

# Spent Nuclear Fuel – the Poisoned Chalice

## A paper for the Nuclear Consultation Group

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### Contents

### Page

Introduction	2
How new nuclear power is to be justified	2
From now on Spent Fuel is Waste	3
What is 'High Burnup Spent Fuel'?	4
How long will spent fuel be stored on-site?	5
Radioactivity Accumulated from New Build	6
Spent fuel pools	7
Interim Storage in Dry Casks	9
Easier-to-handle wastes	11
Radiation – gamma and neutron	12
Conclusions	14
References	16
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Chart 1 – Radioactivity from New Build Nuclear and Legacy	6
Chart 2 – Spent Fuel Pools – How well protected are they?	8
Chart 3 – Past and Future Use of High Burnup Nuclear Fuel	10
Chart 4 – Thermal Power of High Burnup Spent Fuel	11
Chart 5 – Neutron Radiation from 1 tonne of High Burnup Fuel	13
Table 1 – Spent fuel pools	9

The Nuclear Consultation Group (NCG) comprise many of the leading UK experts in the fields of environmental risk, radiation waste, energy policy, energy economics, political science, social science, environmental justice, environmental philosophy, particle physics, and democratic involvement.

It has been established to address the form and function of nuclear consultation processes in the UK. It has already published a widely reviewed document, Nuclear Consultation: Public Trust in Government. In particular the Group has focused on the consultation processes that have been undertaken as part of the development of energy policy and new nuclear power.

[http://www.nuclearconsult.com/NUCLEAR\\_REPORT\\_COMPLETE\\_HIGH.pdf](http://www.nuclearconsult.com/NUCLEAR_REPORT_COMPLETE_HIGH.pdf)

In addition to his contribution to that report Hugh Richards has authored a further NCG paper entitled: "Too hot to handle: the truth about high burnup spent nuclear fuel" available at:

[http://www.nuclearconsult.com/Too\\_Hot\\_to\\_Handle.pdf](http://www.nuclearconsult.com/Too_Hot_to_Handle.pdf)

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## **Introduction**

Warnings of the environmental consequences of a large expansion of nuclear power date back to an influential Royal Commission statement in 1976 that: <sup>1</sup>

"...there should be no commitment to a large programme of nuclear fission power until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long-lived, highly radioactive waste for the indefinite future."

The Government of the time seemed to agree, saying that in future it would: <sup>2</sup>

"...secure the programmed disposal of waste accumulated at nuclear sites", and "...ensure that waste management problems are dealt with before any large nuclear programme is undertaken."

Twenty five years later, with neither of these conditions fulfilled, a government energy review commented in 2002: <sup>3</sup>

The main focus of public concern about nuclear power is on the unsolved problem of long-term nuclear waste disposal, coupled with perceptions about the vulnerability of nuclear power plants to accidents and attack.

Radioactive waste remains an issue that is profoundly important and central to the acceptability of nuclear power. In the face of this 'unsolved problem' the government has decided to facilitate a new generation of nuclear reactors.

It has pointed to progress that has been made in establishing the concept of a 'deep geological repository' for our existing radioactive waste that could be extended to take the waste from new reactors. Nothing of substance has been said about the terrorist threat.

Spent fuel from the proposed reactors will contain the vast majority of the radioactivity from the new reactors. This paper looks at what has been disclosed about this new 'high burnup' spent fuel, and concludes that the accumulation of this material on each reactor site will increase our vulnerability to accidents and attack.

## **How new nuclear power is to be justified**

The recommendations of the International Commission on Radiological Protection (ICRP) require that:<sup>4</sup>

"any decision that alters the radiation exposure situation should do more good than harm".

As a result no practice (activity) involving exposures to radiation should be adopted unless it produces at least sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. Waste management and disposal is regarded as an integral part of the one single practice of nuclear power generation so we have to consider all detriments, including that from the waste, before allowing any new nuclear programme. <sup>5</sup>

Of the four reactor designs submitted for 'generic design assessment' (GDA) two have dropped out, leaving two pressurised water reactors: the AREVA EPR and the Westinghouse AP1000. Assessment by the Environment Agency and the Nuclear Installations Inspectorate will consider the long-term risks over the full life cycle of the reactor including how spent fuel is to be managed and what precautions will be taken to ensure safety and minimise its radiological impact. <sup>6</sup>

For the regulators, the need to ensure that problems are not allowed to build up is central to their philosophy.<sup>7</sup>

“...as regulators, we don't want to see wastes created that cannot be managed through to their final disposal.”

The full range of health and safety detriments has not yet been considered because insufficient information has been provided on spent fuel. It was concluded (of both reactor designs):<sup>8</sup>

“...there is no demonstration that facilities will be provided for through-life storage of wastes and spent fuel.”

Last year the Government's Business Secretary said:<sup>9</sup>

"The Justification Decision is the first major **regulatory** stage for new nuclear reactors, and an important step towards the construction of new nuclear power stations in the UK."

In December 2008 the Justification consultation document was announced:<sup>10</sup>

"This Justification process is yet another example of the facilitative actions the government is taking to support new nuclear power in the UK. At the same time it gives people the opportunity to have their say on the benefits and detriments of the practices involved."

The danger of allowing a department promoting nuclear power to make regulatory decisions is that in 'reducing regulatory risks for investors' it will pre-empt proper consideration of health detriments. It is for good reason that both the European Union and International Atomic Energy Authority (IAEA) require nuclear regulation to be free from any influence that may affect safety.<sup>11 12</sup>

Data on the amounts and characteristics of spent fuel from the new reactors has not yet been assessed by the NDA for its 'disposability' or by the Nuclear Installations Inspectorate (NII) and Environment Agency for the risks from its long term storage, retrieval encapsulation, emplacement and subsequent abandonment in a deep geological repository.

A justification decision that pre-empts consideration of any health detriments that might result, will come to be seen as negligent.

