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SUSTAINABLE DEVELOPMENT COMMISSION

PEER REVIEW OF THE AMEC-NNC REPORT

ROLE OF NUCLEAR POWER IN THE LOW CARBON ECONOMY
SAFETY AND SECURITY

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THIS PEER REVIEW SHOULD BE READ IN CONJUNCTION WITH THE MARKED-UP VERSION OF THE AMEC-NNC REPORT (R3141-A1)

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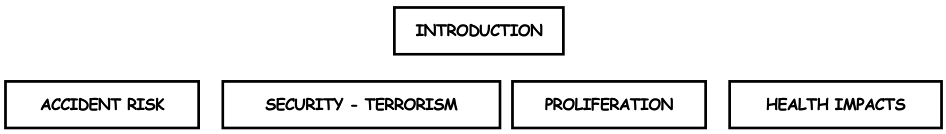
PEER REVIEW FOR THE SUSTAINABLE DEVELOPMENT COMMISSION

ROLE OF NUCLEAR POWER IN THE LOW CARBON ECONOMY - SAFETY AND SECURITY

IN GENERAL:

There are a number of difficulties with the AMEC-NNC reporting on the safety and security issues of nuclear power plants, essentially, these being it is a rambling and often confused account; it is intellectually shallow and, in places it is misleading and sometimes factually incorrect.

In terms of content, the effort is spread over sections dealing with



but these sections poorly inter-relate and do not fit together to present a whole and consistent appreciation of the safety and security of any future nuclear power programme in the United Kingdom.

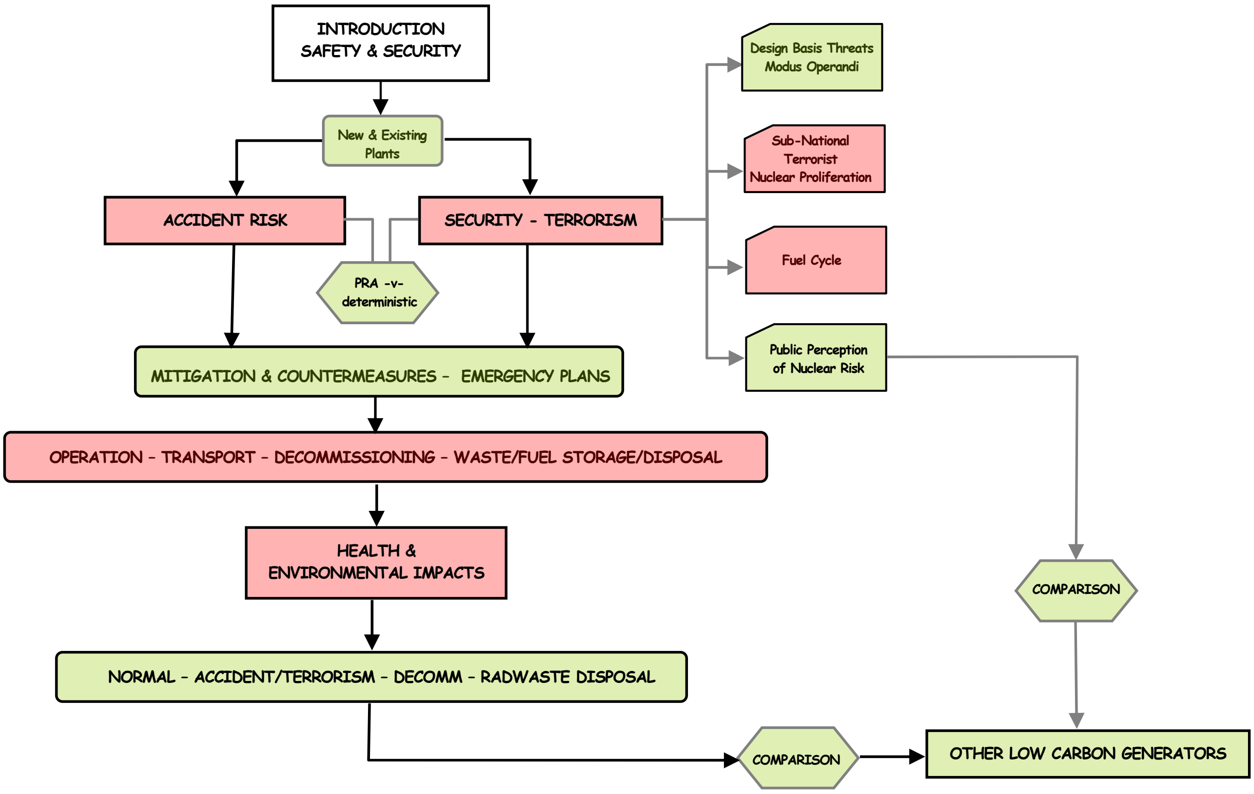
Moreover, there are a number of shortfalls and omissions in the AMEC-NNC reporting, including:

