	1.40E-02	1.40E-02	1.25E-01	1.25E-01	1.25E-01
Total	**5.20E+00**	**2.90E+00**	**2.60E+00**	**7.21E+01**	**4.05E+01**	**3.60E+01**

Table A7.8 Summary of estimated doses to all age groups from short duration release of 6 hours by pathway (µSv)

Scenario	Age group	Inhala-tion	Cloud Gamma	Dep. Gamma	Green veg	Root veg.	Fruit	Milk	Cow meat*	Total dose
NNB GenCo predicted short-term discharges	Adult	1.30E-1	3.10E-2	6.40E-3	4.10E-2	1.00E+0	3.20E-1	2.50E+0	1.10E+0	**5.20E+0**
	Child	8.90E-2	3.10E-2	3.30E-3	5.70E-3	6.70E-1	1.80E-2	1.60E+0	5.00E-1	**2.90E+0**
	Infant	7.50E-2	3.10E-2	2.20E-3	1.00E-2	1.70E-1	1.20E-2	2.30E+0	0.00E+0	**2.60E+0**
Predicted maximum annual discharges	Adult	1.80E+0	2.77E-1	2.47E-2	5.79E-1	1.43E+1	4.51E+0	3.48E+1	1.58E+1	**7.21E+1**
	Child	1.25E+0	2.77E-1	1.26E-2	7.98E-2	9.43E+0	2.51E-1	2.21E+1	7.04E+0	**4.05E+1**
	Infant	1.05E+0	2.77E-0	8.54E-3	1.46E-1	2.35E+0	1.67E-1	3.20E+1	0.00E+0	**3.60E+1**

*****Doses from sheep meat are zero

Table A7.9 Breakdown of dose to the representative person for NNB GenCo's predicted maximium short term releases (adult milk consumer) by radionuclide and pathway (μSv)*

Nuclide	In-halation	Cloud Gamma	Dep. Gamma	Green veg.	Root veg.	Fruit	Milk	Cow meat	Sum of inges-tion dose	Total dose
Ar-41	0.0E+0	1.1E-2	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	**1.1E-2**
C-14	1.2E-1	3.3E-7	0.0E+0	4.1E-2	1.0E+0	3.2E-1	2.5E+0	1.1E+0	5.0E+0	**5.1E+0**
Co-58	1.5E-5	8.6E-7	3.3E-4	9.3E-11	1.2E-11	1.8E-10	5.9E-9	1.5E-10	6.4E-9	**3.5E-4**
Co-60	1.1E-4	2.7E-6	3.3E-3	5.1E-10	6.4E-11	9.7E-10	3.2E-8	8.1E-10	3.5E-8	**3.4E-3**
Cs-134	5.7E-5	1.2E-6	1.5E-3	2.6E-9	6.5E-8	8.3E-8	3.6E-7	1.7E-7	6.9E-7	**1.6E-3**
Cs-137	3.5E-5	4.0E-7	5.9E-4	1.6E-9	4.0E-8	5.1E-8	2.2E-7	1.1E-7	4.2E-7	**6.2E-4**
H-3	3.2E-3	0.0E+0	0.0E+0	5.9E-8	5.8E-7	1.9E-7	1.3E-6	1.1E-7	2.2E-6	**3.2E-3**
I-131	5.7E-4	2.7E-6	5.2E-4	3.7E-8	8.1E-8	2.9E-7	2.6E-6	1.1E-7	3.2E-6	**1.1E-3**
I-133	1.4E-4	5.5E-6	1.2E-4	8.7E-9	1.9E-8	6.8E-8	6.1E-7	2.5E-8	7.3E-7	**2.6E-4**
Kr-85	0.0E+0	2.1E-4	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	**2.1E-4**
Xe-131m	0.0E+0	6.7E-6	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	**6.7E-6**
Xe-133	0.0E+0	5.3E-3	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	**5.3E-3**
Xe-135	0.0E+0	1.4E-2	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	**1.4E-2**
Total	**1.3E-1**	**3.1E-2**	**6.4E-3**	**4.1E-2**	**1.0E+0**	**3.2E-1**	**2.5E+0**	**1.1E+0**	**5.0E+0**	**5.2E+0**

*Food doses derived using NDAWG Food Concentration Factors
* Doses from sheep meat are zero

Table A7.10. Maximum permitted levels (Bq/kg) for foodstuffs (CFILs)

Radio-nuclide	Baby food	Dairy produce	Minor foods	Other foods	Liquid foods
Strontium	7.50E+01	1.25E+02	7.50E+03	7.50E+02	1.25E+02
Plutonium (α)	1.00E+00	2.00E+01	8.00E+02	8.00E+01	2.00E+01
Iodine	1.50E+02	5.00E+02	2.00E+04	2.00E+03	5.00E+02
Others – Cs-134 & Cs-137	4.00E+02	1.00E+03	1.25E+04	1.25E+03	1.00E+03
Others - C-14 & H-3 (proposed)	4.00E+03	1.00E+04	1.25E+05	1.25E+04	1.00E+04

Table A7.11. Activity concentration in food for a single short term release event of 6 hours at NNB GenCo's predicted short duration release (Bq/kg or Bq/l) for comparison with CFILs

Nuclide Parent	Green veg.	Root veg.	Fruit	Milk	Cow meat
C-14	6.20E+00	7.76E+01	7.46E+01	3.89E+01	1.85E+02
Co-58	1.09E-08	6.98E-10	3.22E-08	7.29E-08	1.93E-08
Co-60	1.29E-08	8.25E-10	3.81E-08	8.62E-08	2.28E-08
Cs-134	1.18E-08	1.50E-07	5.86E-07	1.73E-07	8.65E-07
Cs-137	1.06E-08	1.35E-07	5.28E-07	1.56E-07	7.79E-07
H-3	2.84E-04	1.42E-03	1.42E-03	6.60E-04	5.70E-04
I-131	7.41E-07	8.09E-07	8.86E-06	5.45E-06	2.32E-06
I-133	8.81E-07	9.62E-07	1.05E-05	6.49E-06	2.76E-06

