NFLA New Nuclear Monitor Policy Briefing 51 February 2018

Radioactive Waste and the UK’s New Nuclear Programme – submission to the OSPAR RSC

i. Overview of Policy Briefing

This edition of the NFLA’s New Nuclear Monitor provides an overview of concern of the increase to the radioactive waste inventory from a UK new nuclear build programme. It has been developed by the NFLA for KIMO International to provide a joint submission to the OSPAR Radiation Substances Committee (RSC) meeting taking place in Gothenburg, Sweden. The submission outlines the expected radioactive content of liquid and gaseous emissions from the proposed new nuclear programme. It is being submitted to the OSPAR RSC to consider how such a programme fits in with discharges into the marine environment and the plan for all member states to have ‘close to zero’ marine radioactive emissions by 2020 and onwards.

1. Introduction

The role of the English and Welsh Environment Agencies is to ensure the impact of radioactive wastes on the environment is minimised. (1) 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. Independent consultant on radioactivity in the environment, Dr Ian Fairlie says:

“I can think of no other area of toxicology (e.g. asbestos, lead, smoking) with so many studies, and with such clear associations as those between NPPs and child leukaemias.” (2)

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*.” (3)

The nuclear industry has yet to provide a credible scientific case for nuclear waste ‘disposal’. A deep geological disposal facility (GDF) is not expected to be ready to receive waste until around 2040 at the earliest. Waste from proposed new reactors 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. (4)

In addition, the high burn-up fuel expected to be used by these new reactors could require up to 100 years of cooling before it would be cool enough to be emplaced in a GDF. (5) So if a new reactor were to come on stream around 2030, with an expected reactor life of 60 years, this means some spent fuel could still be in storage on the reactor site in 2190.

The total amount of radioactivity in the radioactive waste inventory in the year 2200 would increase, as a result of the new reactor programme, from 4,770,000TBq to 27,300,000TBq – almost a whopping six-fold increase. (6)

2. The UK's New Nuclear Programme

The UK Government's National Policy Statements (NPS) are intended to establish the case for Nationally Significant Infrastructure Projects, as defined in the Planning Act 2008. The current nuclear NPS (EN-6), published in 2011, lists 8 sites as potentially suitable for the deployment of new nuclear power stations by the end of 2025. (7) These sites are: Hinkley Point C, Wylfa, Moorside, Sizewell, Bradwell, Oldbury, Hartlepool and Heysham. The Government is now consulting on a planning framework for new nuclear power for deployment after 2025. (8)

Taken together with the overarching NPS for Energy (EN1), the Government says the current nuclear NPS sets out the need for nuclear power.

The UK Minister for Energy and Industry admits that the new nuclear programme has taken a long time to progress so it is now necessary to designate a new nuclear NPS to facilitate nuclear power stations at sites capable of deployment between 2026 and 2035. In July 2017, EDF Energy revealed that the proposal to build two EPR-type reactors (1.6MW each) at Hinkley Point C in Somerset is likely to be delayed by 15 months to 2027, More recently the former energy secretary, Sir Edward Davey, who signed off on Hinkley Point C has cast doubt on whether the project will ever get built at all, let alone by 2027. (9)

Horizon Nuclear, a subsidiary of Hitachi, is proposing to build two ABWR-type reactors (1.35MW each) at Wylfa on the Island of Anglesey and is aiming to generate the first electricity in the mid-2020s. But it has yet to reach a deal on financing the reactors with the Government, although unconfirmed reports in Japanese media suggest the governments of UK and Japan are set to extend a combined £15bn (€16.8bn) in loans and investment for the project. (10) NuGen, which is in the process of being sold by Toshiba to KEPCO (Korea Electric Power Corporation) had been planning to build three AP1000-type reactors (1.1MW each) at Moorside, near Sellafield, but most observers expect KEPCO to try building its own reactors on the site (The APR-1400). NuGen has said it does not expect anything to be up and running before 2025.

Horizon is also proposing to build two ABWRs at Oldbury in Gloucestershire but won't start construction until the late 2020s at the earliest. And EDF Energy is planning another two EPRs at Sizewell C in Suffolk but these are not expected to begin generating electricity until 2031. China General Nuclear Power Corporation (CGN) and EDF Energy are together intending to develop a new nuclear power station at Bradwell-on-Sea in Essex – probably using two HPR1000-type reactors, but there is no timetable for this as yet. No proposals have been put forward for Hartlepool or Heysham.