### **From now on Spent Fuel is Waste**

In June 2008 a 100 page white paper on 'managing radioactive waste safely' devoted about 50 lines (a little over one page) to spent fuel, even though:<sup>13</sup>

“...any new nuclear power stations that might be built in the UK should proceed on the basis that spent fuel will not be reprocessed and that plans for, and financing of, waste management should proceed on this basis.”

Worldwide, for economic reasons:<sup>14</sup>

“...most of the fuel extracted every year from nuclear reactors is considered as waste, with a relatively small quantity of spent fuel being reprocessed. When managed as a waste, spent fuel will need to be conditioned into an acceptable waste form for deep geological disposal.

The conditioning of spent fuel from new reactors into a waste form that can be disposed of deep underground is going to be difficult. A consequence of concentrating all our past efforts on reprocessing spent fuel is that the UK has

undertaken no research into the feasibility of its direct disposal, and has been reduced to making embarrassing statements at international discussions: <sup>15</sup>

“...work performed...was dedicated to giving results for the national consultation on Managing Radioactive Waste Safely. A literature review of...waste management options was undertaken, as well as preliminary calculations to investigate the key issues for disposal of radioactive materials not currently declared as waste.”

Looking at other peoples' work and writing down a list of the key issues for the direct disposal of spent fuel is a start, but there is a very long way to go.

### **What is 'High Burnup Spent Fuel'?**

Far more serious than ignorance about the direct disposal of spent fuel is unawareness of the nature of the spent fuel that will be discharged from the proposed reactors. To boost the efficiency of their reactors, operators have progressively increased the enrichment of fissile Uranium<sup>235</sup> in the fuel, so it can be left in the reactor for longer. The "burn-up" rate is a measure of the amount of electricity extracted from a given amount of fuel, and is expressed in thousand megawatt-days per tonne of uranium (MWd/tU). High burnup spent fuel is hotter and more radioactive than the historic spent fuel that has built up around the world. The IAEA is currently investigating the implications for the management of spent fuel. <sup>16</sup>

“There has been a continuing trend toward higher burnup, which is now approaching levels that are twice the level achieved in early fuel development a couple of decades ago.

It is acknowledged by the IAEA that any benefits of lower electricity costs during the operation of reactors in this way will be offset by an increase in the cost of managing the spent fuel. <sup>17</sup>

“After having increased the authorized burnup in plants, developing new alloys capable of resisting high burnup, and having accumulated data on fuel evolution with burnup, it has become necessary to establish the limitations....imposed by..... the management of waste and irradiated fuels.....to verify whether the benefits of lower electricity costs would not be offset by an increase in fuel management costs.”

The IAEA also recognized that limits would be reached in the increase in fuel burnup because of the environmental, safety and licensing implications: <sup>18</sup>

“.....the general burnup trend is heading up to still higher level, even though there should be a plateau level in confrontation with regulatory constraints.

The word 'should' is important. The development of nuclear power to the point when the 'benefits' of using Uranium enriched to 5% U<sup>235</sup> are outweighed by the future costs of managing the resulting spent fuel has already been reached.

The nuclear industry, under great economic pressure from a liberalized electricity market, has concentrated on devising fuel cladding capable of staying in the reactor for longer, without regard to the long-term consequences: <sup>19</sup>

“Since the requirements for cladding features for long term dry storage are not well defined, cladding features unique to long term storage are not yet included in fuel design, and the predictions of the long term behaviour of cladding have significant uncertainties.”

This is apparent in doubts about the integrity of high burnup spent fuel over periods of long-term storage. Its safe retrieval from long-term storage and its emplacement in 'deep geological repositories' would be compromised by the degradation of fuel elements. The implications of this hazardous work being undertaken by generations as yet unborn have hardly been acknowledged.

The nuclear power industry has raised the stakes by increasing the power output of its proposed reactors to the point where the difficulties of managing and disposing radioactive waste are becoming insuperable.

The justification process for new nuclear reactors in the UK has come at a time when regulatory 'confrontation' is required, not appeasement.

The Nuclear Installations Inspectorate applies principles that wastes should be placed into a passively safe state as soon as it is reasonably practicable and that the more hazardous the waste the sooner this should be achieved.<sup>20</sup>

In the absence of reprocessing this is supposed to require a dry store for spent fuel (with no active cooling) prior to the availability of a final disposal route.<sup>21</sup>

### **How long will spent fuel be stored on-site?**

In its May 2007 consultation document the government stated that placing waste in a geological repository is a long-term solution.<sup>22</sup>

"In the meantime, waste from any new nuclear power stations would be managed in accordance with the Government's requirements and the Nuclear Decommissioning Authority national strategy for interim storage. This is likely to require on-site storage in facilities capable of holding the waste in a safe condition for long periods until the waste repository is ready to receive it."

International concern about the long-term stability of stored fuel has been expressed by the IAEA:<sup>23</sup>

"It can be reasonably assumed that...the need could persist for ongoing storage over an even longer period. As the facility thus may be in operation for a period of 50–100 years or even longer, due care should be given to the long term stability of all its components and especially those which are safety related.

The Committee on Radioactive Waste Management (CoRWM) recorded the view that it would take around 65 years after a repository opened to emplace the legacy backlog.<sup>24</sup> In the view of the former CoRWM chair, Gordon MacKerron this suggests:<sup>25</sup>

"...new build wastes would not start to be disposed for around 100 years from now - if all goes well. Things of course may not all go well and it will take further decades to emplace new build wastes beyond this 100 year period. Consequently, some new build waste would need storage well beyond 100 years from now, possibly for as long as 150 years.

CoRWM have a preference for the early closure of the legacy fuel repository, but the government position is ambivalent:<sup>26</sup>

"Closure at the earliest opportunity provides greater safety, greater security from terrorist attack, and minimises the burdens of cost, effort and worker radiation dose transferred to future generations. ....however..... it is likely to be at least a century until final closure is possible, which the UK Government believes

provides sufficient flexibility for further research to be undertaken to achieve public confidence and approval...