Table A7.12. Activity concentration in food for a single short term release event of 6 hours at NNB GenCo's predicted maximum annual discharge (Bq/kg or Bq/l)

Nuclide Parent	Green veg.	Root veg.	Fruit	Milk	Cow meat
C-14	8.67E+01	1.09E+03	1.04E+03	5.44E+02	2.59E+03
Co-58	4.37E-08	2.79E-09	1.29E-07	2.91E-07	7.72E-08
Co-60	5.15E-08	3.29E-09	1.52E-07	3.44E-07	9.10E-08
Cs-134	4.72E-08	6.03E-07	2.35E-06	6.96E-07	3.47E-06
Cs-137	4.23E-08	5.41E-07	2.11E-06	6.24E-07	3.11E-06
H-3	5.68E-03	2.84E-02	2.84E-02	1.32E-02	1.14E-02
I-131	1.97E-06	2.15E-06	2.35E-05	1.45E-05	6.17E-06
I-133	2.36E-06	2.57E-06	2.82E-05	1.73E-05	7.39E-06

Table A7.13. Activity concentration in food for a single short term release event of 6 hours for unit (1 GBq) releases (Bq/kg or Bq/l)

Nuclide Parent	Green veg.	Root veg.	Fruit	Milk	Cow meat
C-14	6.20E-02	7.76E-01	7.46E-01	3.89E-01	1.85E+00
Co-58	7.14E-07	4.56E-08	2.11E-06	4.76E-06	1.26E-06
Co-60	7.14E-07	4.56E-08	2.11E-06	4.76E-06	1.26E-06
Cs-134	8.40E-07	1.07E-05	4.19E-05	1.24E-05	6.18E-05
Cs-137	8.40E-07	1.07E-05	4.19E-05	1.24E-05	6.18E-05
H-3	9.47E-07	4.73E-06	4.73E-06	2.20E-06	1.90E-06
I-131	5.41E-06	5.90E-06	6.47E-05	3.98E-05	1.70E-05
I-133	5.41E-06	5.90E-06	6.47E-05	3.98E-05	1.70E-05

Appendix 8 – Independent Assessment of Doses from Direct Radiation (shine)

Introduction

A8.1 Ensuring that assessment of offsite doses to the public from direct radiation is made is the responsibility of the Office for Nuclear Regulation. At operating sites nuclear operators are required to assess direct radiation and report the estimated doses annually. Site operators use appropriate methods such as measuring dose rates at the site perimeter. For prospective assessments, it is normally assumed that the measured doses apply to the future operation of the site.

A8.2 As no UK EPR nuclear power plants have yet been built and operated, it is necessary to estimate the direct radiation dose that may arise. In its application for an environmental permit, NNB GenCo presented a conservative estimate of the potential contribution of direct shine (from the proposed waste storage area) by assuming that the dose rate immediately outside the building is at the upper dose rate threshold for an undesignated area. The potential dose rates to members of the public were then based on simple geometrical relationships. This approach has been reviewed and agreed by the HSE and is therefore also applied in the independent assessment.

A8.3 Direct radiation exposure is included within this assessment for comparison against the relevant dose constraints.

A8.4 The assessment of doses from atmospheric and liquid discharges from the two UK EPR power plants at Hinkley Point C is outlined in Appendices 4 and 5, respectively.. In Appendix 9, we assess the expected dose from Hinkley Point C from discharges and direct radiation in combination. We also assess the expected doses from the past and future discharges from Hinkley Point A, B and C in total.

Direct radiation exposure estimates – NNB GenCo

A8.5 The NNB GenCo approach to calculating potential doses from direct radiation is based on the assumption that the dose rate immediately outside the waste storage building (1 m) could be 0.5 µSv/h. The dose rate at the receptor point (the potential location of the representative person) was then estimated using a 1/r relationship for receptors in close proximity to the building and $1/r^2$ for more distant points.:

A8.6 Dose rates were estimated to the following candidate representative persons, at the following locations

a. Walker on coastal footpath situated outside the site fence (40 m from the waste store);
b. Local residents located at 1.3 and 1.7 km from the waste store location.

The walker was predicted to receive the highest predicted dose rate (of 0.0125 µSv/h) for an exposure period of around 10 minutes per day. The estimated annual dose to this group was therefore around 0.76 µSv/y.

Direct radiation exposure estimates – independent assessment

A8.7 For the independent assessment it was assumed that representative person lives 500m from the waste store and also walks a dog 40m from the store on the cliff path close to the store. Their combined exposure was calculated.

A8.8 The dose rate 40m from the store was estimated as 0.0125 µSv/h. For an exposure time of 10 minutes a day, the annual dose would be 0.76 µSv/y (Table A8.1).

A8.9 The assessment of direct radiation was then made assuming a resident at 500m. The assumptions and results are shown in Table A8.2. At this distance the doses range from 0.9 to 1.2 µSv/y.

A8.10 For purposes of perspective, it is useful to note that the direct radiation dose measured around Sizewell B (the only PWR station in the UK) was reported to be less than 10 µSv/y in 2010 [Ref. A8.1]

A8.11 This direct radiation estimate is assumed to apply to the representative person from atmospheric discharges. This dose has been applied without allowance for shielding during time spent indoors. It has been assumed that local fisherman and their families do not collect seafood from near to the site and do not live close enough to receive a dose from direct radiation.

