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The AP1000 Nuclear Reactors proposed for Moorside in Cumbria and their Environmental Impact.

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July 2017

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Summary

- Gaseous radioactive emissions from an AP1000 type reactor are expected to be higher than from three out of the five reactor types Westinghouse looked at – despite the fact that you might expect a new reactor design to have lower discharges than existing reactors. They are also much higher than gaseous discharges from the French EPR reactor.

- The Environment Agency is not satisfied that Best Available Techniques have been demonstrated for minimising discharges of all aqueous radioactive wastes.

- The Environment Agency says it is unable to complete its assessment for the OSPAR Treaty to show that aqueous radioactive waste management will ensure that AP1000 discharges to sea will comply with the UK's international obligations under the OSPAR treaty to protect the marine environment of the North-East Atlantic.

- Bearing in mind that NuGen is proposing to build 3 AP1000 reactors at Moorside, the total collective dose for Moorside would be about 40 person Sv per year. By applying the widely used fatal cancer risk factor of 10% per sievert we can calculate around 4 deaths will occur somewhere in the world for every year the station operates. Over 60 years the total would be 240 deaths.

- Moorside would produce extremely high levels of radioactive spent fuel. In the year 2200 its spent fuel arisings would amount to 85% of the radioactivity contained in all existing legacy wastes from the UK's nuclear power industry.

- The requirement for 'Best Available Techniques' (and clean technology) for producing electricity should rule out building new electricity generating stations which produce such highly dangerous wastes. Especially as less expensive, quicker and safer alternatives are available which don't produce such wastes.

Preface

The nuclear regulators – the Office for Nuclear Regulation (ONR) and Environment Agency – have been carrying out a new process called 'Generic Design Assessment' (GDA), which looks at the safety, security and environmental implications of new reactor designs before an application is made to build that design at a particular site.

The AP1000– which is the type of reactor currently proposed for Moorside – was one of four designs originally submitted to GDA process. In March 2008, the regulators announced they had found no shortfalls – in terms of safety, security or the environment – that would prevent any of the designs from ultimately being constructed on licensed sites in the UK.

Then Atomic Energy of Canada Ltd pulled its ACR1000 design out of the process, and General Electric and Hitachi Ltd. asked for a temporary halt to the assessment of its Economic Simplified Boiling Water Reactor (ESBWR). This left just the EPR and AP1000 designs.

In June 2010, the Environment Agency released its assessments of the two new reactor designs – EPRs and AP1000s – for consultation. These focused on the waste which would be produced by the reactors and discharges of radioactive waste into the atmosphere and marine environment.

By August 2010, it started to become clear that the ONR (formerly Nuclear Installations Inspectorate) might only be able to issue "interim" approvals for the Areva EPR and Westinghouse AP1000 reactor designs at the end of the generic design assessment (GDA) in June 2011. Construction could only occur after any outstanding "GDA issues" had been resolved.

On 14th December 2011 the Regulators granted interim Design Acceptance Confirmations(iDAC) and interim Statements of Design Acceptability (iSoDA) for the UK EPR and iDAC and iSODA for the AP1000 reactor designs. The Regulators also confirmed that they were satisfied with how EDF and Westinghouse planned to resolve the GDA issues identified during the process.

On 14th December 2011, the regulators also published reports for each design summarising the basis of their decision, together with their technical assessment reports as well as documents explaining how the designers plan to resolve issues identified in a report written by the UK's chief inspector of nuclear installations, Mike Weightman, on the Fukushima accident in Japan. (1)

ONR's interim approval for the two reactor-types came with a long list of caveats –Westinghouse's iDAC for its UK AP1000 contained 51 GDA Issues. At this point Westinghouse decided to request a pause in the GDA process for the AP1000 pending customer input to finalizing it. (2)

In January 2014, Westinghouse became a part of the NuGen consortium when parent company Toshiba bought a 60% stake in Nugen. In August 2014, Westinghouse recommenced the GDA in order to address the 51 outstanding GDA issues which had to be resolved before ONR and EA would consider granting a DAC and SoDA respectively. Then in March 2017, ONR and the Environment Agency granted a Design Acceptance Confirmation (DAC) and Statement of Design Acceptability (SoDA) for the AP1000, despite the fact that just a few days earlier Westinghouse had declared itself bankrupt.

In November 2016, Radiation Free Lakeland issued a report on the AP1000 Reactor Design which draws mainly on the work of the US based Fairewinds Associates, and raises some serious concerns about the safety of the reactor design.

This current report now focuses on the environmental and health implications of the AP1000 design and looks in more detail at the Statement of Design Acceptability issued by the Environment Agency, rather than the Design Acceptance Confirmation issued by the Office for Nuclear Regulation (ONR).

Introduction

The role of the Environment Agency (EA) is to ensure the impact of radioactive wastes on the environment is minimised. (3) Research from around the globe, for instance the KIKK Study from Germany, has shown that there is unquestionably a strong link between proximity to nuclear power stations and childhood cancer. (4) Independent consultant on radioactivity in the environment, Dr Ian Fairlie says:

"I can think of no other area of toxicology (eg asbestos, lead, smoking) with so many studies, and with such clear associations as those between NPPs and child leukemias."

This means that if cleaner ways to generate electricity are available which do not discharge radioactive wastes into our atmosphere and seas these should be used in preference. The evidence is stacking up to show that, in the words of Professor Keith Barnham, author of 'The Burning Answer:

A user's guide to the solar revolution' the UK "*…doesn't need a new generation of expensive nuclear reactors or a dash for shale gas to keep the lights on. An all-renewable electricity supply can provide energy security*." (5)

The nuclear industry has yet to provide a credible scientific case for nuclear waste 'disposal'. Yet the EA proposes postponing this critical issue until some unspecified time in the future. A deep geological disposal facility (GDF) is not expected to be ready to receive waste until around 2040 at the earliest. Waste from new reactors like the ones proposed for Moorside is not expected to be emplaced in the GDF until after all our existing legacy waste has been emplaced which is expected to take around 90 years. So emplacement of spent fuel from the UK's proposed new reactors could not begin until at least 2130. (6)

In addition, the high burn-up fuel expected to be used in AP1000 reactors could require up to 100 years of cooling before it will be cool enough to be emplaced in a GDF. (7) So if it were assumed that Moorside comes on stream around 2030, with an expected reactor life of 60 years, this means some spent fuel could still be in storage on site in 2190. The amount of radioactivity in the spent fuel from Moorside alone in the year 2200 would amount to a whopping 85% of the radioactivity contained in the nuclear wastes which the UK Government has already created. (8)

Gaseous Discharges

According to the Environment Agency's AP1000 Assessment Report on gaseous radioactive waste disposal and limits published in 2011 (9), it is expected that each year the proposed AP1000-type reactors would emit to air 1800 gigabecquerels[1] (GBq) of tritium; 606 GBq of carbon-14; 8047 GBq of radioactive noble gases and 210 MBq of radio-iodines. These are large amounts of radioactivity when compared with the French EPR proposed for Hinkley Point C. The table below compares gaseous emissions from the AP1000 with the EPR.