- it is not at all clear from the introduction if only modern (Generation III AP-1000 and EPR) reactor technology forms the basis of the review or if the role (safety and security) of existing and decommissioned plants are included;
- there is no explanation of the different approaches required to account for accidents *-v-* malevolent and terrorist acts;
- the health impact section almost exclusively deals with normal operation at the neglect of the likely disproportionate health consequences of untoward releases of radioactivity, the burden of future decommissioning the hulks of closed down reactors and, in the longer term, any detriment arising out of this generation's disposal of radioactive waste;
- there is minimal discussion of radiation exposure mitigation measures during and in the aftermath of abnormal release situations, such as the effectiveness of on- and the off-site emergency response;[1]
- the effort spent on nuclear proliferation, perhaps unnecessarily, extends the work into the international political domain;
- not covered by AMEC-NNC in its consideration of security is the vulnerability of nuclear facilities in times of war; and, importantly,
- there is no baseline comparison with other forms of low carbon generators.[2]

The content of the AMEC-NNC work might be improved with the introduction of new and revised elements integrated into the following outline structure:

[1] Off-site countermeasures, etc., as required by the *Radiation (Emergency Preparedness & Public Information) Regulations 2000.*

[2] Although this may be an omission in the SDC specification of the work.



IN DETAIL:

The **INTRODUCTION** makes a point of not giving regard to any site location although it acknowledges that siting is likely to be an issue, specifically relating the susceptibility of certain sites to past republican Irish actions, but this assertion is largely unfounded [JHL11].[3] However, a discussion on siting, and specific locations, would be of interest because it would introduce the quite comprehensive risk assessment and siting selection criteria pioneered by the early nuclear industry, particularly Farmer,[4] and thereafter leading to the very sophisticated methodology in use today.

If it is generally accepted that any new nuclear build would, at least for the first units, be located at existing sites most probably where the earlier A station had closed down for decommissioning, the local community might by now be comfortable with the risk whereas, in contrast, a community unfamiliar with a nuclear plant on its doorstep might develop a burgeoning anxiety over the introduction of a high technology hazard that is actually disproportionate to the actual risk. This contrast demonstrates the somewhat fickle public perception of such things that, whereas some communities and individuals are quite at ease with nuclear technology, others consider any exposure to radiation to be a *'fate worse than death'*. This should have been a worthy of further examination, not only being a possible proponent to demonstrate the case *for* new nuclear builds but, also, enabling some basis to compare these perceived risks for nuclear with other low carbon forms of generation.[5,6,7,8]

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3 Comments enclosed thus [.. . .] refer to the comments appended to the AMEC-NNC draft *R3141-A1 JHL Comments*.

4 Farmer, F R *Siting criteria - a new approach*. Atom, Vol. 128, 152-178. (1963)

5 See also United States Nuclear Regulatory Commission *Probabilistic Risk Analysis, WASH 1400*, 1975

6 For a general discussion of perception of risk *Risk*, Royal Society 1983 and 1992

7 On comparisons of public perception to nuclear and other hazardous plants Lee T R., Brown J, Henderson J, McDermid C, White K., Rees K and Fielding J (1985) *Social Aspects of Radioactive Waste Management*. report to NIREX (Unpublished).

8 For a general discussion of the subject of risk perception, Lee T R *Reconciling Lay and Expert Evaluations of the Riskiness of Hazardous Technologies*, School of Psychology, University of St Andrews, 2004

In other words, AMEC-NNC should have addressed the following:

- Why, apparently, is the public so hostile to nuclear power and if the topics of *safety* and *security* of nuclear installations are important factors contributing to this?
- So, it follows, is nuclear power actually unsafe or is it that it is only sections of the general public that perceive it to be unsafe?
- Is there a basis of comparison between how the safety and, possibly, security regimes are applied to nuclear plants *-v-* other low carbon generators?
- Is this safety regime the same for all types of plants (ie the Health and Safety at Work, Etc Act 1974), or is it harsher or more relaxed for nuclear plants?