A8.12 Direct radiation from the existing Hinkley Point A and B power stations was estimated to be 5 µSv/y. This figure is the average of the direct radiation doses for Hinkley Point taken from the RIFE reports for 2006 – 2010 [Ref. 1 and earlier RIFE reports].

References

A8.1 Food Standards Agency and Joint Environment Agencies. Radioactivity in Food and the Environment, 2010 (RIFE-16) (2011).

Table A8.1 Calculation of dose from waste store to walker at 40m using 1/r

Parameter	Value	Units
Dose rate at 1m:	0.5	µSv/h
Distance of pathway from outside wall:	40	m
dose rate at 40m to walker:	0.0125	µSv/h
exposure time	0.17	h/day
annual dose to walker	**0.76**	µSv/y

Table A8.2 Dose to resident at 500m using $1/r^2$

Parameter	Value	Units
Dose 40m from building	0.0125	µSv/h
Dose 500m from building nr house	0.00008	µSv/h
Indoor location factor	0.1	
Outdoor location factor	1	
Indoor dose rate	0.000008	µSv/h
Outdoor dose rate	0.00008	µSv/h
Indoor Occupancy (h/y)		
Adult	4380	(h/y)
Child	7008	(h/y)
Infant	7884	(h/y)
Outdoor occupancy		
Adult	4380	(h/y)
Child	1752	(h/y)
Infant	876	(h/y)
Annual direct dose		
Adult	0.39	µSv/y
Child	0.20	µSv/y
Infant	0.13	µSv/y
Total dose including walking		
Adult	1.15	µSv/y
Child	0.96	µSv/y
Infant	0.89	µSv/y

Table A8.3: Direct exposure to the representative person for the Hinkley Point C site

Installation	Direct radiation dose (µSv/y)	Total annual dose from direct radiation (µSv/y)
	500m	
Hinkley Point C	0.9-1.1	6
Hinkley Point A and B (from measurements in RIFE)	5	

Appendix 9 – Independent Assessment of Dose from All Three Power Stations at Hinkley Point and Total Dose

Introduction

A9.1 The Environment Agency has responsibility to assess the maximum doses to individuals which may result from a defined source for use at the planning stage in radiation protection [Ref A9.1]. The current applicable criteria to existing sites are:

- 0.3 millisieverts per year (mSv/y) (300 μSv/y) from any source (source dose constraint);
- 0.5 millisieverts per year (mSv/y) (500 μSv/y) from the discharges from any single site (site dose constraint).

A9.2 The Environment Agency has also been directed to ensure that the sum of doses resulting from exposure to ionising radiation (total dose) does not exceed 1 mSv/y (1,000 μSv/y) [Ref A9.1].

A9.3 In its consultation document on advice on the application of the 2007 ICRP Recommendations to the UK [Ref. A9.2], the HPA has recommended that a maximum source constraint for members of the public of 150 μSv/y for new nuclear power stations should be used.

Dose from Hinkley Point C

A9.4 The dose for comparison with the source dose constraint includes the contributions from discharges from a given source and any additional contribution from direct radiation. The assessment of doses from predicted future discharges from Hinkley Point C nuclear power station is outlined in Appendices 4 and 5 for discharges to atmospheric and liquid discharges, respectively. The dose from direct radiation was estimated, as outlined in Appendix 8.

A9.5 The adult milk consumer is the candidate representative person who will be most exposed to gaseous discharges. The adult milk consumer also has some exposure to liquid discharges and their dose from Hinkley Point C is predicted be 8.4 μSv/y (Table A9.1). This is much less than the dose constraint for a single source of 300 μSv/y and also much less than the proposed dose constraint for new nuclear power stations of 150 μSv/y.

A9.6 The adult custaceans consumer is the candidate for representative person who will be most exposed to liquid discharges. The adult crustaceans consumer is also exposed to gaseous discharges and their dose from Hinkley Point C is predicted to be up to 3.7 μSv/y (Table A9.1). This is much less than the dose constraint for a single source of 300 μSv/y and also much less than the proposed dose constraint for new nuclear power stations of 150 μSv/y.

Site dose from Hinkley Point

A9.7 The total dose from discharges from all three power stations at Hinkley Point should be compared with the 500 μSv/y site dose constraint. The total site dose has been assessed for adult milk consumer local to the site, infant milk consumer local to the site and adult crustacea consumer. The assessment assumes the expected maximum discharges from Hinkley C and discharges from Hinkley A and B at their current limits.. Allowance was made for the operation of an incinerator on the Hinkley Point B site.

A9.8 The highest dose from combined discharges from Hinkley Point were between 7.4 and 15.5 μSv/y arising from the liquid and gaseous discharges and are shown in Table A9.2, A9.3 and A9.4. Highest dose was assessed as 15.5 μSv/y to an adult milk consumer and 13.4 to an infant milk consumer local to the site. Doses from liquid and gaseous discharges to an adult crustacea consumer were lower at 7.4 μSv/y. All the site doses were less than the dose constraint of 500 μSv/y.

A9.9 An incineration facility currently exists on the Hinkley Point B site; and although not currently in use, the facility remains permitted. The potential contribution of this facility to the total dose has been estimated to be 1 µSv/y.

Total dose

A9.10 An assessment of total dose for comparison with the dose limit would take account of:

- Historical discharges from any other reactors or practices with which the proposed nuclear power station is co-located;
- Historical discharges from other sites that lead to elevated levels of radioactivity in the area;
- Future discharges from the proposed nuclear power station and co-located reactors or other practices;
- Direct radiation from the proposed power station and co-located reactors or other practices; and,
- Future discharges from other sites that lead to elevated levels of radioactivity in the area.