Radionuclide	**AP1000**	**EPR** (10)
Tritium	1800GBq	500GBq
Carbon-14	606GBq	350GBq
Radioactive Noble Gases	8047GBq	800GBq
Radio-iodines	210MBq	50MBq

Table One: Predicted Annual Gaseous Emissions.

Even Westinghouse's own comparison of total predicted gaseous radioactive emissions from the AP1000 with published emissions from other nuclear reactor types shows these have lower discharges. Westinghouse data show the predicted AP1000 annual discharges are lower than those from Cook 1 and Sizewell B, but higher than those from South Texas 1, Braidwood 1 and Vogtle 1. (11)

The Committee on Medical Aspects of Radiation in the Environment (COMARE) recommended that as:
"*…part of a new generation of plants, it might be expected that discharges would be lower than existing facilities, rather than 'within the range of historic discharges' which seems to be the criterion being applied by EA*." (12)

[1] A becquerel (Bq) is a unit of radioactivity: it means one nuclear disintegration (or decay) per second. Each disintegration results in the emission of radiation. One GBq means one billion disintegrations per second, and one MBq means one million disintegrations per second.

The table below based on a table on page 8 of the EA’s Assessment Report on Gaseous Radioactive waste Disposal and limits shows that this is far from the case, and that most of the individual radionuclides in gaseous emissions will be at the high end of the range from existing reactors. From the point of view of residents living in the vicinity of Moorside it also has to be borne in mind that NuGen intends to build 3 AP1000 reactors on the site so the actual discharges will be tripled.

Radionuclides or group of radionuclides	AP1000 predicted annual discharge	Range for 1000 MWe station
Tritium GBq	1800	100 - 3600
Carbon-14 GBq	606	40 - 530
Noble gases GBq	8047	100 - 10000
Iodine-131 MBq	210	<1 - 2000
Other radionuclides not specifically limited MBq	13.44	<1 - 1000

Table Two: Comparison of gaseous emissions from AP1000 reactors with those from other stations.

Radiation Risks

In the assessment of radiation risks to local people, aerial emissions from nuclear reactors are more important than liquid discharges for two reasons. First, the key parameter in estimating radiation doses to local people from radioactive isotopes is their concentration in environmental materials. Contrary to popular perceptions, air emissions result in much higher environmental concentrations than sea discharges, because water is much more effective than air at diluting contaminants. This is not to accept that dilution is the solution to pollution: it isn’t. It merely reflects the fact of current (ill-advised) methods of disposing nuclear wastes. (13)

Second, individual and collective doses from aerial emissions are much larger than from sea discharges. People living near Nuclear Power Plants (NPPs) receive doses from eating contaminated food, drinking contaminated water, breathing contaminated air, and skin absorption (especially of tritiated water vapour).

For example, the contamination of local foods occurs by air emissions - particularly tritium and carbon-14 emissions. The only exception is contaminated sea foods. But these concentrations are very low. People who elect to live near discharge sites can largely avoid eating contaminated sea foods but, they cannot avoid breathing contaminated air from aerial emissions. It is for these reasons that NPP operators go to considerable lengths to divert radioactive releases away from aerial emissions towards sea discharges. The tritium discharges to sea for example from the AP1000 type of reactor are ~20 times larger than tritium air emissions.

Best Available Techniques

Despite the fact that the Agency is not completely satisfied with efforts to minimise emissions of tritium and carbon-14, it concludes that, overall, the AP1000 utilises the best available techniques (BAT) to minimise discharges of gaseous radioactive waste. Despite the larger gaseous emissions from the AP1000 compared with the EPR and other reactors, the EA concludes that the gaseous discharges from the AP1000 should not exceed those of comparable power stations across the world. It does, however, highlight that the proposed discharge of carbon-14 in particular is slightly higher than the range for other European PWRs.

It's also worth noting that COMARE has highlighted the recent report of the Advisory Group on Ionising Radiation (AGIR) (November 2007) suggests that current dose estimates for tritiated water are too low.

Radionuclides	**Westinghouse BAT**	**EA View on BAT**	**Proposed Annual Limit (per reactor)**	**Critical Group Dose**
Tritium	Using a condenser to divert tritiated water vapour from the gaseous waste stream into the liquid waste where the impacts are reduced.	Operational techniques to minimise tritium discharges will be a matter for future operators of the AP1000. EA will seek assurances that hand over between Westinghouse and future operators will address this matter.	1,800GBq	*Local resident family comprises infants, children and adults who live 100 m from the aerial discharge point 0.086 $\mu Sv\ y^{-1}$
Carbon-14	Direct discharge without abatement	Will look for future operators to consider this in their periodic BAT reviews. Developing technology needs to be kept under review.	606 GBq	Local resident family – 3.3 $\mu Sv\ y^{-1}$ COMARE notes that C-14 dominates the dose impact.
Strontium-90	High Efficienct Particulate Air Filter (HEP filtration			Local resident family 0.000096 $\mu Sv\ y\text{-}^{1}$.
Noble Gases	Carbon beds to delay the discharge of noble gases and, therefore, reduce discharged radioactivity through radioactive decay	Techniques considered by Westinghouse for the abatement of xenon & krypton are BAT Operators will need to ensure that any fuel used in their reactors meets quality expectations and that its design represents BAT.	8047 GBq	Local resident family argon-41 0.029 $\mu Sv\ y^{-1}$. krypton-85 0.00137 $\mu Sv\ y^{-1}$ xenon-133 is 0.00064 $\mu Sv\ y^{-1}$
Iodine radionuclides	Westinghouse claims that iodine radionuclides will be delayed by the carbon delay beds in the WGS, however they do not provide an estimate of reduction in discharges as a result of delay.	Westinghouse has demonstrated that BAT	0.56GBq	local resident family 0.13μSvy^{-1}

Other radionuclides	Westinghouse claims that using carbon delay beds and HEPA filtration in the ventilation systems is BAT.	EA agrees	13.44MBq	local resident family 0.0028 μSv y^{-1} for Cobolt-60; 0.00013 μSv y-1 Caesium-137

Table Three: Best Available Techniques for Gaseous Radioactive Discharges from AP1000 reactors

Tritium

The largest aerial emissions are of tritium in the form of tritiated water vapour, i.e. radioactive water. In recent years, many official reports have discussed the hazards of tritium - the radioactive form of hydrogen. In the past, this isotope had been regarded as being only "weakly" radiotoxic: this view is now changing among governments and international agencies concerned with radiation exposures. For example, recent reports have been published by radiation safety agencies in the UK, Canada and France. (14) These reports draw attention to the hazardous properties of tritium including its extremely rapid distribution in the environment, its heterogeneous distribution within tissues, its ability to bind with organic molecules resulting in higher doses, and its high biological effectiveness compared with gamma radiation.