Sealing off radioactive waste deep underground as soon as possible gives greater protection from terrorist attack, but depends on the feasibility of disposal of new build waste in the legacy repository.

Long-term storage of such intensely radioactive spent fuel will be difficult to achieve in a passively safe form. Active cooling in ponds is likely to be required for many decades before 'passive' storage in dry casks is possible.

It is clear that 'burdens of cost, effort and worker radiation dose' will be transferred to the future generations that have to retrieve the fuel from its long term storage, safely encapsulate it in containers for disposal and emplace it deep underground. These exposed individuals will not have received any benefit from the new reactors to offset the radiation detriment they suffer.

### Radioactivity Accumulated from New Build

In a study of radioactive waste implications associated with a 10 GW programme of new build reactors undertaken by NIREX in February 2007<sup>27</sup> a chart illustrated the build up of radioactivity over time from a programme of Westinghouse AP1000 reactors. The raw data, obtained from the Nuclear Decommissioning Authority has been redrawn for the first 200 years.

Chart 1

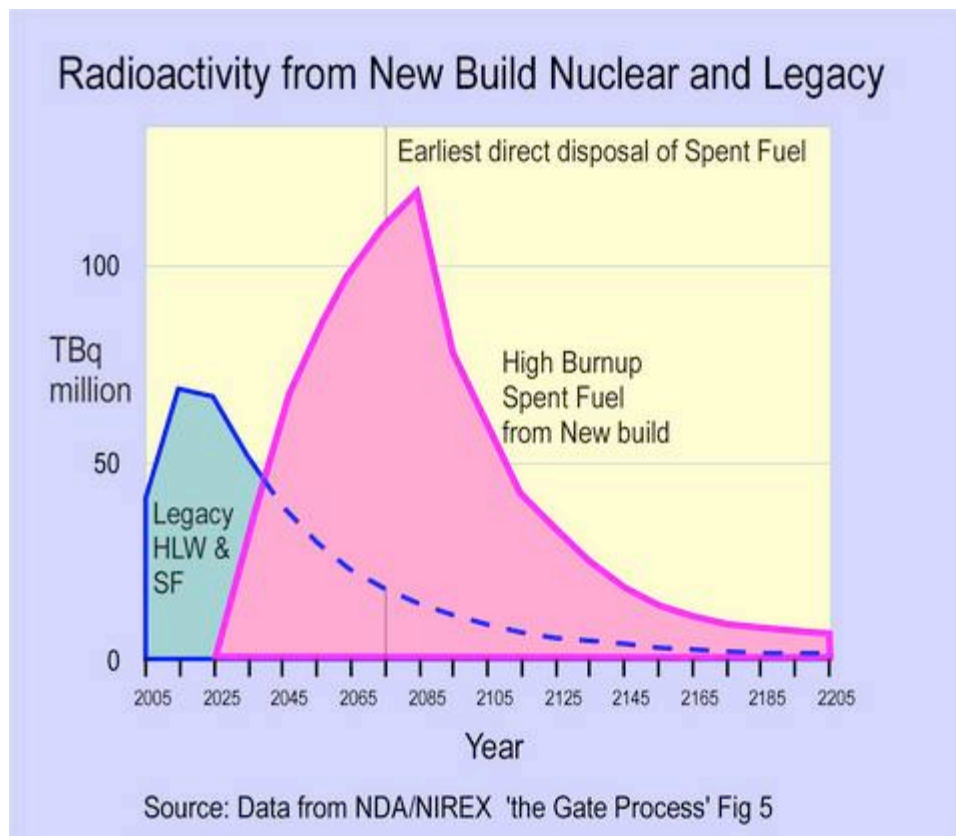


Chart 1 shows the total build up of radioactivity (pink) that would be stored on the sites of new reactors. By 2085 the amount of radioactivity from a new 10GW programme will be twice the 2015 peak of all radioactivity from Britain's nuclear legacy. By 2075 when it is intended that HLW and spent fuel from the legacy waste may be placed in a deep underground repository the new build

waste will contain six times as much radioactivity as legacy waste, and for reasons explained later it will be far too hot to be buried.

### **Spent fuel pools**

Because it is intensely radioactive and hot when spent fuel is discharged from a nuclear reactor active cooling methods are required. Once it has cooled down sufficiently, passive systems may be used for its management.

After spent fuel is removed from the reactor it is stored in ponds located within the reactor building to (a) cool the fuel to stop it heating up to high temperatures generated by radioactive decay, (b) act as a barrier to releases of radioactivity and shield people from the radiation emitted, and (c) prevent criticality accidents (from an uncontrolled nuclear chain reaction). Eight metres of water, laced with boric acid (to absorb neutrons), cover the spent fuel assemblies to shield people from radiation, while pumps circulate the water to prevent any boiling.

As the spent fuel pools could contain up to six reactors worth of spent fuel it is vital that they and the building containing them are able to withstand a terrorist attack. In 2006 a US committee reviewing the safety of spent fuel storage concluded that the cooling and shielding:<sup>28</sup>

“...could be compromised by a terrorist attack that partially or completely drains the spent fuel pool.”

Such an event would, according to a 2003 scenario<sup>29</sup> lead to the rapid heat-up of spent fuel in a densely-packed pool to temperatures at which the zirconium alloy cladding would catch fire and release many of the fuel's fission products, particularly caesium-137. The fire could spread to the older spent fuel, resulting in long-term contamination consequences worse than those from the Chernobyl accident. A study by US regulators<sup>30</sup> confirms that in such a pool, a cladding fire would probably spread to most or all of the fuel pool, driving “borderline aged fuel” into a molten condition leading to the release of fission products comparable to molten fuel in a reactor core.