A9.11 The RIFE reports for 2006 - 2010 indicates that the total dose to high rate terrestrial food consumers at the Hinkley Point site from all sources is of the order of 5 µSv/y [A9.3]. This figure has largely remained the same for the period from 2006 – 2010. Doses from exposure to the marine environment over the last 5 years range from 20-48 µSv/y with an average value of 36 µSv/y. Direct radiation ranged from 2-10 µSv/y and averaged around 5 µSv/y (Table A9.5).

A9.12 The total dose from the Hinkley Point site including direct radiation and historic discharges is shown in table A9.6. Adult milk consumer was predicted to receive 27 µSv/y. .This is made up of the prospective dose from gaseous and liquid discharges from all three power stations at Hinkley Point of 15.5 µSv/y; expected direct radiation from Hinkley Point C of 1.2 µSv/y; current direction radiation from Hinkley Point A and B of 5 µSv/y; and the current dose arising from historic discharges and other sources of 5 µSv/y. An adult fish crustacean consumer was predicted to receive 43 µSv/y. This is made up of the prospective dose from gaseous and liquid discharges from all three power power stations at Hinkley Point of 7.4 µSv/y; and the current dose arising from historic discharges and other sources of 36 µSv/y. These assessed dose are all significantly less than the dose limit of 1000 µSv/y.

References

A9.1 Joint Agencies, Principles for the Assessment of Prospective Public Doses (Interim Guidance) December 2002.

A9.2 Health Protection Agency, HPA Advice on the Application of the ICRP's 2007 Recommendations to the UK, Consultation Document, HPA, Chilton, (2008).

A9.3 Food Standards Agency and Joint Environment Agencies. Radioactivity in Food and the Environment, 2010 (RIFE-16) (2011).

Table A9.1 Summary of doses from the Hinkley Point C to an adult milk consumer and adult crustacean consumer for predicted liquid and gaseous discharges (μSv/y).

Candidate for representative person	Dose from Hinkley Point C				
	Atmospheric	Liquid	Direct radiation	Total dose	Dose constraint for single source
Adult milk consumer	7.2	0.002	1.2	8.4	300
Adult crustacea consumer	3.2	0.51	0	3.7	300

Table A9.2 Summary of doses from the Hinkley Point site including Hinkley Point C to an adult milk consumer at maximum expected discharges (μSv/y).

Site	Site Dose from Hinkley Point (including contribution from proposed UK EPR units at Hinkley Point C)		
	Atmospheric	Liquid	Total
Hinkley Point C	7.2	0.002	7.2
Hinkley Point B	7.2	0.0005	7.2
Hinkley Point A	0.03		
Hinkley Point Site total	**14.4**	**0.003**	**14.4**
Hinkley Point B incinerator+	1.1	-	1.1
Hinkley point site total including incinerator	**15.5**	**0.003**	**15.5**
Dose constraint for a site	**500**	**500**	**500**

+ Incinerator is not currently in use but remains permitted. Discharge data and other incinerator information were taken from reference A9.4.

Table A9.3 Summary of doses from the Hinkley Point site including Hinkley Point C to an infant milk consumer for predicted discharges (μSv/y).

Site	Site Dose from Hinkley Point (including contribution from proposed UK EPR units at Hinkley Point C)		
	Atmospheric	Liquid	Total
Hinkley Point C	4.2	0	4.2
Hinkley Point B	7.9	0	7.9
Hinkley Point A	0.02		
Hinkley Point Site total	**12.1**	**0**	**12.1**
Hinkley Point B incinerator+	1.3	-	1.3
Hinkley point site total including incinerator	**13.4**	**0**	**13.4**
Dose constraint for a site	**500**	**500**	**500**

+ Incinerator is not currently in use but remains permitted. Discharge data and other incinerator information were taken from reference A9.4.

Table A9.4 Summary of doses from the Hinkley Point site (including Hinkley Point C) to an adult crustacea consumer for maximum expected discharges (μSv/y)+.

Site	Site Dose from Hinkley Point (A, B and C)		
	Atmospheric	Liquid	Total
Hinkley Point C	3.2	0.5	3.7
Hinkley Point B	3.3	0.04	3.3
Hinkley Point A	0.03	0.36	0.4
Hinkley Point Site total	**6.5**	**0.9**	**7.4**
Site dose constraint	**500**	**500**	**500**

+See also table A5.11

Table A9.5 Summary of doses from historic discharges and direct radiation from the Hinkley Point site to adult (or infant) (μSv/y).

Site	Atmospheric pathways	Direct radiation	Liquid pathways
2006	5(i)	2	48
2007	<5(i)	4	29
2008	6(i)	5	37
2009	<5(i)	4	46
2010	5(i)	10	20
Average	**5(i)**	**5**	**36**

(i) Dose to an infant

Table A9.6. Assessment of total dose to representative person from Hinkley Point Site, including contributions from Hinkley Point A, B and C, direct radiation, historic discharges and other sources (μSv/y)

Representative Person	Radiation Source					Total	Dose limit for members of the public
	Prospective doses from atmospheric discharges from A,B and C combined*	Prospective doses from liquid discharges from A,B and C combined	Direct Radiation from A&B	Direct radiation from C	Doses from past discharges from A&B		
Adult milk consumer	15.5	0.003	5	1.2	5	**27**	**1000**
Adult crustacea consumer	6.5	0.9	0	0	36	**43**	**1000**

*including a contribution of 1.1 μSv/y from the incinerator

Appendix 10 – Independent Assessment of Radiological Doses to Non-human Species

A10.1 An assessment of potential dose rates to non-human species as a consequence of gaseous and liquid discharges from the proposed Hinkley Point C Nuclear Power Station and the neighbouring Hinkley Point B and Hinkley Point A Nuclear Power Station has been undertaken The assessment has been carried out for terrestrial and marine organisms using Tier 2 of the ERICA Assessment Tool (ERICA Tool) [Ref. A10.1]. The methodology applied is described in subsequent sections of this appendix.