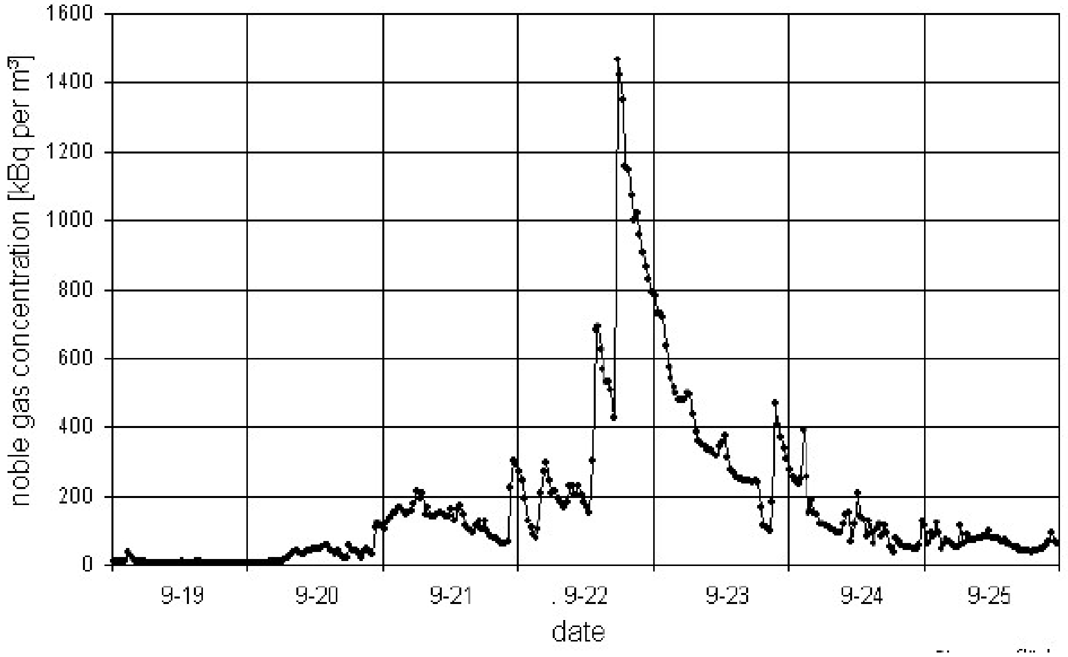
Over 60 epidemiological studies world-wide have examined cancer incidences in children near nuclear power plants (NPPs): most of them indicate leukemia increases. These include the 2008 KiKK study commissioned by the German Government which found relative risks (RR) of 1.6 in total cancers and 2.2 in leukemias among infants living within 5 km of all German NPPs. The KiKK study has retriggered the debate as to the cause(s) of these increased cancers.

Although, several studies in the late 1980s and early 1990s revealed increased incidences of childhood leukemia near UK nuclear facilities, official estimated doses from released nuclides suggest these would have been too low by 2 to 3 orders of magnitude to explain the increased leukaemias.

A suggested hypothesis is that the increased cancers arise from radiation exposures to pregnant women near NPPs. However any theory has to account for the >10,000 fold discrepancy between official dose estimates from NPP emissions and observed increased risks. An explanation may be that doses from spikes in NPP radionuclide emissions are significantly larger than those estimated by official models which are diluted through the use of annual averages. In addition, risks to embryos/fetuses are greater than those to adults, and haematopoietic tissues (stem cells that create other blood cells) appear more radiosensitive in embryos/fetuses than in newborn babies. The product of possible increased doses and possible increased risks per dose may provide an explanation. (15)

The evidence for radionuclide spikes during refuelling was revealed for the first time in November 2011. Published data from the Gundremmingen NPP in Southern Germany showed that very large spikes of radioactive noble gases were released during refuelling than were emitted during normal power operation throughout the rest of the year. (See graph below). According to the International Physicians for the Prevention of Nuclear War (IPPNW) in Germany, the normal emission concentration during the rest of the year is about $3kBq/m^3$ but during inspection/refuelling episodes this concentration increased to ~$700kBq/m^3$ with a peak of $1,470kBq/m^3$. Nuclide emissions during the period of refuelling were about 65% of total annual releases. Noble gas concentrations can be used as a proxy for other gaseous emissions, including tritium, C-14 and iodine releases. (16)

Graph 1. Noble gas concentrations from Gundremmingen C. 1/2 hourly values. Sept 19 to 25



In order to refuel, the pressure vessels of all nuclear reactors are opened up about once a year. This releases large volumes of radioactive gases and vapours, including noble gases, tritium, carbon-14 and iodine-131, to the environment. Until now, these nuclide releases had been published only as annual data throughout the world. After repeated requests by the SPD-Green Party Government in Bavaria, half-hourly data were made available for scientific evaluation for the first time. Brief exposures to high concentrations are more hazardous to residents near NPPs than chronic exposures to low concentrations. Exposures to high concentrations result in higher internal doses, so these nuclide spikes during re-fuelling could go a long way to explaining the increased incidences of child leukaemias near NPPs shown by the KiKK findings.

Kinlen Debunked

In September 2016, COMARE published a report on child cancers near nuclear power stations. (17) The report downplays radioactive releases as an explanation for the nearby raised levels of cancers. Instead it champions the Kinlen hypothesis. Since 1988, Professor Kinlen has been suggesting that increases in childhood cancers near nuclear facilities are due to an infective, perhaps viral, agent arising from the influx of new workers to rural areas. But most scientists throughout the world discredit this theory because of its myriad problems and inconsistencies. First, the idea leads to the expectation of a sharp rise in leukaemia incidence, followed by a decline as the situation settles down. However at Dounreay and Sellafield most of the leukemias arose several decades after the population influxes. In addition, increased leukemias and non Hodgkin lymphoma (NHLs) continued long after the influxes had stopped and indeed were STILL occurring as recently measured in the 2000s, and are probably still arising today, were the Government to release all the relevant and most recent data.

Second, for the hypothesis to be true the leukaemias should occur in the indigenous population and not in the migrants. In fact, at Sellafield, the reverse was mainly the case.

Third, the theory does not explain why leukemias have arisen near nuclear facilities without population influxes, e.g. Aldermaston and other UK nuclear facilities and hundreds of reactors in other countries.