The consequences of such a rupture are regarded by some as so grave that the fuel should be transferred to dry cask storage after five years to reduce the radioactive inventories in spent fuel pools and allow the remaining fuel to be stored less densely to allow for more effective coolant circulation, should a loss-of-pool-coolant event occur.

Chart 2 illustrates the two reactor designs currently being assessed for use in Britain. Both designs place the spent fuel pools outside the reactor containment that is designed to prevent the escape of radioactivity. In each design the pools are above ground level, adjacent to the wall of the containment with voids to the sides, above and below, so that any object that breaches the pool wall would allow some or all of the water to escape.

The proposed storage ponds increase our vulnerability because of the density at which the fuel elements are stored, their thermal power and the radioactivity that they contain. Both designs submitted to the UK regulators increase the storage density of spent fuel racking from the designs put forward in Finland and in the USA.

In the Olkiluoto version of the EPR with a 110m<sup>2</sup> pool within the reactor building.<sup>31</sup>

"The fuel pool can accommodate six to seven years worth of spent fuel from the reactor."

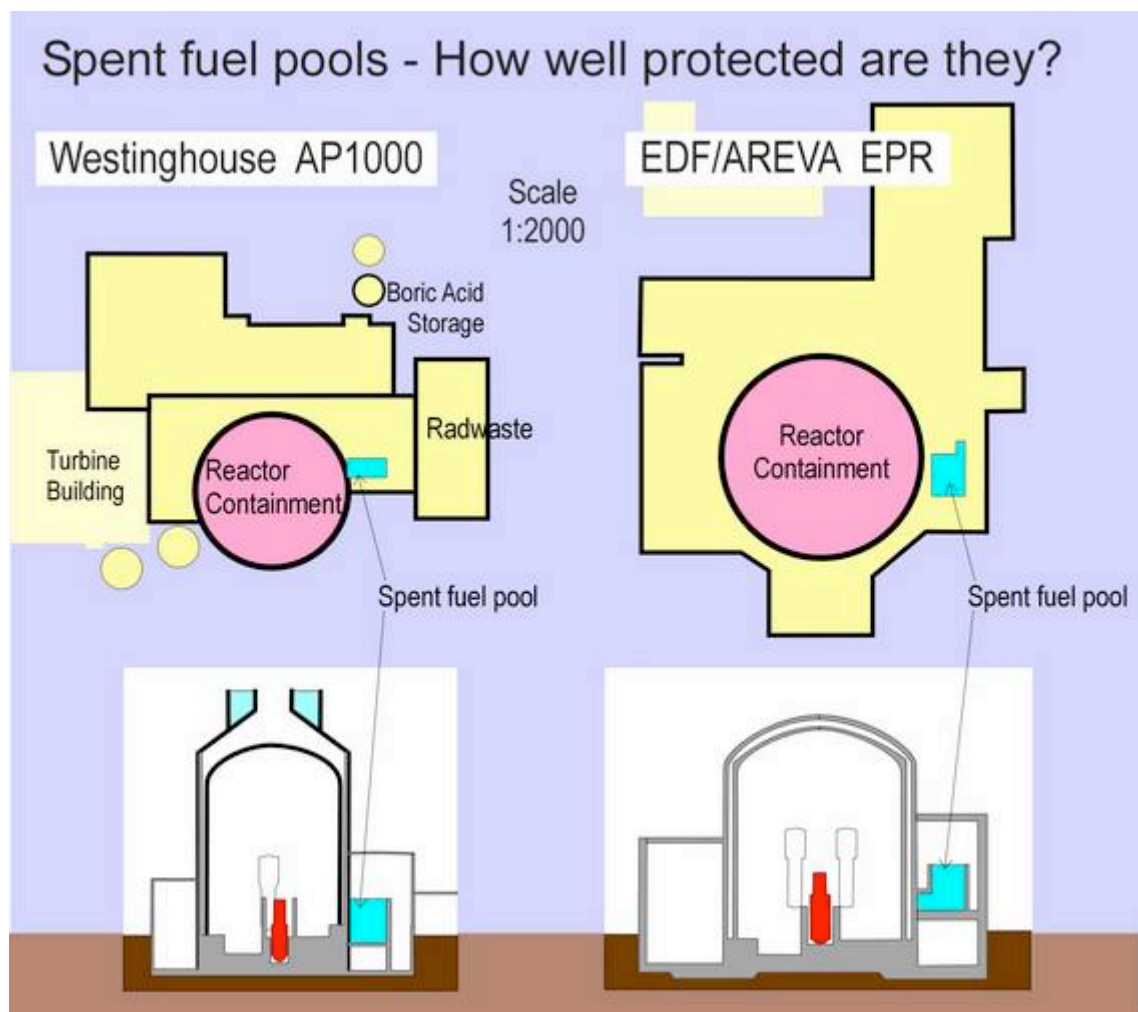
Yet in the EPR submitted as part of the 'justification application':<sup>32</sup>

"The pool capacity allows the spent fuel from at least 10 years of operation to be stored prior to export.

Five years after discharge, each square metre of spent fuel in the EPR cooling ponds will generate 17 kW of heat compared with 11 kW from the same area of Sizewell B's spent fuel pool. The high density of the AP1000 spent fuel racks mean that between 24 and 36 kW of heat will require to be removed from each square metre.

There is good understanding of 'normal' spent fuel stored in ponds over long periods, but as the high burnup spent fuel proposed for the AP1000 requires high concentrations of boric acid (2700ppm of boron, compared with 2000ppm in the Sizewell B reactor coolant) in the spent fuel pools, the long-term effects on older fuel are unknown.

### Chart 2



In the US the density of spent fuel in the pools within the reactor buildings has been increased to reduce costs and avoid building additional storage pools.