A10.2 The assessment was based on the concentration of radionuclides in the environment generated using the dispersion models contained in the PC CREAM 08 suite of radiological modelling software [Ref. A10.2]. The PC CREAM modelling was based on the predicted maximum annual gaseous and liquid discharges from the proposed new power station, and current permit limits for the existing power stations [Ref. A10.3].

Calculation of dose rates to non-human species

A10.3 Potential dose rates to non-human biota have been determined using the ERICA TOOL. The ERICA TOOL is a multi-tiered software programme that allows dose rates to biota in three ecosystems (terrestrial, freshwater and marine) to be assessed. A number of reference organisms representative of the types of organisms that are likely to be present in each type of ecosystem are included within the assessment tool.

A10.4 The ERICA TOOL calculates dose rates to reference organisms on the basis of a simplified (e.g. ellipsoid) geometry representative of the dimensions of the main body of the organism (i.e. extremities such as legs, wings etc are not included). Dose conversion coefficients (DCCs) for both internal and external exposure to radionuclides are specific to these organisms and geometries.

A10.5 The ERICA TOOL is comprised of 3 tiers, representing different levels of complexity. Tier 1 of the ERICA TOOL is a simple conservative step that applies media concentration and pre-calculated environmental media concentration limits (EMCL) to estimates dose rates to default organisms. This tier requires minimum data input and is suitable for screening assessment or in circumstances where site specific data are lacking.

A10.6 Tier 2 of the ERICA TOOL is a more interactive stage that provides the user with more flexibility in the choice of parameters for the assessment. This tier allows the user to introduce non-default reference organism and radionuclides to the assessment and to edit or change default parameters (including concentration ratios, distribution coefficients, dose conversion coefficients, radiation weighting factors and occupancy factors).

A10.7 Tier 3 of the ERICA TOOL is similar to the Tier 2 but allows probabilistic risk assessment and access to the FREDERICA database [Ref. A6.1]. This allows up-to-date scientific literature to be applied (which may not be available at Tier 2) on the biological effects of exposure to ionising radiation in a number of different species.

A10.8 The ERICA TOOL does not support the assessment of doses due to discharges of noble gases. Potential doses to an unspecified ‘worst affected terrestrial organism’ due to discharges of noble gases have been determined using Stage 2 of the Environment Agency’s Initial Assessment Methodology [Ref. A6.4]. Argon-41 has been used as surrogate for radioisotopes of Xenon in this assessment.

A10.9 The assessment of dose rates to reference organisms was undertaken at tier 2 of the ERICA TOOL. Default parameters were used throughout the assessment where available.

A10.10 Three non-default organisms that are likely to be present within the vicinity of the proposed nuclear power station were included in the terrestrial dose rate assessment. These are Badger, Bat and Fox. The concentration ratios (CR) for badger and bat have been based on the default CR values for mammal (deer) and mammal (rat) respectively. The CR values for fox were based on the data for 'carnivore mammal' in Table 6.9 of the Environment Agency's EAR&D128 publication [Ref. A6.5][19].

A10.11 Bats were assumed to reside 'on soil' all the time, whilst Badgers were assumed to spend half the time 'in soil' and the other half 'on soil'. Fox was assumed to reside 'on soil' 60% of the time and 'in soil' 40% of the time.

A10.12 Site specific media concentration data were used for the purpose of this assessment. For the terrestrial assessment, activity concentration in air and deposited activity at a distance of 500m from release stacks were modelled using the PLUME module of PC CREAM 08 [Ref. A6.2]. For marine assessment, activity concentrations in the marine environment due to liquid discharges were determined using the DORIS module of PC CREAM 08 [Ref. A6.2]. The media concentration values used for this assessment are presented in Tables A6.1 and A6.2.

Assessed dose rates to non-human species

A10.13 Dose rates to a range of marine and terrestrial reference organisms have been assessed. A summary of predicted dose rates to these organisms are given in Table A6.3 to Table A6.8. Dose rates were used to derive risk quotient (RQ). The risk quotient (RQ) is the ratio of estimated dose rates to the screening dose rate, used as a screening tool to aid decision. RQ<1 are indicative of low risk situations in which case it may be decided that no further action is necessary

A10.14 For discharges from the proposed Hinkley Point C nuclear power station, the limiting organism for liquid releases to the marine environment is reptile with a total dose rate of 1.28E-03 µGy/h (RQ of 1.28E-04). The limiting terrestrial organism for discharges to atmosphere is mammal (deer) with a total dose rate of 3.46E-03 µGy/h (RQ of 3.46E-04).

A10.15 For total discharges from all three power stations at Hinkley Point, the limiting organism for liquid releases to the marine environment is polychaete worm with a total dose rate of 8.07E-03 µGy/h (RQ of 8.07E-04). The limiting terrestrial organism for discharges to atmosphere is mammal (rat) with a total dose rate of 6.55E-03 µGy/h (RQ of 6.55E-04).

A10.16 A total dose rate to the worst affected terrestrial organism due to discharges of noble gases from the proposed nuclear power plant has been determined as 2.10E-3 µGy/h. The predicted total dose rate to the worst affected terrestrial organism from discharges of noble gases from all three power stations is 8.76E-03 µGy/h.

A10.17 The assessed dose rates to all reference organisms considered as a result of all discharges from the Hinkley Point site are significantly lower than the ERICA screening level of 10 µGy/h.

References

A10.1 ERICA Assessment Tool, http://www.erica-tool.com/

A10.2 Smith, J G and Simmonds, J R (Eds), The methodology for assessing the radiological consequences of routine releases of radionuclides to the environment used in PC-CREAM 08, HPA-RPD-058, HPA, Chilton (2009).