Fourth, and most tellingly, no infective agent or virus has ever been found at UK facilities despite much research over many decades. It does not seem a wise scientific policy to try to reinstate this old and discredited infective theory for leukemias and lymphomas. (18)

COMARE's Chairman Professor Alex Elliott expressed the view that "*according to independent science, the discharges from Sellafield* ***are*** *much too low to be the cause of leukaemia".* In contrast German Federal Government radiation expert Dr. Hoffmann's says COMARE scientists are simply wrong: "*There is little evidence of the population mixing hypothesis and there is absolutely no evidence of the virus hypothesis. There is neither a virus nor are there antibodies, in other words, forget this whole infection hypothesis. These hypotheses have arisen primarily to explain away any risk of radiation.*" (19)

Liquid Discharges

During the initial EA consultation exercise held in 2010 (20) many respondents expressed concern about the UK's lack of compliance with its obligations under the OSPAR Convention on the Protection of the Marine Environment of the North East Atlantic. EA says its conclusions were changed as a result to reflect this concern. (21)

Under the treaty the UK Government is committed to:

"*...progressive and substantial reductions of discharges, emissions and losses of radioactive substances, with the ultimate aim of [achieving] concentrations in the environment near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances."* [by 2020].

A Statutory Guidance to the Environment Agency sets out the Government's Guidance on Radioactive Discharges. This highlights the importance of the use of Best Available Techniques (BAT) in the optimisation of doses and the setting of discharge limits. (22)

The application of "*best available techniques and best environmental practice, including, where appropriate, clean technology*" is one of the Guiding Principles of the OSPAR Strategy with regard to radioactive substances. (23)

"Clean Technology" should not, in the view of many environmental commentators, involve end-of-pipe filters to remove pollution from discharges to the environment – it should be a technique which produces no pollution to begin with. The requirement for 'Best Available Techniques' (and clean technology) for producing electricity should rule out the possibility of building new electricity generating stations which produce highly dangerous wastes when alternative ways of generating electricity are available which don't produce such wastes. (24)

The EA's Final Assessment Report on Aqueous Radioactive Waste Disposal and Limits, published in 2011, makes almost no mention of the OSPAR requirement for progressive and substantial reductions in discharges of radioactive substances and achieving close to zero concentrations in the environment for artificial radioactive substances by 2020. It simply says "*the impact of radioactive discharges to the marine environment from the AP1000 design will be less than the currently operating nuclear power plants in the UK, and as these are replaced we anticipate a reduction in the total UK discharges*." (25)

Comparison of liquid discharges from AP1000s compared with other reactors.

According to the EA's Final Assessment Report on Aqueous Radioactive Waste Disposal and Limits the emissions detailed in the table below can be expected.

Radionuclides or group of radionuclides	AP1000 predicted annual discharge	Range for 1000 MWe station
Tritium (TBq)	33.4	2 – 30
Carbon-14 (GBq)	3.3	3 - 45
Iodine radionuclides MBq	15	10 - 30
Other radionuclides not specifically limited (GBq)	2.7	<1 - 15

Table Four: Comparison of liquid emissions from AP1000 reactors with those from other stations.

Unlike gaseous discharges, Westinghouse data show the predicted AP1000 annual discharges output are lower than those from Cook 1 and Sizewell B, South Texas 1, Braidwood 1 and Vogtle 1. Comparison with the EPR is shown in the table below.

	AP1000	EPR
Tritium	33,400GBq	52,000GBq
Carbon-14	3.3GBq	23GBq
Iodine Radionuclides (MBq)	15MBq	7MBq
Other radionuclides	2.7GBq	0.6GBq

Table Five: Predicted Annual Liquid Emissions.

However, it is worth noting that NuGen is proposing to build three AP1000 reactors at Moorside with a total capacity of 3.4GW compared with EDF Energy's plans for Hinkley Point C where only two EPR reactors are proposed.

Best Available Techniques

EA says it requires Westinghouse to demonstrate that the AP1000 uses Best Available Techniques (BAT) from the initial generation of radioactivity to final discharge. However the EA reports that **it is not satisfied** that BAT has been demonstrated for minimising discharges of all aqueous radioactive wastes. The AP1000 design allows for additional techniques to be installed so the EA does not consider this a fundamental GDA Issue (i.e. an issue which has to be resolved before the AP1000 can be issued with a Statement of Design Acceptability.) However, it is instead described as "*an assessment finding*" which means future operators will need to demonstrate that BAT for their location is used to minimise discharges of aqueous radioactive wastes. In particular the provision of evaporation may be a BAT requirement. EA says "*the use of an evaporator must be considered as an option for aqueous wastes to minimise the discharge of radioactivity from the site so that exposures of any member of the public and the population as a whole are kept as low as reasonably achievable (ALARA) and to protect the environment.*"

EA also says it was unable to complete its OSPAR assessment because the AP1000 design does not include treatment options for certain aqueous wastes that are incompatible with the design standard of filtration and ion exchange. It will be for future operators to show on a site-specific basis that their proposals for aqueous radioactive waste management will ensure that their discharges to the sea will comply with the UK obligations under OSPAR. The EA concludes that the AP1000 utilises the best available techniques (BAT) to minimise **most** (but not all) discharges of aqueous radioactive waste: (emphasis added) (26)

EA says that, at this time, direct discharge of tritium to the sea is BAT for the AP1000. Westinghouse estimates that the radiological impact from the representative 12-month plant discharge of tritium to sea will result in a dose to the local fisherman family, selected to represent the exposure pathways associated with discharges from the AP1000 to the coastal environment, of 0.024 μSv y-1.

The fisherman and his family are assumed to spend time on intertidal sediments in the area and consume high levels of locally caught fish and shellfish as well as smaller amounts of locally produced fruit and vegetables from local sources up to 500 m from the aerial discharge point. According to EA this group live far enough from the site not to be exposed to direct radiation from atmospheric releases

Details of some of the discussions between EA and Westinghouse about the Best Available Technique for reducing discharges of other radionuclides are given in the table below.