In the section addressing **ACCIDENT RISK** the discussion is overly reliant upon the so called *International Nuclear Event Scale* or INES which, like the Beaufort Wind Force Scale [JHL18], has little real meaning when applied to post-analysis of incident severities. The cross analysis of INES rated incidents between UK and France is of interest but, for this, AMEC-NNC relies upon a possibly bias nuclear industry source [JHL23] and seem to disregard the IAEA caution that it is not appropriate to use the INES for meaningful international comparisons.[9]

AMEC-NNC present a number of past accidents as example, describing these in terms of the detailed sequence of events that led to failure whereas, in fact, almost all of the 'accidents' presented are examples of a broader institutional failure, being attributed to the nuclear industry (and its regulators) as a whole rather than just being laid on the shoulders on one individual or the failure of a simple (or complex) technical gizmo. The sense projected by AMEC-NNC is that the nuclear industry, collectively, learns from each of these events so that it can never happen again but, in arriving at this conclusion, AMEC-NNC has not resisted the temptation to dismiss the causes of these accidents as 'obvious' and, in this respect, its hindsight is deceptively unreliable.

For example, in describing the Windscale fire of 1957 much is made of the complexity of how and in what detail the plutonium producing pile cascaded uncontrollably down the route to fire, but no reference is made to Penny's damming conclusion[10] that the most serious omission was the almost complete lack of formal operating documentation. When discussing causes for the Chernobyl, AMEC-NNC notes that this event arose, in part, because of lack of adequate preparation (ie paperwork) and that this could never happen in the UK, whereas it did at Windscale in 1957, and more recently at THORP, Sellafield in 2005.[11,12]

In other words, AMEC-NNC thinking on and approach to nuclear safety is channelled into the paradigm *'it could never happen here (again)'* because as it rightly claims the United Kingdom has, over the years, developed an impressive safety regime that, with a few exceptions, has successfully operated by the UK nuclear industry and its regulators. But rather than examine the underlying reasons for the apparent success of the UK's safety regime and if there are any latent weakness lurking within it, AMEC-NNC choose to describe the scantlings (the SCLs, SAPs, BSLs and BSOs etc) that hold the nuclear safety regime in place but which do not give insight into its fundamental principles and application. Thus, it would have be more appropriate for safety and accident risk to have been discussed in terms of the adequacy of the engineered and management systems to detect and respond to the underlying causes of incidents, that is exploring the organisational structure and decision-making at senior management levels[13] and, particularly, recognising that the responsibility and authority for nuclear safety extend far beyond the nuclear plant boundary. It is this organisational structure or 'institution' that enables complex, hazardous plants to operate within a specified and 'tolerable' safety regime – this is something more than AMEC-

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[9] *The International Nuclear Event Scale: User's Manual* (2001 Edition). International Atomic Energy Agency, 2001

[10] Penney W, Scholand B, Kay J and Diamond J, *Report on the Accident at Windscale No 1 Pile on 10 October 1957*, Report to the Chairman of the United Kingdom Atomic Energy Authority, October 1957

[11] Large J H *Leak of Radioactive Liquor in the Feed Clarification Cell at BNG THORP Sellafield, Review of the Management and Technical Aspects of the Failure and its Implications for the Future of THORP*, November 2005 - http://www.largeassociates.com/R3127-a2%20frontispiece.pdf

[12] Board of Inquiry Report, *Fractured Pipe with Loss of Primary Containment in the THORP Feed Clarification Cell*, 26 May 2005, BNG but released publicly in redacted form on 29 June 2005.