A10.3 NNB GenCo, UK EPR Hinkley Point C, Radioactive Substances Regulation Environmental Permit Application, NNB-OSL-REP-000155 (2011).

[19] CR values for Cobalt and Iodine were not available in the EAR&D128 publication and the assessment does not include contribution from these radionuclides.

A10.4 Environment Agency, Initial Radiological Assessment Methodology (Parts 1 and 2), Science Report SC030162/SR1 (2006)

A10.5 Copplestone, D et al, Impact Assessment of Ionising Radiation on Wildlife, R&D Publication 128 Environment Agency, Bristol (2001)

Table A10.1 Activity concentration in seawater and sediment from discharges to the marine environment

Radionuclide	Hinkley Point C		Hinkley Point site	
	Unfiltered seawater (Bq/l)	Seabed sediment (Bq/kg)	Unfiltered seawater (Bq/l)	Seabed sediment (Bq/kg)
Ag-110m	1.11E-05	4.96E-04	1.11E-05	4.96E-04
C-14	2.00E-03	2.58E+00	2.00E-03	2.58E+00
Co-58	3.41E-05	2.37E-03	3.41E-05	2.37E-03
Co-60	5.84E-05	8.04E-02	**1.56E-04**	**2.14E-01**
Cr-51	8.06E-07	2.06E-05	8.06E-07	2.06E-05
Cs-134	1.13E-05	2.90E-03	**7.89E-03**	**2.02E+00**
Cs-137	1.97E-05	2.48E-02	**1.15E-02**	**1.44E+01**
H-3	1.58E+00	2.70E+00	**8.39E+00**	**1.44E+01**
I-131	3.89E-07	8.52E-08	3.89E-07	8.52E-08
Mn-54	5.04E-06	1.47E-03	5.04E-06	1.47E-03
Ni-63	1.96E-05	7.68E-02	1.96E-05	7.68E-02
S-35	0.00E+00	0.00E+00	**1.78E-02**	**1.24E-02**
Sb-124	8.15E-06	9.17E-05	8.15E-06	9.17E-05
Sb-125	1.66E-05	2.58E-03	1.66E-05	2.58E-03
Te-123m	4.77E-06	1.05E-04	4.77E-06	1.05E-04

Table A10.2 Activity concentration in air and on ground from discharges to atmosphere

Radionuclide	Hinkley Point C		Hinkley Point site	
	Activity concentration in air (Bq/m^3)	Activity concentration in soil (Bq/kg)	Activity concentration in air (Bq/m^3)	Activity concentration in soil (Bq/kg)
Ar-41	7.09E-02	-	1.77E+00	-
C-14	7.67E-02	-	1.41E-01	-
Co-58	3.34E-06	8.12E-05	3.34E-06	8.12E-05
Co-60	3.94E-06	2.12E-03	2.36E-05	1.27E-02
Cs-134	3.07E-06	7.06E-04	3.07E-06	7.06E-04
Cs-137	2.75E-06	5.01E-03	2.75E-06	5.01E-03
H-3	3.29E-01	-	5.48E-01	-
I-131	1.97E-05	4.54E-04	4.51E-05	1.04E-03
I-133	2.36E-05	5.68E-05	2.36E-05	5.68E-05
KR-85	3.43E-01	-	3.43E-01	-
S-35	0.00E+00	0.00E+00	5.99E-03	1.83E-01
Xe-131m	7.40E-03	-	7.40E-03	-
Xe-133	1.56E+00	-	1.56E+00	-
Xe-135	4.88E-01	-	4.88E-01	-

Table A10.3 Dose rates to marine organisms due to liquid discharges from the proposed Hinkley Point C nuclear power station

Organism	Total Dose Rate per organism [µGy h-1]	Screening Value [µGy h-1]	Risk Quotient (expected value)	Risk Quotient (conservative value)
(Wading) bird	1.10E-03	1.00E+01	1.10E-04	3.29E-04
Benthic fish	8.62E-04	1.00E+01	8.62E-05	2.59E-04
Benthic mollusc	7.27E-04	1.00E+01	7.27E-05	2.18E-04
Crustacean	7.42E-04	1.00E+01	7.42E-05	2.23E-04
Macroalgae	5.50E-04	1.00E+01	5.50E-05	1.65E-04
Mammal	1.28E-03	1.00E+01	1.28E-04	3.83E-04
Pelagic fish	8.13E-04	1.00E+01	8.13E-05	2.44E-04
Phytoplankton	8.92E-06	1.00E+01	8.92E-07	2.68E-06
Polychaete worm	7.98E-04	1.00E+01	7.98E-05	2.39E-04
Reptile	**1.28E-03**	**1.00E+01**	**1.28E-04**	**3.83E-04**
Sea anemones or true corals - colony	7.22E-04	1.00E+01	7.22E-05	2.17E-04
Sea anemones or true corals - polyp	7.13E-04	1.00E+01	7.13E-05	2.14E-04
Vascular plant	5.59E-04	1.00E+01	5.59E-05	1.68E-04
Zooplankton	6.18E-04	1.00E+01	6.18E-05	1.85E-04

Table A10.4 Dose rates to marine organisms due to total liquid discharges from the Hinkley Point site.