Radionuclide	**Westinghouse BAT**	**EA view on BAT**	**Proposed Annual Limit (per year/per reactor)**	**Critical Group Dose**
Tritium	Direct Discharge	accepted	60,000 GBq	Fisherman family 0.024 μSv y^{-1}
Carbon-14	Direct Discharge	Now considers that other options for carbon-14 abatement are unlikely to be available in the short term and have not carried forward as an assessment finding for GDA.	7 GBq	Fisherman family 1.6 μSv y^{-1}.
Iodine	Westinghouse has provided little detail on the techniques for abatement of iodine	Using demineralisers may contribute to reducing the amount of iodine radionuclides	No specific limit proposed	
Strontium-90	Ion Exchange	Considers the optioneering study does not contain enough detail to identify the best option.	0.0005 GBq	Fisherman family 0.0000015 μSv y-^{1}.
Caesium-137	Demineralisation	Westinghouse has demonstrated that BAT	0.05 GBq	Fisherman family 0.0034 μSv y^{-1}.
Plutonium-241	Using filtration and ion exchange and using the fuel storage pool cooling and clean up system along with monitoring of discharges is BAT for plutonium-241	We do not consider that monitoring of discharges is an abatement technique, however we recognise that filtration / ion exchange and using the fuel storage pool cooling and clean up system will provide abatement for plutonium-241.	0.0002 GBq	Fisherman family 0.0000027 μSv $y^{-1.}$

Table Six Best Available Techniques for Liquid Radioactive Discharges from AP1000 reactors

Fate and Behaviour of Radioactivity in the Sea

The dominant historical justification for the discharge of liquid radioactive wastes to sea since the commencement of the UK military and civil nuclear programmes is the hypothesis that the wastes will inevitably be dispersed and diluted throughout the water column and the marine environment. The idea was that long lived, non-soluble nuclides such as the alpha emitting actinides like plutonium (Pu) and americium (Am), would become adsorbed to the surface of sedimentary particles in the marine water column, sink to the sea bed and remain permanently bound and immobilised in seabed sedimentary deposits close to the point of discharge. In contrast, soluble radionuclides such as caesium and tritium would dilute and disperse through the water column until they reached "background" concentrations.

However, scientific ignorance of the subject was so great that eventually the nuclear industry was forced to admit that sea disposal, particularly in the Irish Sea, had really been an enormous experiment, but an unfortunate one. In fact, both soluble and insoluble nuclides can travel for at least several hundreds of kilometres and both are available for transport out of the sea area of their initial discharge. Deposition of suspended sediments and their associated radioactivity occurs (under the influence of a range of mechanisms) into estuarine and coastal sub tidal sediments, estuarine and coastal fringing inter-tidal mud and salt flats and offshore sub-tidal sediment deposits.

The evolving evidence now conclusively demonstrates that the original proposed model was certainly incorrect (with respect to non-soluble nuclides) and that there were, in fact several mechanisms by which non-soluble radioactive wastes discharged to sea did not remain permanently bound and immobilised to the sea bed sediments. Studies have demonstrated increased concentrations of non-soluble radionuclides in marine aerosols resulting in their transfer from sea to land.

The evidence also suggests mechanisms by which soluble radionuclides can re-concentrate in the marine environment. Soluble radionuclides such as caesium 137 are enriched in wet marine sediments throughout UK coastal and inshore waters (relative to ambient concentrations). So it is clear that re-concentration mechanisms exist for soluble radionuclides in the marine environment. The original simple hypothesis that discharged liquid radioactivity would dilute and disperse until it reaches "background" concentration is now shown to be highly simplistic. (27)

Conclusion on liquid discharges

So, the EA has been unable to complete its OSPAR assessment; the AP1000 does not currently utilise the best available techniques (BAT) to minimise all discharges of aqueous radioactive waste; and despite being a new generation of reactor, discharges are not lower than existing facilities, but are within the range of historic discharges.

Critical Group Doses

The EA has assessed that the total impact of radioactive discharges (including gaseous discharges) from the AP1000 to the most exposed person to be 8μSv y^{-1}. The contribution from aqueous discharges is less than 1 μSv y^{-1} illustrating the point made earlier that aerial emissions are more important than liquid discharges. The critical group dose from aerial emissions is dominated by carbon-14.

These numbers compare with the radiological dose limits to members of the public of 1,000μSv y^{-1} with dose from any single new source not to exceed 300μSv y^{-1}. The former Health Protection Agency (now Public Health England) had advised the UK Government to select a constraint value of less than 150 μSv (0.15mSv) per year for members of the public for new nuclear power stations. (28)

The UK Strategy for Radioactive Discharges 2001-2020 included an aim to progressively reduce human exposure to ionising radiation arising from radioactive discharges, so that a representative member of a critical group of the general public will be exposed to an estimated mean dose of no more than 20μSv y^{-1} from liquid radioactive discharges to the marine environment made from 2020 onwards. (29) The 20μSv y^{-1} figure was subsequently dropped from the 2009 updated strategy without explanation, but it still aims for "*progressive reductions in human exposures to ionising radiation resulting from radioactive discharges*." (30)

Given that the Moorside proposal is to build three AP1000 reactors, each potentially giving a critical group dose of 8μSv y^{-1}, we could start to see this 20 μSv y^{-1} figure breached albeit from a combination of liquid and gaseous discharges. In addition, the Moorside development would be adjacent to Sellafield and local people would be exposed to both. (31) According to the Preliminary Environmental Information report (para 21.4.9) the predicted prospective dose to the critical group including the contribution from direct exposure, is 13 μSv/y. These prospective dose assessments relate to a single reactor on a generic site in the UK, which emphasises the point that with three reactors the 20 μSv y^{-1} figure could be breached. (32)

Collective Doses

In 1991, the International Commission on Radiological Protection (ICRP) adopted a linear, no-threshold model for radiation's effects. Thus no dose of radiation, no matter how small is without some added level of risk. Collective dose is an important measure of the total exposure of a population over time from a given release of radionuclides and it is an indicator of total detriment to health. The collective dose is, to a first approximation, the average individual dose in an exposed population multiplied by the size of the population. Collective dose represents an attempt to quantify the radiological impact of radioactive discharges to populations larger than the critical group. Collective doses are measured in person-sieverts (person Sv).

Collective doses are sometimes calculated for UK or European populations, but for radionuclides which have long half-lives and become globally dispersed, including tritium, carbon-14, krypton-85 and iodine-129, it is internationally accepted practice to calculate their global collective doses. Calculating the global collective dose can also be seen as morally important when one considers the fact that no-one outside the UK is receiving a countervailing benefit from discharges.

As with critical group doses, estimates of the risks associated with a particular collective dose are fraught with uncertainties and unknowns. The behaviour of radionuclides in the global environment must be predicted over long time-scales and the computer models used to do so are unlikely to be validated by comparison with sufficient data. Future human behaviour and the behaviour of each radionuclide in the human body must also be predicted and estimation of the dose-risk factor in itself involves a large number of assumptions and several models all with uncertainties attached which have to be multiplied together.

Such risks from collective doses are underestimates as they do not include detriental human health effects other than fatal cancers (e,g. skin cancers) and genetic effects.

Of course the above dose/risk estimates in this report neglect detriment to ecosystems, organisms and species.

It is sometimes argued that collective doses should be truncated to 500 years, because after that the uncertainty becomes too great. However, just because there is uncertainty does not seem to be a good enough reason to assign a zero risk.