The spent fuel pool of the AP1000 design put forward to the US regulators in 2002<sup>33</sup> has room for 616 fuel assemblies and ten years of operation. It is therefore of concern that the design undergoing assessment in the UK goes further. It has the same size pool but includes a zone of even higher density racking. Storage capacity for up to 889 fuel assemblies represents a claimed storage capacity for 18 years of operation.

After five years cooling each square metre of high burnup spent fuel in zone 1 of the AP1000 pond will generate 24 kW, but the fuel will by then require to be transferred into the high density racking where each square metre will have a thermal power of 36 kW.

Table 1 - Spent fuel pools	Sizewell B	AP1000		EPR
		Zone 1	Zone 2	
Size of spent fuel pool sq m	144 (overall)	54		110
Burnup in MWd/tU	30,000 (design)	60,000		60,000
Tonnes Uranium per fuel assembly	0.5234	0.5414		0.528
Tonnes per sq m	7.7 (over racks)	7.1	10.6	5.1
KW per sq m at five years (ref 27)	10.8	24.0	36.0	17.2

If these new reactors are built, our safety will depend on the effective and continuous removal of the huge thermal power of high burnup spent fuel. This will require additional pumps, back up electricity supplies and backup water supplies: all systems vulnerable to mechanical failure or deliberate disruption.

Densely packed high burnup spent fuel compounds the difficulty, requiring additional neutron absorbers to reduce the possibility of criticality. Various boron containing absorbers have created operational problems, reacting with the spent fuel pool water to generate hydrogen<sup>34</sup>, or breaking down in the high gamma field of spent fuel, releasing silica and boron into the pond<sup>35</sup>. The resulting soup blocks filters and reduces visibility of the fuel cells.

### Interim Storage in Dry Casks

A few dry cask storage systems have received licenses for high burnup spent fuel in the US, but these are only for a maximum of 20 years of storage. It is instructive that, although two of these dry cask storage systems are made by AREVA, EDF have themselves opted for interim pool storage in their UK 'justification' application,<sup>36</sup> and state elsewhere that the interim storage pool fuel racks would cover an area of approximately 250m<sup>2</sup>.<sup>37</sup>

There is a crisis of confidence about the management and disposal of spent fuel. As the US Nuclear Regulatory Commission head put it this way in 2000<sup>38</sup>:

“...the high-level waste disposal issue is a top tier concern in the minds of those assessing the merits of new plant construction.

The NRC had certified casks for "normal" undamaged spent fuel to address a short-term spent fuel pool-capacity crisis. But serious shortcomings had arisen:

“There have been entirely too many instances where casks have had design deficiencies, such as incompatible materials resulting in generation of hydrogen gas; others where the casks have been improperly maintained, such as inadequate weld repair documentation; or instances where casks were improperly loaded with fuel without adequate procedures in place to unload the cask.

By 2004 high burnup spent fuel was driving his regulators:<sup>39</sup>

“Evolving cask designs are pushing the technical envelop and require that a more detailed technical analysis be performed by NRC staff. ....the staff continues to address....high burnup fuel thermal issues.”

Dry casks are designed to cool the fuel, contain the radioactivity and shield people from the radiation without the use of water or active mechanical systems. Westinghouse state in the NIA 'justification' application that:

“Spent fuel can also be placed in a storage cask and stored at an onsite facility.”<sup>40</sup>

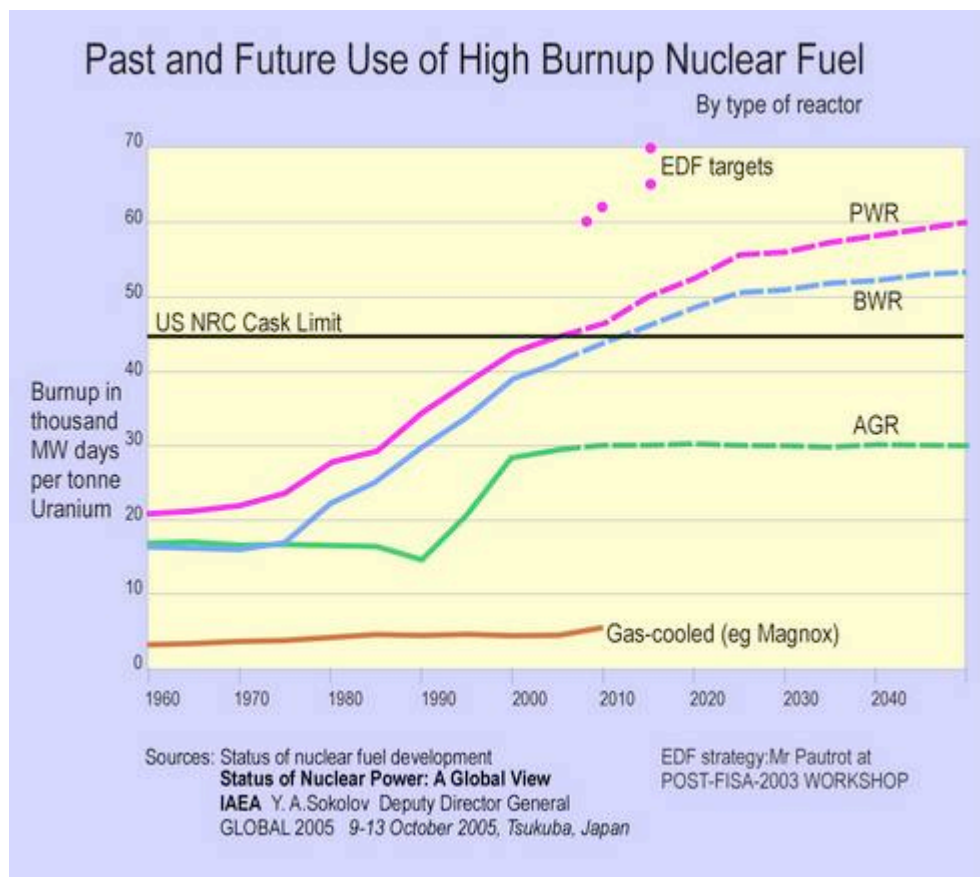
Passive fuel cooling relies on a combination of heat conduction through solid materials and natural convection or thermal radiation through air to move decay heat from the spent fuel into the surrounding environment. The cask materials provide radiation shielding. Typically, concrete, lead, and steel are used to shield gamma radiation, and polythene, concrete, and boron-impregnated metals or resins are used to shield neutrons. The spent fuel currently stored in dry casks is regarded as manageable because it has less thermal power, dating from a time when fuel was used less intensively.