[13] Weaver K, *A Review of Safety Considerations in Organisational Decision Making*, Canadian Nuclear Society, Ottawa 1989

NNC's much lauded mechanistic redundancy and diversity based *safety culture* matched to the somewhat idealised and abstract NII *Safety Assessment Principles* (SAPs).[14]

Put another way, nuclear technology has advanced so rapidly but with so few serious accidents en route it is impossible to extrapolate into the future from the meagre pool of past system and human failures. The weakness of the AMEC-NNC presentation of risk is that it is rooted in aggregating the probabilities of failures from a very large number of sub-systems (eg valves, welds, pumps etc.) then matching these to regulatory targets (SAPs), arriving at risks that are remote (eg One in a Million and less) but which are, presented this way, inconceivable to members of the public – AMEC-NNC's vision of nuclear power plants is that these are failsafe, unsinkable ships but the public know that the unsinkable Titanic sank and it did so on its maiden voyage (One in One).

AMEC-NNC's presentation of nuclear safety results in dichotomy: On one hand, it fails to properly acknowledge the very impressive achievement of the UK nuclear industry in the safety of operation of its nuclear plant and systems but, on the other, it skips over cases of utter bungling, particularly in the front- and back-end fuel processes.[11,[JHL20]]

When discussing **SECURITY ISSUES**, **AMEC**-NNC suggests that the response of a plant designed to ride out a range of accident situations by virtue of the diversity and robustness of the active countermeasures or, ultimately, via passive features that can only lead to its closedown, will be sufficient to withstand any reasonably foreseeable terrorist action. It follows, that this reasoning results in the flawed logic that any *reasonably foreseeable* terrorist act would not result in radiological consequences greater than those arising out of any of the design-basis accident scenarios for which the plant is protected against.

However, accidental and intentional (malevolent) events are very much different and should be treated as such [JHL36], particularly in that a terrorist act is likely to be an intelligent, intentional action that seeks out the vulnerabilities of the target plant and, moreover, which may go on to disrupt any post-event emergency actions and countermeasures put in place to mitigate the consequences.[15,16] It follows that that the probability or chance of the occurrence of a malicious human act, such as the terrorist attack of 11th September (9/11), cannot be determined by classical *a priori* probabilistic means, thus it is only realistic to apply chance to the success of the attack once it has been initiated.[17,18,19]

Indeed, AMEC-NNC considers aircraft impact in some detail but for this relies upon a somewhat doubtful reference [JHL44] in the claim that the reactor containment would withstand a commercial aircraft impact even though that prior to 9/11 the impact by large aircraft was not a design requirement. In fact there have been a number of pre-9/11 aircraft <u>accident</u> impact studies which demonstrate existing reactor containment structures to be vulnerable but evaluate the risk or frequency of such a event to be acceptably low.[20,21,22,23] Also, it is a

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14 *Safety Assessment Principles for Nuclear Plants*, Nuclear Safety Directorate, Health and Safety Executive, 1992

15 Large J H *The Implications of September 11 for the Nuclear Industry,* United Nations for Disarmament Research, Disarmament Forum, 2003 No 2, pp29-38

16 Large J H and Schneider M, *International Terrorism - The Vulnerabilities and Protection of Nuclear Facilities*, Oxford Research Group, December 2002,

http://www.largeassociates.com/TerrorismLargeSchneider.pdf

17 Put another way, applied to the terrorist attack of 11th September the P_{hit} or success rate was 3 out of 4 airborne aircraft, (P_{hit} = 0.75), which means that the hijackers had obtained sufficient flying skills to ensure that, once that the aircraft has been commandeered, the mission would have a high, almost certain rate of achieving its objective.

18 There are many publications addressing the motives of international terrorists but an excellent basis is the *9/11 Commission Report*, Final Report of the National Commission on Terrorist Attacks upon the United States August 2004

Summary at http://www.9-11commission.gov/report/911Report_Exec.htm

19 Although it is acknowledged that this is drawn from a statistically insignificant grouping (just the 11th September data), the assumptions for the Sizewell B aircraft impact safety case include a reliability on military pilots to avoid the vulnerable parts of the building must also be drawn from a lean set of data although this is permitted in *Accident Analysis for Aircraft Crash into Hazardous Facilities*, DOE-STD-3014-96, 1996 and also for practical application *NUREG-0800, Section 3.5.1.6 Aircraft Hazards*, Nuclear Regulatory Commission, 1981. If the aircraft that crashed in Pennsylvania is discounted, the P_{hit} for those aircraft on their target run was 3 out of 3 or 100% - the AMEC-NNC ground size footprint analogy between the World Trade Centre, Pentagon and the fuel store and reactor containment buildings is meaningless because, after all, large commercial aircraft land on a runway strip (and pilots are expected to do this without beacon guidance) that is narrower in width than a nuclear power plant island.