To convert from collective doses to fatal cancers, the ICRP's absolute fatal cancer risk of 10% per Sv can be used, although some analysts apply a dose and dose rate reduction factor (DDREF) which reduces the number of estimated fatal cancers in Europe by a factor of 2, and in the US by 1.5. However, as pointed out by Beyea (2012) many epidemiology studies offer little support for the use of such a factor, certainly for solid cancers (Little et al, 2008). Also, the recent WHO (2013) report on risks from Fukushima recommends that a DDREF should not be used for longer term exposures. (33)

The EA reports that its independent assessment of collective doses calculated collective doses to be 12.2 to 12.6 person Sv per year of discharge for atmospheric discharges and 0.052 to 0.054 person Sv per year of discharge for liquid discharges which are essentially equivalent to those calculated by Westinghouse. However the truncation periods for these estimates are not cited.

The radiation protection community is usually reluctant to translate collective dose into numbers of deaths. This seems to stem from the Greenpeace campaign during the THORP public consultation in 1993-4 when it was argued that THORP would cause 600 deaths (calculated using a 5% risk factor). But Sumner and Fairlie have stated that radiation protection should be about protecting people, not the industry from criticism. (34) Bearing in mind that NuGen is proposing to build 3 AP1000 reactors at Moorside, the total collective dose for Moorside would be in the region of 40 person Sv per year of discharge. By applying the risk factor of 10% per sievert we can calculate that this means there will be around 4 deaths somewhere in the world for every year the station operates. Over 60 years, the total would be 240 deaths.

Uncertainties

There are many uncertainties in current estimates of radiation doses and risks and larger uncertainties exist with internal radiation.[2] These arise mainly from the many steps used to derive doses, and partly from lack of statistical precision in deriving risks from epidemiology studies. The size of these uncertainties has been estimated by a number of expert dosimetrists: for some nuclides these are very large. A report by the Committee Examining Radiation Risks of Internal Emitters (CERRIE) recommended that uncertainties should be acknowledged and dealt with by the government. Its parent committee, the Committee on Medical Aspects of Radiation in the Environment COMARE, backed these findings. (35)

A 2001 Consultation Paper from the Department for Environment Food and Rural Affairs summed up the view which prevailed at the time:

[2] The following sequential stages are used for the estimation of fatal cancer risks from internal emitters:

(a) **biokinetic models** to estimate radionuclide concentrations within organs/tissues;

(b) **dosimetric models** to estimate absorbed dose in organs/tissues per unit concentration of each nuclide, ie dose coefficients derived principally from Specific Effective Energies (SEEs);

(c) weighting of absorbed dose by **radiation weighting factors (w_R)** to take account of the biological damage from each type of radiation. These are estimated from experimentally-derived RBEs;

(d) weighting of equivalent dose (in sieverts) in each organ/tissue by **tissue weighting factors (w_T)** summed to obtain whole-body effective doses; and

(e) derivation of **fatal cancer and other risks** (per Sv) from epidemiological studies, predominantly from Japanese bomb survivors.

The threefold uncertainties (ie arising from RBEs, dosimetric models, and risk estimates) mean that the uncertainties in dose coefficients from internal emitters can be very large in particular instances. Such large uncertainties have implications for radiation protection practices and procedures, especially (but not only) in assessing doses to individuals

"*The unnecessary introduction of radioactivity into the environment is undesirable, even at levels where the doses to both humans and non-human species are low, and on the basis of current knowledge are unlikely to cause harm*" (36)

Radioactive Waste Volume

The nuclear industry and the government repeatedly claim that the volume of nuclear waste produced by new reactors will be small, approximately 10% of the volume of existing wastes; implying this additional amount will not make a significant difference to finding an underground dump for the wastes the UK's nuclear industry has already created. The use of volume as a measure of the impact of radioactive waste is, however, highly misleading. (37)

Volume is not the correct measure to use to assess the likely impact of wastes and spent fuel from a new reactor programme, in terms of its management and disposal. The 'high burn-up fuel' which Moorside is expected to use will be much more radioactive than the spent fuel produced by existing reactors like Heysham 1 and 2. So rather than using volume as a yardstick, the Bq amounts of radioactivity in the waste, (which in turn affects how much space will be required in a GDF), is a much more appropriate way of measuring the impact of nuclear waste from new reactors.

According to Radioactive Waste Management Ltd, the radioactivity from existing waste (i.e. not including new reactors) is expected to be 4,770,000 terabecquerels (TBq) in the year 2200.

It would be interesting to see how much the mooted Moorside reactors would add to this pile. We can calculate this as we know the radioactivity of spent fuel alone (not including other types of waste) from a 16GW programme of new reactors would be around 19,000,000 TB of which Moorside would generate 3.4/16 x 19,000,000 = 4,037,500 TBq. This is about 85% of the radioactivity in existing nuclear wastes. (38)

The Government expects spent fuel from the proposed new generation of reactors to be stored not reprocessed. In fact the Thermal Oxide Reprocessing Plant (THORP) at Sellafield which reprocesses the spent fuel from Heysham is due to close in 2018, and there are no plans to replace it. Instead spent fuel is expected to be emplaced between 200 and 1000 metres underground in a Geological Disposal Facility (GDF) –a site for which has still to be found. A GDF is not expected to be ready to receive such wastes until around 2040.

Waste from new reactors like Moorside is not expected to be emplaced in the GDF until after all the government's existing waste has been emplaced which is expected to take around 90 years – around 2130. (39) This means that spent fuel from Moorside could remain on the site for at least the next 100 years. The other factor which needs to be taken into account is that Moorside is expected to use high-burn up fuel which could require up to 100 years of cooling before it will be cool enough to be emplaced in a GDF. (40) So assuming Moorside comes on stream around 2030, although spent fuel might start to be emplaced in 2130, as the reactors are expected to have a life of 60 years, there may be some spent fuel still stored in Cumbria up until about 2190. (NuGen's Preliminary Environment Information Report says that storage of some radioactive wastes on site will continue until at least 2150. (41))

The potential impact of the disposal of AP1000 spent fuel on the size of the geological disposal facility has been assessed. The area required represents approximately 6% of the area required for legacy HLW and spent fuel per AP1000 reactor, so approximately 18% of the space will be required for the 3 AP1000 reactors proposed for Moorside. (42)

In 2009 RWMB (now RWM Ltd) carried out a Disposability Assessment for Westinghouse. This assumed that all fuel elements will be stored for 90 years between discharge from the reactor and emplacement in the GDF. So whilst spent fuel may be cool enough to start burying in 2120, the GDF might not be available to accept spent fuel from the AP1000 fleet as soon as the heat generation reaches an acceptable level.