The behavior of high burnup fuel under both wet and dry long term storage conditions was emphasised at a 2003 workshop because of their highly hydrided and high internal gas pressure state<sup>41</sup>. These concerns have lead the IAEA to demand more research on fuel behaviour in dry storage as essential.<sup>42</sup>

“In particular...high burnup fuels and mixed oxide (MOX) fuels will need to be carefully assessed in the context of ensuring long term storage safety.”

Chart 3 illustrates that the use of higher burnup spent fuel is a worldwide trend that has already reached the 45,000 MWD/tU limit for dual purpose storage and transportation casks licensed in the US. EDF's strategy is, for economic reasons, to go much further and faster than other operators in 'optimising' the use of nuclear fuel through ever-higher burnup.

**Chart 3**



Confidence about the ability of dry casks to safely contain spent fuel is based largely on the examination of undamaged fuel assemblies with a burnup of 36,000 MWd/MtU after 14 years of dry storage. The need for a dry storage demonstration program to keep pace with increasing spent fuel burnup has intensified over the last decade, to:<sup>43</sup>

“...obtain confirmatory data about the potential changes in cladding mechanical properties induced by dry storage, which would have implications to the transportation, handling, and disposal of high-burnup spent fuel.”

But researching the long term safety of high burnup spent fuel and its containment requires decades to establish scientific confidence:<sup>44</sup>

“...given the relatively short storage duration of the demonstration program (nominally five years), few if any generic data are expected to be obtained on the cask components.”

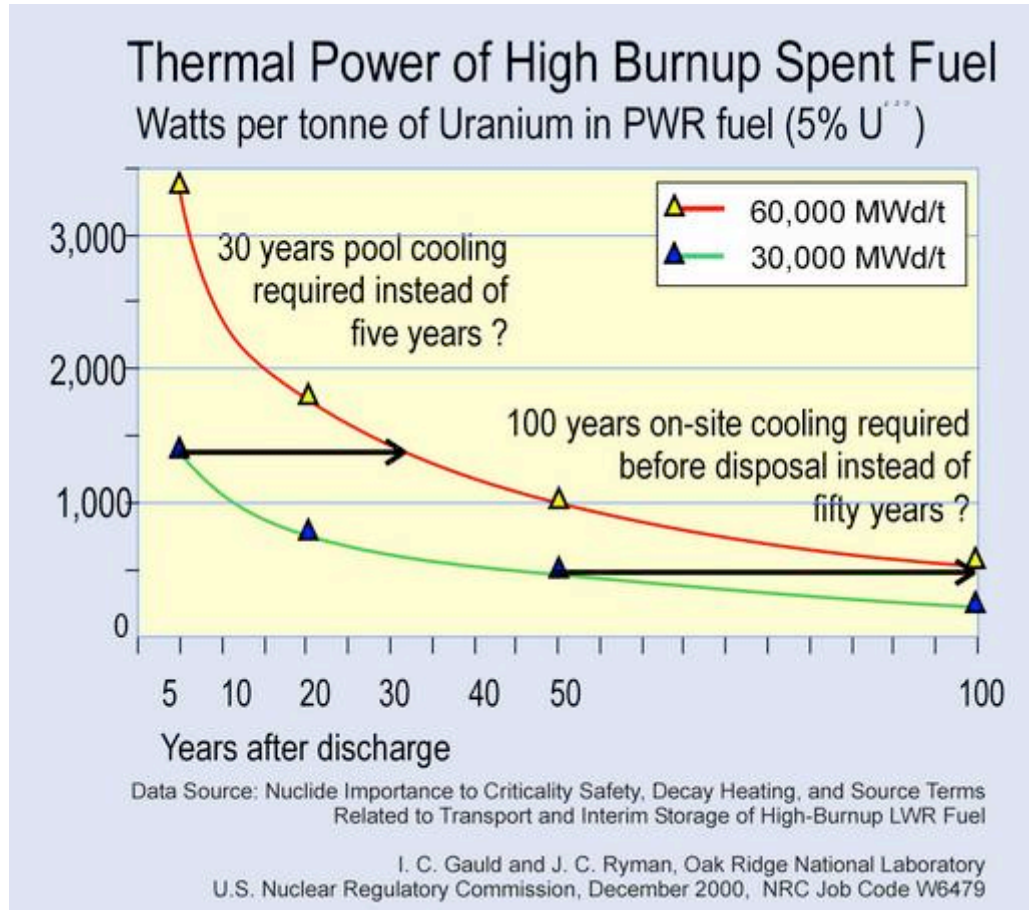
Despite scientific concerns about the long-term behaviour of high burnup spent fuel the Nuclear Industry Association says new nuclear build in the UK should not be dependent on a solution to the waste issue being found:<sup>45</sup>

"If new build does occur, a repository dealing with legacy wastes could readily accommodate the smaller volumes of easier-to-handle wastes from that new generation of nuclear plants."

#### Easier-to-handle wastes

High burnup spent fuel of the type proposed is twice as radioactive and twice as hot as spent fuel from reactors such as Sizewell B (green line below).