Organism	Total Dose Rate per organism [µGy h-1]	Screening Value [µGy h-1]	Risk Quotient (expected value)	Risk Quotient (conservative value)
(Wading) bird	2.98E-03	1.00E+01	2.98E-04	8.93E-04
Benthic fish	4.37E-03	1.00E+01	4.37E-04	1.31E-03
Benthic mollusc	4.28E-03	1.00E+01	4.28E-04	1.29E-03
Crustacean	3.96E-03	1.00E+01	3.96E-04	1.19E-03
Macroalgae	4.34E-03	1.00E+01	4.34E-04	1.30E-03
Mammal	3.15E-03	1.00E+01	3.15E-04	9.44E-04
Pelagic fish	1.29E-03	1.00E+01	1.29E-04	3.86E-04
Phytoplankton	4.62E-05	1.00E+01	4.62E-06	1.39E-05
Polychaete worm	**8.07E-03**	**1.00E+01**	**8.07E-04**	**2.42E-03**
Reptile	5.17E-03	1.00E+01	5.17E-04	1.55E-03
Sea anemones or true corals - colony	5.09E-03	1.00E+01	5.09E-04	1.53E-03
Sea anemones or true corals - polyp	5.05E-03	1.00E+01	5.05E-04	1.52E-03
Vascular plant	3.97E-03	1.00E+01	3.97E-04	1.19E-03
Zooplankton	9.36E-04	1.00E+01	9.36E-05	2.81E-04

Table A10.5 Breakdown of dose rates to the limiting marine organisms

Radionuclide	Hinkley Point C (Reptile) µGy/h	Hinkley Point Site (Polychaete worm) µGy/h
Ag-110m	2.15E-04	2.65E-05
C-14	**1.01E-03**	5.71E-04
Co-58	5.57E-06	1.21E-05
Co-60	2.39E-05	4.10E-04
Cs-134	3.02E-06	1.93E-03
Cs-137	2.92E-06	**5.04E-03**
H-3	1.29E-05	6.92E-05
I-131	9.88E-11	6.15E-10
Mn-54	6.15E-06	9.89E-07
Ni-63	4.09E-08	1.01E-06
Sb-124	1.40E-06	2.63E-06
Sb-125	7.90E-07	2.28E-06
Te-123m	5.65E-07	3.21E-07
Cr-51	3.19E-07	3.14E-08
S-35	0.00E+00	9.30E-07
Total	**1.28E-03**	**8.07E-03**

Table A10.6 Dose rates to terrestrial organisms due to atmospheric discharges from the proposed Hinkley Point C nuclear power station

Organism	Total Dose Rate [µGy/h]	Screening Value [µGy h-1]	Risk Quotient (expected value)	Risk Quotient (conservative value)
Amphibian	3.34E-03	1.00E+01	3.34E-04	1.00E-03
Bird	3.45E-03	1.00E+01	3.45E-04	1.04E-03
Bird egg	2.37E-03	1.00E+01	2.37E-04	7.11E-04
Detritivorous invertebrate	1.35E-03	1.00E+01	1.35E-04	4.06E-04
Flying insects	1.33E-03	1.00E+01	1.33E-04	3.98E-04
Gastropod	1.35E-03	1.00E+01	1.35E-04	4.05E-04
Grasses & Herbs	2.36E-03	1.00E+01	2.36E-04	7.08E-04
Lichen & bryophytes	2.36E-03	1.00E+01	2.36E-04	7.08E-04
Mammal (Deer)	**3.46E-03**	**1.00E+01**	**3.46E-04**	**1.04E-03**
Mammal (Rat)	3.45E-03	1.00E+01	3.45E-04	1.04E-03
Reptile	3.45E-03	1.00E+01	3.45E-04	1.04E-03
Shrub	2.36E-03	1.00E+01	2.36E-04	7.09E-04
Soil Invertebrate (worm)	1.35E-03	1.00E+01	1.35E-04	4.06E-04
Tree	3.36E-03	1.00E+01	3.36E-04	1.01E-03
Badger	3.42E-03	1.00E+01	3.42E-04	1.03E-03
Bat	3.41E-03	1.00E+01	3.41E-04	1.02E-03
Fox	1.94E-03	1.00E+01	1.94E-04	5.81E-04

Table A10.7 Dose rates to terrestrial organisms due to total discharges to atmosphere from the Hinkley Point site.

Organism	Total Dose Rate [µGy/h]	Screening Value [µGy h-1]	Risk Quotient (expected value)	Risk Quotient (conservative value)
Amphibian	6.35E-03	1.00E+01	6.35E-04	1.90E-03
Bird	6.54E-03	1.00E+01	6.54E-04	1.96E-03
Bird egg	4.56E-03	1.00E+01	4.56E-04	1.37E-03
Detritivorous invertebrate	2.70E-03	1.00E+01	2.70E-04	8.09E-04
Flying insects	2.64E-03	1.00E+01	2.64E-04	7.91E-04
Gastropod	2.68E-03	1.00E+01	2.68E-04	8.05E-04
Grasses & Herbs	5.07E-03	1.00E+01	5.07E-04	1.52E-03
Lichen & bryophytes	5.07E-03	1.00E+01	5.07E-04	1.52E-03
Mammal (Deer)	6.55E-03	1.00E+01	6.55E-04	1.96E-03
Mammal (Rat)	**6.55E-03**	**1.00E+01**	**6.55E-04**	**1.97E-03**
Reptile	6.54E-03	1.00E+01	6.54E-04	1.96E-03
Shrub	5.07E-03	1.00E+01	5.07E-04	1.52E-03
Soil Invertebrate (worm)	2.70E-03	1.00E+01	2.70E-04	8.09E-04
Tree	6.91E-03	1.00E+01	6.91E-04	2.07E-03
Badger	6.49E-03	1.00E+01	6.49E-04	1.95E-03
Bat	6.47E-03	1.00E+01	6.47E-04	1.94E-03
Fox	3.76E-03	1.00E+01	3.76E-04	1.13E-03

Table A10.8 Breakdown of dose rates to the limiting terrestrial organism

Radionuclide	Hinkley Point C (Mammal - deer) µGy/h	Hinkley Point Site (Mammal - rat) µGy/h
Co-58	1.68E-08	4.16E-08
Co-60	1.08E-06	1.59E-05
H-3	4.07E-04	6.78E-04
C-14	**3.04E-03**	**5.59E-03**
Cs-134	1.39E-06	8.96E-07
Cs-137	5.18E-06	3.85E-06
I-131	6.22E-08	2.41E-07
I-133	1.37E-08	2.29E-08
S-35	0.00E+00	2.66E-04
Total	**3.46E-03**	**6.55E-03**

Appendix 11 – Assessment of Doses to People from Sediments Entering a Cut in the Skin.