The EA says an AP1000 operator will need

- to assure ONR that storage will be safe for the lengthy durations envisaged, and
- to demonstrate to the EA that the storage conditions and fuel characteristics are such that disposability of the fuel will not degrade to an unacceptable degree during the period of storage.

The EA Assessment concludes that the AP1000 is not expected to produce ILW or spent fuel for which there is no foreseeable disposal route. However, the EA says it will need to see more definitive assessments to confirm

- how the ILW and spent fuel will be conditioned for disposal,
- that the selected conditioning methods represent the application of BAT, and
- that in their conditioned forms the ILW and spent fuel will continue to be disposable. (43)

Spent Fuel Management

The strategy proposed by Westinghouse for managing spent fuel following its removal from the reactor, is to transfer spent fuel to the spent fuel pool for storage and initial cooling for some years, although the period of cooling is currently under review and may be reduced. The fuel is then proposed to be transferred to an interim storage facility (a dry interim store is proposed as a reference case for potential operators) until such time a geological disposal facility becomes available for direct disposal. (44)

Next Steps

NuGen's latest consultation document (45) states that the Company is proposing to submit its application to the Planning Inspectorate for a Development Consent Order (DCO) for Moorside in Quarter 2 of 2017. This now looks destined to be delayed until at least the end of 2017. (46) The Stage 2 public consultation finished at the end of July 2016, but there has still been no feedback report despite the fact that it was promised for Autumn 2016. (47)

Plans to build the £2.8bn power transmission line connecting Moorside have been put on hold by National Grid following the news that NuGen has been forced to undertake a *'strategic review of options'* following the financial meltdown of Moorside's sole investor Toshiba and the bankruptcy of its subsidiary Westinghouse who was to supply the AP1000 reactors for the project. (48)

According to *The Sunday Times* Toshiba is unable to proceed with a £15bn-plus power station at Moorside and is seeking a buyer for NuGen but bidders will be scarce and the sale fraught with complexity. (49)

Conclusions

The future of the Moorside nuclear proposals have been plunged into doubt in recent months after Westinghouse declared bankruptcy. There has even been talk of NuGen being sold to the Korean state-owned utility KEPCO. If this were to occur KEPCO would want to build its own reactor-type – the APR1400 – which would have to undergo a new Generic Design Assessment, which would delay the start of construction by at least two years. (50)

However, we can conclude from this study that the AP1000 reactor has higher gaseous emissions - far more important that liquid emissions in terms of radiation doses to local people – than other similar reactors from an AP1000 type reactor are expected to be higher than from three out of the five reactor types.

We know that the Environment Agency is not satisfied that Best Available Techniques have been demonstrated for minimising discharges of liquid radioactive wastes, and has been unable to complete its assessment for the OSPAR Treaty to show compliance with the UK's international obligations under the OSPAR treaty to protect the marine environment of the North-East Atlantic.

Bearing in mind that NuGen is proposing to build 3 AP1000 reactors at Moorside we can calculate around 4 deaths will occur somewhere in the world for every year the station operates. Over 60 years the total would be 240 deaths.

Moorside would produce extremely high levels of radioactive spent fuel. In the year 2200 its spent fuel arisings would amount to 85% of the radioactivity contained in all existing legacy wastes from the UK's nuclear power industry.

The requirement for 'Best Available Techniques' (and clean technology) for producing electricity should rule out building new electricity generating stations which produce such highly dangerous wastes. Especially as less expensive, quicker and safer alternatives are available which don't produce such wastes.

References

(1) Platts 14th December 2011 https://www.platts.com/latest-news/electric-power/london/uk-regulators-issues-interim-licenses-for-two-8697810

(2) Nuclear Power in the United Kingdom, World Nuclear Association May 2017 http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-kingdom.aspx

(3) GDA AP1000 nuclear power plant design by Westinghouse Electric Company LLC, Summary of Decision Document, EA December 2011 (See para 1 Introduction) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296700/geho1211btog-e-e.pdf

(4) Fairlie, I Childhood Leukemias Near Nuclear Power Stations: new article, 25th July 2014 http://www.ianfairlie.org/news/childhood-leukemias-near-nuclear-power-stations-new-article/

(5) New Scientist 7th June 2017 https://www.newscientist.com/article/2133760-energy-security-is-possible-without-nuclear-power-or-fracked-gas/

(6) Consultation on a Methodology to Determine a Fixed Unit Price for Waste Disposal and Updated Cost Estimates for Nuclear Decommissioning, Waste Management and Waste Disposal, DECC March 2010 Para 3.2.23 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42533/1_20100324145948_e____ConsultationonFixedUnitPricemethodologyandupdatedcostestimates.pdf

(7) Ref (6) See Footnote 20 on page 22

(8) Geological Disposal: An overview of the differences between the 2013 Derived Inventory and the 2010 Derived Inventory, RWM Ltd July 2015 https://rwm.nda.gov.uk/publication/differences-between-2013-and-2010-derived-inventory/

(9) AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC, Final Assessment Report Gaseous Radioactive Waste Disposal and Limits, Environment Agency, 2011. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296671/geho1211btnw-e-e.pdf

(10) UK EPR Nuclear Power Plant Design by Areva NP SAS and EDF SA, Final Assessment Report Gaseous Radioactive Waste Disposal and Limits, Environment Agency, 2011. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296904/geho1211btnc-e-e.pdf

(11) AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC, Final Assessment Report Gaseous Radioactive Waste Disposal and Limits, Environment Agency, 2011.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296671/geho1211btnw-e-e.pdf For the actual numbers see Table 4.11, page 53 The AP1000 Nuclear Power Plant BAT Assessment, Westinghouse 2011. http://www.westinghousenuclear.com/Portals/5/Documents/documentation%20pdfs/AP1000%20Nuclear%20Power%20Plant%20BAT%20Assessment.pdf

(12) ibid para 29.

(13) Submission to Environment Agency radioactive waste permit for the proposed Hinkley Point nuclear reactor, Somerset submission 2/2 –aerial gaseous discharges, Nuclear Free Local Authorities, December 2011 http://www.nuclearpolicy.info/docs/nuclearmonitor/NFLA_New_Nuclear_Monitor_No26.pdf

(14) See (13) for a full list of citations

(15) Fairlie, I (2014) A hypothesis to explain childhood cancers near nuclear power plants, Journal of Environmental Radioactivity Volume 133, July 2014, Pages 10-17.