**Chart 4**



The need for additional cooling will drive difficult choices for safe management, as the IAEA acknowledge:<sup>46</sup>

“The higher burnup of fuel has a significant impact on the choice of the storage option and on the design of storage systems, due to the increased decay heat, inter-alia, which is roughly proportional to burnup, imposing a higher cooling load to the storage system.”

The high burnup spent fuel resulting from the EPR and the AP1000 indicated by the red line in Chart 4, has twice legacy waste’s thermal power, and this persists indefinitely. Dry cask storage systems will have to cope with much greater cooling loads and provide much greater shielding. Alternatively, the high burnup spent fuel would be left in cooling pools for thirty years instead of five years. In the US this stark choice is resulting in operators seeking to reduce the risks and costs associated with high burnup spent fuel by transferring responsibility to the taxpayer before dry casks are used:

“To minimize operational risks and lower costs, utilities can be expected to send the high-burnup fuel directly from their spent fuel pools to the repository. Under those conditions, (US) Department Of Energy will assume responsibility for dry storage until the spent fuel is ready to be disposed.”<sup>47</sup>

This suggests what may happen in the UK. Fifty years after discharge, the thermal power of spent fuel from new build PWR’s will still exceed the 1160 Watts limit set by NDA/Nirex for spent fuel packages for disposal by a large margin.<sup>48</sup> This problem might be addressed by spacing out the high burnup spent fuel in more containers covering a wider area to avoid a build up of heat, which would affect the waste, its containers, the engineered barriers and the ‘host rock’ formations. There are doubts about whether the geology of the UK contains a large area enough with sufficient homogeneity for such a facility. Alternatively, the high burnup spent fuel would be left in the on-site interim stores for 100 years instead of fifty years before being disposed of underground. It is unlikely that the reactor operator will be in existence by then.

### **Radiation – gamma and neutron**

While the gamma dose rate increases in proportion with the burnup, the neutron dose rate increases by the fourth power of the fuel burnup (due to the build-up of Cm-244, the primary neutron source). Thus there is a<sup>49</sup>:

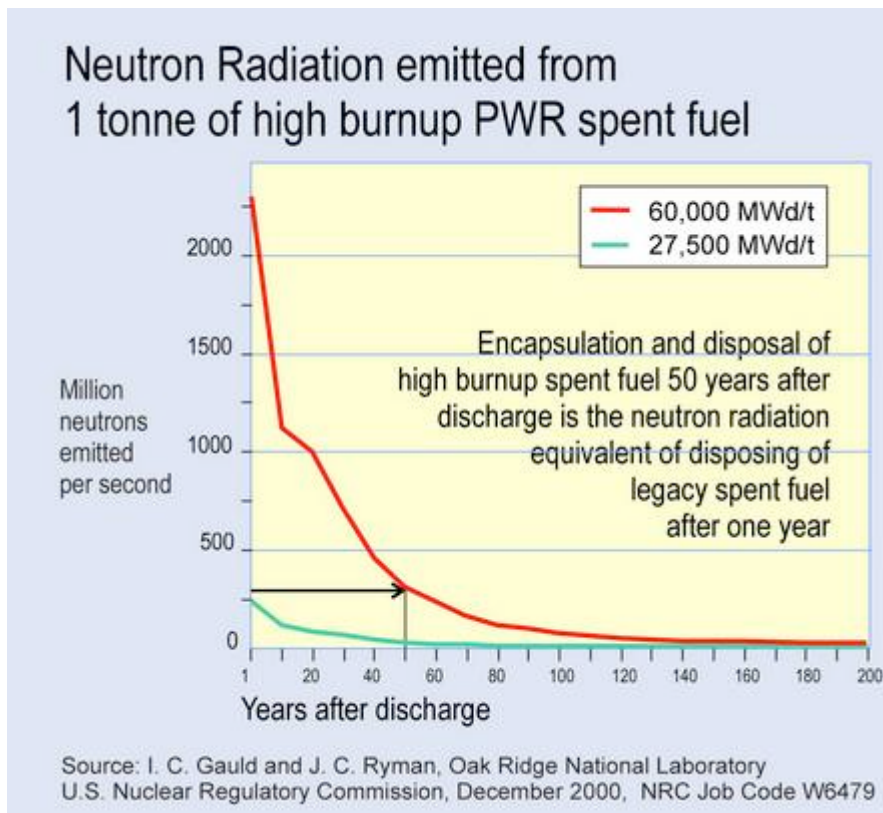
“..rapid increase in the neutron dose rate component with burnup relative to the gamma-ray component.”

The ten-fold biological effectiveness of neutron radiation (compared with gamma) makes every transfer of high burnup spent fuel particularly hazardous. Even after 50 years high burnup spent fuel emits more neutrons per second than Sizewell B spent fuel (30,000 MWd/tU) one year after discharge.

Encapsulation and disposal of such fuel may prove impossible. Chart 5 illustrates the problem. It is not clear from the information submitted to government how the designers intend to shield workers and public once the spent fuel is no longer shielded by eight metres of borated water. AREVA acknowledge that spent fuels with higher gamma and neutron radiation levels than current fuels will require greater shielding and that coping with this is still at an experimental stage.<sup>50</sup>

“....to work towards achieving the ‘low as readily achievable’ criterion in relation to the control of radiation doses to workers and the public .....efforts are being focused on developing enhanced shielding designs.

Chart 5



Neutrons have the capacity to irradiate people within hundreds of metres of dry cask arrays. Without details of the radiation shielding designs, and the engineered barriers necessary to protect the public from large arrays of spent fuel casks, the Environment Agency’s March 2008 statement that the annual radiation impact of the reactors on people is well below the UK limit is strange.

Scandinavian work on concepts for spent fuel disposal has not solved the practical problems of managing and disposing of high burnup spent fuel.