20 *Accident Analysis for Aircraft Crash into Hazardous Facilities*, DOE-STD-3014-96, 1996 see also for practical application NUREG-0800, Section 3.5.1.6 *Aircraft Hazards*, Nuclear Regulatory Commission, 1981

relatively straightforward calculation to show that the structural materials and thicknesses typically deployed in containment structures would be penetrated by 'hard' components (undercarriage spars, turbine shafts, etc) of the aircraft that detach and thereafter act as free-flying missiles[24] and, quite independent of this, that the building structure would be prone to collapse solely on the basis of energy exchange during the impact sequence.[25]

So, past analysis of accidental commercial aircraft impact has revealed nuclear containments to be at risk but, since the anticipated frequency is assessed to be so low (less than 1 in 7 million), the event was deemed incredible, so much so that no engineered defence was considered necessary. Now, following 9/11, those same nuclear power plants could be targeted for intentional aircraft impact using much the same, if not heavier and more fuel laden commercial aircraft, but AMEC-NNC consider even existing nuclear plants to have somehow transmogrified to be able to resist such attack [but see JHL44].[26]

A major weakness in the reasoning of AMEC-NNC is its failure to recognise that the modus operandi of a would-be terrorist is flexible and not confined solely to that of aircraft crash [JHL47]. In the United States a number of regulations specifically considered means to avert acts of radiological sabotage,[27] with these developing into licensing requirements in the form of *Design Basis Threats* (DBTs) as defined by the Nuclear Regulatory Commission (NRC). The NRC requires nuclear plant operators to submit to *force-on-force* trials simulating a range of intentional malicious actions perpetrated by various groups and individuals[28,29] with, since 1991, the NRC having conducted 91 trials or *Operational Safeguards Response Evaluation* (OSRE) tests. When subject to OSREs, about 45% of the tested nuclear plants failed and, most disturbing, is that three plants tested shortly before 11^{th} September, Farley, Oyster Creek and Vermont Yankee, were the worst on record. In another

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21 *Evaluation of Aircraft Crash Hazards for Nuclear Power Plants*, Kot C A, et al, Argonne National Laboratory, 1982 which gives a chance of crash into a nuclear plant 11.5 miles to the south of an air corridor at 33,000 ft to be about 2.36×10^{7} per year and *Evaluation of Air Traffic Hazards at Nuclear Power Plants*, Hornyik K, Nucl Technology 23, 28, 1974

22 *Aircraft Impact on Sizewell B*, Part 1 *Safety Involvement of Buildings on Site*, PWR/RX774 (pt 1) 1987

23 Sizewell B PWR Supplement to the *Pre-Construction Safety Report on External Hazards, Aircraft Crash*, CEGB Report No GD/PE-N/403, 1982, *Aircraft Impact on Sizewell B*, Part 2(a), *The Effects of Impact of Heavy Aircraft Adjacent to but not directly on Vulnerable Buildings.* (b) *Light Aircraft on the Vulnerable Buildings*, PWR/RX774 (Pt 2), 1987 and *Aircraft Impact on Sizewell B* Part 3 *Fire Following Aircraft Crash*, PWR/RX774 Part 3, 1987

24 After R F Recht, *Ballistic Perforation Dynamics of Armor-Piercing Projectiles*, NWC TP4532, 1967. which, for a blunt nose ogive, is

$$x = 1.61M/(bA)[V - a/b\ln([a+bV]/a)]$$

where a and b relate to the material properties of the target, M is the mass of the projectile and V the projectile closing velocity. For an aircraft impact, if it is assumed that a sufficiently robust penetrator will present itself in the form of a main turbine shaft of an aero engine which, with its blades and other attachments, might represent a mass of 0.25 tonnes of 150mm projected diameter (stub end of shaft), typical strength of materials properties give $a = 2.10^{9}$ and $b = 10.10^{6}$, so that the final penetration thickness into a steel element (ie a building stanchion) is about 200mm.