(16) Submission to Environment Agency radioactive waste permit for the proposed Hinkley Point nuclear reactor, Somerset submission 2/2 –aerial gaseous discharges, Nuclear Free Local Authorities, December 2011 http://www.nuclearpolicy.info/docs/nuclearmonitor/NFLA_New_Nuclear_Monitor_No26.pdf

(17) Further consideration of the incidence of cancers around the nuclear installations at Sellafield and Dounreay, COMARE 17th Report, September 2016 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/554981/COMARE_17th_Report.pdf

(18) See http://www.ianfairlie.org/news/kinlen-theory-debunked/

(19) See CORE 5th February 2017 http://corecumbria.co.uk/news/the-kinlen-virus-hypothesis-arisen-to-explain-away-the-risks-from-radiation/ For Hoffman's quote see CORE Cumbria 3rd October 2016 https://www.youtube.com/watch?v=VfMYrujvTz8

(20) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC, Consultation Document, Environment Agency 2010 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296538/geho0510bruw-e-e.pdf

(21) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC. Final Assessment Report on Aqueous Radioactive Waste Disposal and Limits, EA 1st December 2011 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296675/geho1211btnx-e-e.pdf

(22) Statutory Guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment, Department of Energy and Climate Change 2009 http://webarchive.nationalarchives.gov.uk/20121217150421/http:/decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/nuclear/radioactivity/dischargesofradioactivity/1_20091202160019_e_@@_guidanceearadioactivedischarges.pdf

(23) See Annex 1 of UK strategy for radioactive discharges 2001 – 2020, DEFRA, July 2002 http://www.scotland.gov.uk/Resource/Doc/46746/0024243.pdf

(24) See Cleaner Production vs End of Pipe, Centric Austria International, http://www.centric.at/services/cleaner-production/cleaner-production-versus-end-of-pipe

(25) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC. Final Assessment Report on Aqueous Radioactive Waste Disposal and Limits, EA 1st December 2011 para 211 page 39. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296675/geho1211btnx-e-e.pdf

(26) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC. Final Assessment Report on Aqueous Radioactive Waste Disposal and Limits, EA 1st December 2011 para 210 page 39. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296675/geho1211btnx-e-e.pdf

(27) Submission to Enviroment Agency radioactive waste permit for the proposed Hinkley Point nuclear reactor, Somerset submission 1/2 – marine discharges, NFLA New Nuclear Monitor, No. 25 December 2011. http://www.nuclearpolicy.info/docs/nuclearmonitor/NFLA_New_Nuclear_Monitor_No25.pdf

(28) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC. Final Assessment Report Radiological Impact on Members of the public, EA 1st December 2011 para 42 page 13

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296692/geho1211btod-e-e.pdf
(29) UK Strategy for Radioactive Discharges 2001 – 2020, DEFRA July 2020 http://www.gov.scot/Resource/Doc/46746/0024243.pdf
(30) UK Strategy for Radioactive Discharges DECC et al July 2009 http://www.gov.scot/Resource/Doc/280203/0084414.pdf
(31) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC. Final Assessment Report Radiological Impact on Members of the public, EA 1st December 2011 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296692/geho1211btod-e-e.pdf
(32) Preliminary Environmental Information Report, Chapter 21 Radiological, NuGen, May 2016 https://nugenconsultation.com/wp-content/uploads/2016/05/N0010290-Moorside-Project-PEIR-Chapter-21-Radiological.pdf
(33) See http://www.ianfairlie.org/news/assessing-long-term-health-effects-from-fukushimas-radioactive-fallout/ and http://www.ianfairlie.org/?s=collective+dose for further discussion on Collective Dose and DREFF.
(34) Fairlie, I and Sumner, D. In Defence of Collective Dose, Journal of Radiological Protection 20 (2000) 9 - 19
(35) See CERRIE Report here: http://webarchive.nationalarchives.gov.uk/20140108135436/http://www.cerrie.org/ and Fairlie, I Uncertainties in Doses and Risks from Internal Radiation, Medicine, Conflict and Survival Vol. 21. Issue. 2,2005
(36) Statutory Guidance on the Regulation of Radioactive Discharges into the Environment from Nuclear Licensed Site, Consultation Paper, DEFRA 2001.
(37) For example, Dr Peter Bleasdale who went on to become Managing Director of the National Nuclear Laboratory said: "Already there are significant volumes of historic wastes safely stored, and a programme of new reactors in the UK will only raise waste volumes by up to 10%." BBC 13th May 2008 http://news.bbc.co.uk/1/hi/sci/tech/7391044.stm
(38) Geological Disposal: An overview of the differences between the 2013 Derived Inventory and the 2010 Derived Inventory, RWM Ltd July 2015 https://rwm.nda.gov.uk/publication/differences-between-2013-and-2010-derived-inventory/
(39) Consultation on a Methodology to Determine a Fixed Unit Price for Waste Disposal and Updated Cost Estimates for Nuclear Decommissioning, Waste Management and Waste Disposal, DECC March 2010 Para 3.2.23 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42533/1_20100324145948_e____ConsultationonFixedUnitPricemethodologyandupdatedcostestimates.pdf
(40) Ref (25) See Footnote 20 on page 22
(41) Preliminary Environmental Information Report, Chapter 21 Radiological, NuGen, May 2016 para 21.5.4 https://nugenconsultation.com/wp-content/uploads/2016/05/N0010290-Moorside-Project-PEIR-Chapter-21-Radiological.pdf
(42) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC. Final Assessment Report Spent Fuel, EA 1st December 2011 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296682/geho1211btnz-e-e.pdf
(43) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC. Final Assessment Report Disposability of ILW and Spent Fuel, EA 1st December 2011 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296684/geho1211btoa-e-e.pdf
(44) Generic Design Assessment, AP1000 Nuclear Power Plant Design by Westinghouse Electric Company LLC. Final Assessment Report Spent Fuel, EA 1st December 2011 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296682/geho1211btnz-e-e.pdf
(45) Moorside Stage Two Consultation Document: Proposed Scheme, NuGen, May 2016 page 13 https://nugenconsultation.com/wp-content/uploads/2016/05/Proposed-scheme.pdf
(46) CORE 8th March 2017 http://corecumbria.co.uk/news/moorside-timetable-slips-further-behind/
(47) CORE 17th May 2017 http://corecumbria.co.uk/briefings/nugens-investment-turmoil-sparks-pylon-delay-for-moorside-new-build/ and CORE 30th June 2017 http://corecumbria.co.uk/news/open-letter-to-nugen-ceo-on-consultation-status/

(48) CORE 17th May 2017 http://corecumbria.co.uk/briefings/nugens-investment-turmoil-sparks-pylon-delay-for-moorside-new-build/
(49) Sunday Times 7th May 2017 https://www.thetimes.co.uk/edition/business/troubled-toshiba-could-spark-a-meltdown-rt8sm77d8
(50) Telegraph 28th June 2017 http://www.telegraph.co.uk/business/2017/06/28/kepco-confirms-talks-toshiba-uk-nuclear-but-reactors/