Table 1 – the UK's proposed new nuclear programme

Proposed Nuclear Station	Technology Proposed	Developer	Construction start expected	Commercial operation forecast
Hinkley Point C (Somerset)	2 x 1600MW EPRs	EDF 66.5% CGN 33.5%	First concrete 2019	End of 2025 with risk of 15 month delay (11)

Wylfa Newydd (Anglesey)	2 x 1350MW ABWRs	Horizon Nuclear Power - wholly owned subsidiary of Hitachi, Ltd.	2020	First electricity mid-2020s - 2025-2028 (12)
Moorside (Cumbria)	3 x 1150MW AP1000s (but could be replaced by 2 x 1400MW APR1400)	NuGen (currently owned by Toshiba – but hoping to sell to KEPCO) (13)	No date – but a 4-5year Generic design Assessment process required for APR1400, so ~2023-4	Not by 2025 – no new date
Sizewell C (Suffolk)	2 x 1600MW EPRs	EDF 80% CGN 20% (14)	2021	2031 (15)
Oldbury B (Gloucestershire)	2 x 1350MW ABWRs	Horizon Nuclear Power - wholly owned subsidiary of Hitachi, Ltd.	Late 2020s at the earliest. (16)	Mid to late 2030s?
Bradwell B (Essex)	2 x 1000MW UK HPR1000	CGN 66.5% EDF 33.5% (17)	No defined timeline; began GDA process in Jan 2017	

3. Radioactive Wastes

Here we will look at the radioactive waste expected to be produced by EPRs, ABWRs and AP1000s – even though the likelihood of the AP1000 being built in the UK appears slim – because these are the reactor-types which have mostly completed the Generic Design Assessment process by the Office for Nuclear Regulation and the Environment Agency.

4. Gaseous Discharges

Table 2: Predicted gases discharges for a single reactor of each type

Radionuclide	**EPR (18)**	**AP1000 (19)**	**ABWRs (20)**	**Range for 1000 MWe station (21)**
Tritium	500GBq	1800GBq	2700GBq	100 – 3600GBq
Carbon-14	800GBq	606GBq	910GBq	40 – 530GBq
Radioactive Noble Gases	350GBq	8047GBq	1980GBq	100 – 10,000GBq
Radio-iodines	50MBq	210MBq		<1 – 2000MBq

Given that there are four EPRs proposed, three AP1000s and four ABWRs the total gaseous discharges from the proposed new nuclear programme are noted in Table 3.

Table 3: Predicted gaseous discharges from notional UK new reactor programme

Radionuclide	**4 x EPRs**	**3 x AP1000s**	**4 x ABWRs**	**Total**
Tritium	2,000GBq	5,400GBq	10,800GBq	18,200GBq
Carbon-14	3,200GBq	1,818GBq	3,640GBq	8,658GBq
Radioactive Noble Gases	1,400GBq	24,141GBq	7,920GBq	33,461GBq
Radio-iodines	200MBq	630MBq		830MBq

The UK 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*." (22)

This begs the question: if EPRs can reduce tritium emissions to the atmosphere to 500GBq per reactor why can't ABWRs and AP1000s? If AP1000s can reduce Carbon-14 emissions to 66GBq why can't the other reactor types?

5. 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. (23)

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 mainly 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 almost 20 times larger than tritium air emissions. With the ABWR this situation is reversed with tritium emissions to the atmosphere thirteen times larger than tritium emissions to the sea.

6. Tritium

The largest aerial emissions from the proposed new UK nuclear programme 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. COMARE has highlighted a report by the Advisory Group on Ionising Radiation (AGIR) (November 2007) which suggests that current dose estimates for tritiated water are too low. And recent reports have been published by radiation safety agencies in Canada and France. (24) 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.