25 The maximum impact i_t before yielding commences is given by

$$i_r = [2Lim/En]^{0.5}\, \partial_y/Ah$$

which (adopting conventional notation) for a typical rc construction, with a roof slab load per column assumed at 35t, the structure yields at about 1,750 Pa-s. The impulse force arising from a crashing aircraft of, say 200 tonnes all-up weight considered impacting over its projected front end fuselage area (about $30m^2$) with the event lasting over the entire collapse of the fuselage length, gives an impulse force of about 20,000 Pa-s or about x10 the yield strength of the typical reinforced concrete structure described above. Just on the basis of kinetic energy alone the three levels of aircraft crash referred to, for example, by the STUK regulator in considering the nuclear safety case of the EPR now under construction in Finland, increase from Level 1 (light aircraft) to Level 2 (Jet Fighter) to Level 3 (Commercial) airliner in the ratio 1 to 50 to 1500 or that the energy available from a crashing commercial airline (impact alone) is 1500 times that of a light aircraft.

26 Complex engineered systems, such as a nuclear power plant, take considerable time to introduce, design, prove and gain approval of major revisions so adapting a PWR design for the events of 9/11 might, overall, occupy about 10 years once that the process of change had been initiated.

27 US Code of Federal Regulations *Requirements for Physical Protection of Licensed Activities in Nuclear Power Reactors Against Radiological Sabotage*, S55, PT73

28 The groups identified by the NRC include for an armed insurgency groups and individuals such as passive insiders (those who provide sensitive information), active insiders and a 'Farmer Brown' character who is taken to represent any aggrieved individual, such as the Oklahoma Bomber. The DBTs comprise a range of activities including plant sabotage, truck bombs at the perimeter of the plant, and armed insurgency and failure of the OSRE is if a key critical area of the plant is entered or damaged to the extent that safety function can no longer be fulfilled [JHL47].

29 Brousse C, et al, *IRSN Activities in Physical Protection in Support of the IAEA: The Insider Threats Approach*, EUROSAFE 2003, Seminar 5 Nuclear Material Security

http://www.eurosafe-forum.org/forum2003/seminaires/5_9Paper.pdf.

assessment, the NRC notes that between 15 to 20% of US nuclear plants would sustain safety critical levels of damage from vehicle bombs accessing close to the supervised boundary of the plant.[30]

AMEC-NNC dismiss the intrusions into Sizewell B nuclear power station in 2003 by Greenpeace UK as being easily recognisable to be stunts because of the large number of individuals involved. To the contrary, the second Greenpeace incursion involved only a small group of campaigners (11) in the absence of the usual glare of publicity, being modelled on the NRC's 'armed insurgency group' DBT OSRE. Contrary to the reporting of this exercise by AMEC-NNC [JHL40], the Greenpeace group entered a number of key areas of the plant, they were not challenged by security guards for about 20 minutes into the escapade and the much bemused and unarmed local police officers did not attend the incident until about 1 hour 20 minutes had passed. Clearly, on that occasion Sizewell B nuclear power station would have failed the NRC OSRE if such applied in the United Kingdom.

AMEC-NNC might have also referred to a substantial number of reports and studies undertaken by the French Authorities following the 9/11 terrorist attacks,[31,32,33] and the numerous recommendations and outpourings of the International Atomic Energy Agency (IAEA) for the security of land based nuclear plants. As well as identifying a number of plant weakness and DBT scenarios that have not been voiced by the UK nuclear industry, these concerns illustrate the international dimension of nuclear terrorism.

There are a number of errors and significant omissions in the AMEC-NNC treatment of the transportation of new and irradiated (spent) fuels [JHL52] and, particularly, it is misleading to present the IAEA testing regime for spent fuel[34] as proof against terrorist attack because these regulations give no cognisance whatsoever to malevolent acts, being based solely on simulating certain accident conditions. In fact, the IAEA itself recognises the transportation stage of nuclear and radioactive materials to be particularly vulnerable to terrorist attack, calling for special arrangements, especially for *Category 1* materials.[35,36,37]

Analysis and tests have demonstrated that the transportation flasks are vulnerable to terrorist actions, both from shaped or propelled explosive charge,[38,39] from fire being deliberately set when the flask(s) are trapped within a confined space,[40] such as a tunnel or ship hold, generally with the security arrangements overall for the transportation of new, unirradiated MOX fuel and spent fuel,[41,42,43,44,45] and acts of sabotage.[46]

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30 Lyman E, *Terrorism Threat and Nuclear Power: Recent Developments and Lessons to be Learned,* Rethinking Nuclear Energy and Democracy after 09/11, Int Symp, PSR/IPPNW Switzerland, Basel April 2002

31 Cornu P, et al *Protection of Nuclear Facilities and Nuclear Materials Against Malevolent Actions*, EUROSAFE 2001 Nuclear Risk Management, Seminar 5 Nuclear Material Security. http://www.eurosafe-forum.org/down2001/semb5_3.doc.