A11.1 As part of the initial consultation on the Hinkley Point C permit application, a comment was received from one consultee about the dose from ionizing radiation that might be received from exposure to sediments containing artificial radionuclides passing into the blood stream through a wound in the skin.

A11.2 To answer this query, two initial screening assessment has been made assuming 500 mg of sediment carrying radionuclides enters a wound and passes into the blood stream. The assessment adopts the assumption that the entry of radionuclides on sediment is equivalent to an injection of radionuclide into the blood and 100% is absorbed into the blood stream.

A11.3 The first assessment was made using concentrations of radionuclides measured in sediment in the environment. The sediment in the wound is assumed to contain radioactivity levels similar to thos recently seen in the River Parret Estuary and reported in RIFE (Ref A11.1, A11.2, A11.3) (Table A11.1). The measured levels reflect past discharges from the Hinkley Point site, trace levels of radionuclides from past discharges from Sellafield and trace levels of radionuclides from fallout, including Chernobyl.

A11.4 The average concentrations are 27 Bq/kg of Cs-137, 1.3 Bq/kg of Co-60 and 2.5 Bq/kg of Am-241. Levels of Am-241 over the past three years have averaged below the limit of detection. The assessment was made at the average LoD for Am-241 as shown in table A11.2

A11.5 These levels gives radionuclide transfer into the blood stream body as shown in table A11.2. The dose from the transfer of activity into the body was estimated using injection dose factors from Reference A11.4. The assessment outcome shows that the dose could be up to 0.5µSv. The majority of this dose would be from Am-241 asseociated with the sediment.

A11.6 The second assessment was made using predicted concentrations in sediments from expected discharges of radionuclides from the proposed new power station at Hinkley Point. The predicted levels in sediments are shown in Table A11.3. The predicted doses are 0.002 µSv.

References

A11.1 Food Standards Agency and Joint Environment Agencies. Radioactivity in Food and the Environment, 2010 (RIFE-16) (2011).

A11.2 Food Standards Agency and Joint Environment Agencies. Radioactivity in Food and the Environment, 2010 (RIFE-15) (2010).

A11.1 Food Standards Agency and Joint Environment Agencies. Radioactivity in Food and the Environment, 2010 (RIFE-14) (2009).

A11.4 IAEA Safety Methods for Assessing Occupational Radiation Doses Due to Intakes of Radionuclides Safety series 37 (2004)

Table A11.1 Concentrations of radionuclides in sediments (Bq/kg) of the Parrett Estuary

Year	Nuclide		
	Cs-137	Co-60	Am-241
2008	33	<1.0	<4.0
2009	28	<1.5	<1.8
2010	20	<1.3	<1.7
Average	**27**	**1.3**	**2.5**

Table A11.2 Doses from radionuclides transferred from sediment to the blood from a wound

Nuclide	Quantity of sediment entering the body through the wound		Average activity concentrations in sediment	Activity entering the body from a wound with the sediment	Internal dose factor from injection	Dose	
	mg	kg	Bq/kg	Bq	Sv/Bq	Sv	µSv
Cs-137	500	0.0005	27	0.0135	**1.40E-08**	1.89E-10	1.89E-04
Co-60	500	0.0005	1.3	0.00065	**1.90E-08**	1.24E-11	1.24E-05
Am-241	500	0.0005	2.5	0.00125	**4.00E-04**	5.00E-07	0.50
Total			**-**	**-**	**-**	**5.00E-07**	**0.50**

Table A11.3 Doses from radionuclides transferred from sediment to the blood from a wound, from predicted levels in sediment from discharges from the new power station

Nuclide	Mass of sediment entering wound		Predicted activity concentration in sediment	Activity entering the body from a wound with the sediment	Internal dose factor from injection	Dose
	mg	kg	Bq/kg	Bq	Sv/Bq	µSv
C-14	500	0.0005	2.6	1.30E-03	5.00E-10*	6.50E-07
Co-60	500	0.0005	0.08	4.00E-05	1.90E-08	7.60E-07
Cr-51	500	0.0005	0.00002	1.00E-08	5.40E-05+	5.40E-07
Cs-134	500	0.0005	0.003	1.50E-06	1.90E-08	2.85E-08
Cs-137	500	0.0005	0.025	1.25E-05	1.40E-08	1.75E-07
H-3	500	0.0005	3.6	1.80E-03	1.80E-11	3.24E-08
I-131	500	0.0005	0.00000009	4.50E-11	2.20E-08	9.90E-13
Mn-54	500	0.0005	0.0015	7.50E-07	5.40E-05+	4.05E-05
Ni-63	500	0.0005	0.08	4.00E-05	5.40E-05+	2.16E-03
Sb-124	500	0.0005	0.00009	4.50E-08	5.40E-05+	2.43E-06
Sb-125	500	0.0005	0.003	1.50E-06	5.40E-05	8.10E-05
Te-123m	500	0.0005	0.0001	5.00E-08	5.40E-05+	2.70E-06
Total	**-**	**-**	**-**	**-**	**-**	**2.29E-03**

* No injection dose factor available – ingestion dose coefficient used
+ No injection dose factor available – value for Sb-125 used

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