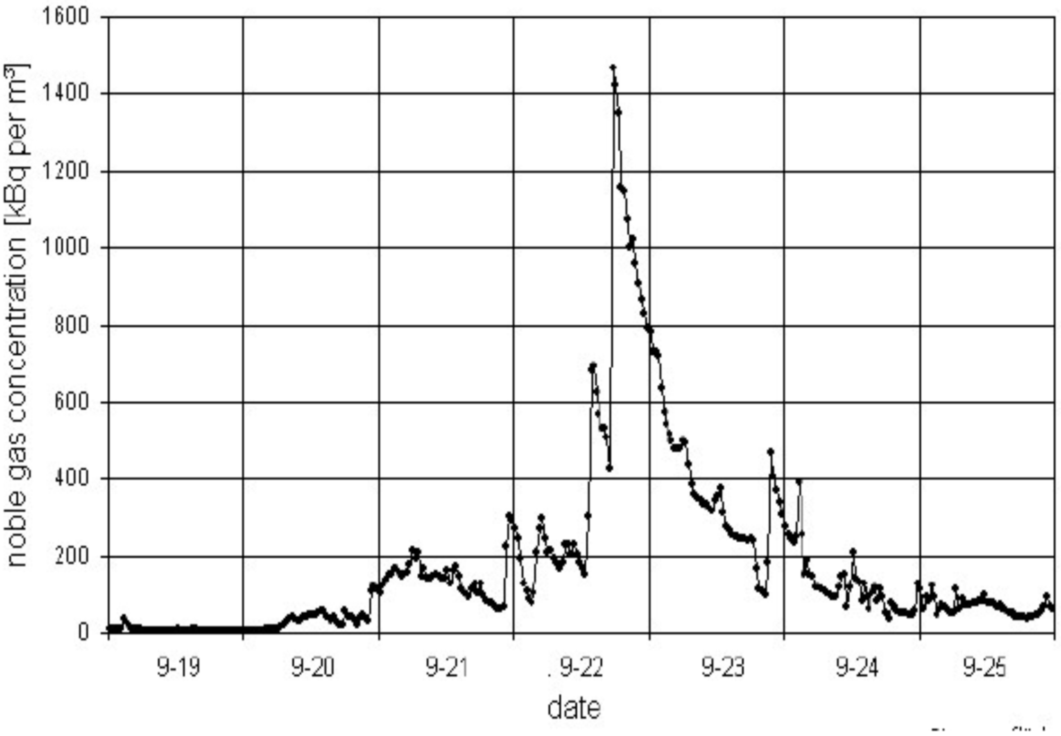
Over 60 epidemiological studies world-wide have examined cancer incidences in children near nuclear power plants (NPPs): most of them indicate leukemia increases. These include the 2008 KiKK study commissioned by the German Government which found relative risks (RR) of 1.6 in total cancers and 2.2 in 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. (25)

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. (26)

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.

7. Liquid Discharges

Table 4: Predicted liquid discharges for a single reactor of each type;

Radionuclide	EPR (27)	AP1000 (28)	ABWRs (29)	Range for 1000 MWe station
Tritium	52,000GBq	33,400GBq	200GBq	2,000 – 30,000Gbq
Carbon-14	23GBq	3.3GBq		3-45GBq
Iodine radionuclides	7MBq	15MBq	0.035MBq	10-30MBq
Other radionuclides	0.6GBq	2.7GBq	2.3MBq*	<1-15GBq

*This is Fe-55. According to the Environment Agency the aqueous discharge activity is dominated by tritium (H-3), which is not abated and constitutes over 99.99% of the activity in the aqueous discharges. The second largest contributor of activity to the discharges is iron-55 (Fe-55), which only constitutes 0.0012% of the activity discharged.

Table 5: Predicted liquid discharges from notional UK new reactor programme

Radionuclide	4 x EPRs	3 x AP1000	4 x ABWRs	Total
Tritium	208,000GBq	100,200GBq	800GBq	309,000GBq
Carbon-14	92GBq	9.9GBq		101.9GBq
Iodine radionuclide	28MBq	45MBq	0.14MBq	73.14MBq
Other radionuclides	2.4GBq	8.1GBq	9.2MBq	10.5GBq

With regard to the UK's proposed new reactor programme, concern has been expressed 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. (30)

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].

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. (31)

"*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. (32)

8. Critical Group Doses

The Environment Agency has assessed that the total impact of radioactive discharges (including gaseous discharges) as follows:

Table 6: estimated critical group doses for each reactor-type.