32 Vernot R, et al, *Physical Protection, Accountancy and Control Systems Vulnerability Assessments*, EUROSAFE 2002, Seminar 5 Nuclear Material Security.

http://www.eurosafe-forum.org/ipsn/pdf/euro2_5_5_physical_protection.pdf.

33 Aurelle J, et al, *Short and Medium Term Consequences of the 11th September Attacks on Physical Protection Activities in France*, EUROSAFE 2002, Seminar 5 Nuclear Material Security. http://www.eurosafe-forum.org/ipsn/pdf/euro2_5_2_consequences_france.pdf.

34 IAEA Safety Standards Series, *Safety Requirements, Regulations for the Safe Transport of Radioactive Materials*, TS1-R-1

35 IAEA, *Convention on the Physical Protection of Nuclear Materia*l, INFCIRC/274/Rev.1, May 1980.

36 IAEA, *The Physical Protection of Nuclear Material*, INFCIRC/225/Rev.4 (corrected), June 1999.

37 Large J H. Marignac Y, Submission to the International Atomic Energy Agency - Convention on the Physical Protection of Nuclear Material (CPPNM) – IAEA InfCirc/274 & InfCirc/225/Rev.4 - *IAEA Requirements on Design Basis Threat Assessment - Non Compliance of Eurofab LTA shipment from US to France on UK Vessel: Security and Physical Protection Issues*, IAEA 20 September 2004

http://www.largeassociates.com/JointAssessmentIAEA.pdf

38 *Behavior of Transport Casks Under Explosive Loading* Didier Brochard, Bruno Autrusson, Franck Delmaire-Sizes, Alain Nicaud, Institut de Protection et de Sûreté Nucléaire; F. Gil, CS Communications et Systems Group; J.M. Guerin, P.Y. Chaffard, F. Chaigneau, CEA/DAM Ile de France.

39 *International Initiatives in Transportation Sabotage Investigations* Richard, SNL; Bruno Autrusson, Didier Brochard, IPSN/DSMR/SATE; Gunter Pretzsch, GRS; Frances Young, J.R. Davis, US NRC; Ashok Kapoor, US DOE, F. Lange, Gesellschaft für Anlagen-und Reaktorsicherheit - Dietrich, A.M., and W.P. Walters*, Review of High Explosive Device Testing Against Spent Fuel Shipping Casks*, Prepared by U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, Prepared for U.S. Nuclear Regulatory Commission, 1983.

40 F. Chalon, M. Héritier, B. Duret, *Numerical Study of the Thermal Behaviour of Packages Subjected to Fires of Long Duration*, in *Proceedings, PATRAM'98, 12th International Conference on the Packaging and Transportation of Radioactive Materials, Paris, 10-15 May 1998*, vol. 4, pp. 1773-1780.

41 Y. Marignac , X. Coeytaux, M. Schneider & al., *Les transports de l'industrie du plutonium en France: une activité à haut risque,* WISE-Paris, February 2003. English summary: http://www.wise-paris.org/english/reports/030219TransPuMAJ-Summary.pdf Report, in French only:

http://www.wise-paris.org/francais/rapports/transportpu/030219TransPuRapport.pdf

Appendices: http://www.wise-paris.org/francais/rapports/transportpu/030219TransPuRapport_Annexes.pdf.