The encapsulation plants planned in Sweden and Finland are designed to protect workers from the radiation emitted by ‘normal’ spent fuel (under 45,000MWd/tU). Similarly even the KBS3 disposal canisters intended for spent fuel from the first EPR under construction at Olkiluoto are for an average burn up of 48,000MWd/tU.<sup>51</sup> Similar parameters guided work on underground repositories and the shielding for emplacement machines.

In 2006, after fifteen years of inconclusive research on deep underground burial, the failure to find a solution lead the French parliament to authorize continuation of both this work and that on long-term storage of the wastes. The latter includes four types of sub-surface storage facilities, including one providing centralised storage for material with strong thermal density and having an ‘evolutionary system of cooling’. Such storage facilities would guarantee the preservation and recovery of packages “for periods of up to 300 years” but “is not designed to become final”.<sup>52</sup>

Our government’s proposal is that the operators would, after a period of storage to allow the spent fuel to cool down and become less radioactive, encapsulate

the waste in containers that could be accepted for disposal, and at that time the taxpayer would take title to and responsibility for the waste.

Despite characterising their wastes as 'easier-to-handle' all the nuclear industry submissions to government consultation on the subject strongly objected to the encapsulation of spent fuel on-site, preferring it to be encapsulated centrally at the repository. According to British Energy and the NIA this is because encapsulation requires a large, complex and expensive plant.<sup>53</sup>

Having already secured the principle of a fixed price to dispose of spent fuel, the nuclear industry wants more from government, and is actively lobbying for the taxpayer to take their high burnup spent fuel off the site in its raw state, encapsulate it centrally in the plant that will condition legacy waste, and then dispose of it in deep geological repositories.

Encapsulation of high burnup spent fuel requires a plant with much greater provision of radiation shielding than that envisaged for 'legacy' spent fuel. Both Westinghouse and EDF believe a common facility for spent fuel encapsulation at the repository site would be 'more cost effective' than nuclear operators doing it on-site.

Demonstrating the ability of not just the proposed reactor designs but their spent fuel storage facilities to withstand aircraft attacks or 'Islamabad Marriott' type truck bombs is central to establishing public acceptance of new nuclear power stations. If such an attack did result in the release of radioactive material anywhere in the world it could threaten the viability of commercial nuclear power.<sup>54</sup> Yet far from examining these issues openly they are being ignored.

## **Conclusions**

A predictable outcome of government presenting Britain as the best place in the world in which to invest in nuclear power is that untried, untested ideas are being pushed harder in Britain than elsewhere. Neither the reactor vendors, nor the government and its agencies, have properly considered uncertainties about the safety and the feasibility of long-term storage of high burnup spent fuel or its direct disposal. There are signs that the designers cannot face the consequences of their designs. They want the government to take responsibility for disposing of the waste but have not yet decided on the ways in which it will be kept safe until they can get rid of it.

Significant additional hazards are to be imposed on nuclear sites, without proper consultation based on sufficiently detailed information from the nuclear industry.<sup>55</sup> The use of high burnup (60,000MWd/tU) fuel is in its infancy and there is no experience of its long-term management after discharge. This will lead to a series of grave consequences:

- High burnup spent fuel is twice as hot and twice as radioactive as 'legacy' spent fuel.
- It emits ten times as many neutrons per second as legacy spent fuel.
- Dense-packing of high burnup spent fuel in the pools increases the likelihood of a fuel fire and meltdown should the pool water be lost in an accident or terrorist attack.
- Insufficient information has been supplied for the management or the safety of high burnup spent fuel to be assessed.
- No details of wet or dry 'interim spent fuel stores' have been provided, so it is impossible to judge their ability to withstand aircraft attacks.
- Existing dry casks cannot safely accommodate high burnup spent fuel.

- The accumulation of high burnup spent fuel at the sites of new reactors will increase the radiological hazard beyond the existing vulnerability on nuclear sites, and cannot be justified.
- High burnup spent fuel will require greater radiation shielding during encapsulation and deep underground emplacement, and no designs for its safe encapsulation and emplacement exist.
- It cannot be accommodated in the same 'deep geological repository' as that intended for legacy spent fuel and high level waste.
- The peak of radioactivity from a new programme of reactors will occur at least seventy years later than legacy waste.
- As high burnup spent fuel would be far more hazardous but doesn't yet exist, its creation requires a quite separate and more rigorous process to test and validate proposals for its management and disposal.

Far from demonstrating beyond reasonable doubt that a method exists to ensure the safe containment of long-lived, highly radioactive waste for the indefinite future, the nuclear industry proposes to:

- Use highly enriched fuel about which there is even greater uncertainty in operation, in storage and in disposal.
- Withhold detailed information on the quantity and nature of the spent fuel.
- Clad it in alloys designed to endure in reactors with no regard to its long term storage capabilities.
- Pack it densely in spent fuel pools that cannot withstand direct impact from large aircraft.
- Avoid providing details of facilities for the safe containment of spent fuel outside the spent fuel pools.
- Accumulate up to 60 years worth of spent fuel on each reactor site.
- Ask government to take spent fuel off their hands for encapsulation elsewhere.
- Transfer responsibility for spent fuel before a method is demonstrated to exist to ensure its safe long term containment, retrieval or disposal.

Since Sept 11<sup>th</sup> 2001 we have learned to be suspicious of prospective pilots who want to learn to take off and fly aeroplanes but show no interest in learning to land them. There is an appalling resemblance in an industry that wants to build and operate nuclear power stations but shows little interest in what it is going to happen with the lethal waste that results. The possibility that these dual threats could come together should preclude the development of nuclear power. Indifference to the possibility would be a dereliction of the primary duty of government, as sole 'justifying authority', to ensure the security of the nation.

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and has been submitted to NDA in confidence under contractual arrangements (section  
41 "information supplied in confidence" of the Freedom of Information Act 2000 is  
applicable). We have sought advice from the Requesting Parties asking their agreement  
to the release of the information, but this has not been granted.