Reactor-type	Critical group dose	Contribution from aqueous	Comment
EPR (33)	31 µSv y^{-1}	28 µSv y^{-1}	primarily from carbon-14 in fish

AP1000 (34)	8.4μSv y^{-1}	<1μSv y^{-1}	critical group dose dominated by aerial carbon-14
ABWR (35)	14 - 24μSv y^{-1}	<1μSv y^{-1}	critical group dose dominated by aerial carbon-14

These numbers compare with the radiological dose limits to members of the public of 1000μSv 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. (36)

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. (37) 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*." (38)

Given that each of the proposed sites have two or even three new reactors proposed, EPRs would certainly breach the 20 μSv y^{-1} figure and other reactor-types could potentially breach this figure albeit from a combination of liquid and gaseous discharges.

9. 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 detrimental human health effects other than fatal cancers (e.g. skin cancers) and genetic effects. And of course the 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. (39)

Independent assessments of collective dose for the three reactor types have been reported as noted in Table 7.

Table 7: estimated collective dose for each reactor-type

Reactor-type	Gaseous Discharges	Liquid Discharges	Total
EPRs	16 person Sv.yr^{-1}	1.1 person Sv.yr^{-1}	17.1person Sv.yr^{-1}
AP1000s	12.2 – 12.6 person Sv.yr^{-1}	0.052-0.054 person Sv.yr^{-1}	Up to 12.65 person Sv.yr^{-1}
ABWRs	29.9 person Sv.yr^{-1}	0.00003 person Sv.yr-1	30 person Sv.yr^{-1}

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. (40)

However, given that the current proposed UK new nuclear programme includes four EPRs, 3 AP1000s and 4 ABWRs, the total collective dose would be as shown in table seven below. By applying the risk factor of 10% per sievert we can estimate a number of theoretical deaths in the world for each year the stations operate. Over 60 years, the total number of deaths for all 11 reactors can be estimated at 1380.

Table 8: Total collective dose for each proposed reactor type and estimated number of deaths over 60 year operating life.

Reactor-type	Total Collective Dose	No. of deaths for each year reactors operate	No. of deaths over 60 years
4 x EPRs	68.4 person Sv.yr^{-1}	~7	420
3 x AP1000s	38 person Sv.yr^{-1}	~4	240
4 x ABWRs	120 person Sv.yr^{-1}	~12	720
Totals		**~23**	**1380**

10. Uncertainties

There are many uncertainties in current estimates of radiation doses and risks and larger uncertainties exist with internal radiation. 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. (41)

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

"*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.*" (42)

11. 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. (43)

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 the proposed new reactors are expected to use will be much more radioactive than the spent fuel produced by existing reactors. Rather than using volume as a yardstick, the amount of radioactivity in Becquerels in the waste would be a much more appropriate way to measure 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. The Radioactive Waste Management Ltd Derived Inventory 2013 calculates that the waste inventory in 2200 after a 16GW programme of new reactors would be around 27,300,000 TBq – almost a six-fold increase. That means an extra 22,530,000TBq (almost five times the amount already produced) or 1,408,125TBq for every GW of new nuclear capacity. (44)

For every Gigawatt of new nuclear capacity, the radioactive waste inventory will increase by a staggering 30%!

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 most existing reactors 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 is not expected to be emplaced in the GDF until after all the currently existing waste has been emplaced. This is expected to take around 90 years , so won't be complete until around the year 2130. This means that spent fuel could remain on the new reactor sites for at least the next 100 years. The other factor which needs to be taken into account is that high-burn up fuel could require up to 100 years of cooling before it will be cool enough to be emplaced in a GDF. (45) So assuming new reactors come on stream around 2030, although some spent fuel might start to be emplaced from 2130 onwards, as the reactors are expected to have a life of 60 years, there may be some spent fuel still stored up until about 2190.

12. Conclusions

Gaseous and liquid emissions from the UK's proposed new reactor programme could mean up to 23 theoretical deaths somewhere in the world for every year all of the reactors operate. Since they are each expected to operate for 60 years the total number of theoretical deaths could be 1380.

The new reactors would produce extremely high levels of radioactive spent fuel. In the year 2200 spent fuel arisings would amount to almost five times 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.

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