42 Large & Associates, *Potential Radiological Impact and Consequences Arising from Incidents Involving a Consignment of Plutonium Dioxide under Transit from COGEMA La Hague to Marcoule/Cadarache*, R3108-A6, 2 March 2004,

The risk posed by nuclear reactor spent fuel in transit, obviously, it is not a matter of absconding with a transportation flask carrying irradiated fuel [JHL55] but more a terrorist action that might entrap the flask(s), say in a siding where an explosive charge might breach the containment,[47] or within a tunnel where the flask might be subject to fierce fire. Modelled by the National Radiological Protection Board (NRPB), a hypothetical terrorist attack on a PWR spent fuel flask standing at Willesden Junction in London, gave one airborne dispersion condition prediction of 1,300 fatalities over the interim and longer terms.[48]

AMEC-NNC has completely overlooked the potential health impact[49] arising from an airborne release of unirradiated mixed oxide (MOX) fuel.[50] Contrary to the claims by one MOX manufacturer (British Nuclear Group) that MOX is a low-dispersible material (LDM) which wins the support of AMEC-NNC in its description of the fuel pellets being generally *'not easily dispersed even under severe impacting and fire'* [JHL92], the IAEA *Transport Safety Standards Advisory Committee* (TRANSACC) has yet to accept MOX to be within this transport category, so Type B(M) transportation flasks are a prerequisite for its transport in order to minimise its release and airborne dispersion upon failure of the flask containment.[51,52]

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http://www.greenpeace.org/international_en/multimedia/download/1/424600/0/Large_report.pdf.

43 Large J H, 1) *Disposition of Surplus Weapons Plutonium Using Mixed Oxide Fuel – Comments on Opinion on the Applicability and Sufficiency of the Safety, Security and Environmental Requirements and Measures as these Apply to the Transatlantic Shipment, European Waters and France,* 2) *The Role of PNTL Ships in the Atlantic Transit Phases*, 3) *Summary of the Findings of the French-sourced Plutonium Dioxide Transportation*, 23 March 2004 – US Nuclear Regulatory Commission Hearing, 2004.

44 Y. Marignac, Large J H, S*afety and Security Concerns over the FS47 Transportation Cask*, September 2004.

45 B. Autrusson, D. Brochard (IRSN), *"The French approach concerning the protection of shipping casks against terrorism"*, paper from a presentation given in ASME Pressure Vessels and piping, Cleveland (USA), 21-24 July 2003

http://www.irsn.fr/netscience/liblocal/docs/docs_DEND/frenchapproach.pdf.

46 Halstead R, *Nuclear Waste Transportation Terrorism and Sabotage: Critical Issues*, State of Nevada, Agency for Nuclear Projects; James David Ballard, Grand Valley State University, School of Criminal Justice; Fred Dilger, Nuclear Waste Division, Clark County, Nevada - Audin, L., *Analyses of Cask Sabotage Involving Portable Explosives: A Critique*, Draft Report, Prepared for Nevada Agency for Nuclear Projects/Nuclear Waste Project Office, 1989 - Schmidt, E.W., Walters, M.A. and Trott, B, *Shipping Cask Sabotage Source Term Investigation*, Batelle Columbus Lab., Columbus, NUREG/CR-2472, BMI-2095 (Oct. 1982) - *Experiments to Quantify Potential Releases and Consequences from Sabotage Attack on Spent Fuel Casks* Florentin Lange, Gunter Pretzsch, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH; Eugen Hoermann, Dornier GmbH; Wolfgang Koch, Fraunhofer Institute for Toxicology and Aerosol Research.

47 See Footnote 12 of Large J H *A Brief Assessment of the Possible Outcomes of a Terrorist Attack on the Cogema La Hague Nuclear Reprocessing Works*, October 2005 http://www.largeassociates.com/3137-a1.pdf - for the range of armour piercing rocket propelled grenade rounds that could pierce the Excellox and CASTOR type flasks used for PWR fuel transport.

48 Shaw K B, Mairs J H, Charles D and Kelly G N *The Radiological Impact of Postulated Accidental Releases during the Transportation of Irradiated PWR Fuel through Greater London*, NRPB-R147, September 1983

49 Because of its long radioactive half-life (24,300 years) plutonium, remains a hazard for something like half a million years. Unlike chemical or biological hazards, plutonium is essentially impossible to destroy (except by irradiation in a fast-breeder reactor). Thus plutonium dispersed in an accident will be present in the environment essentially forever. Contaminated materials containing plutonium (PCMs), arising from clean-up operations, would need to be very securely disposed of to prevent eventual migration back to the environment over hundreds of thousands of years. The chief hazard from plutonium derives from the alpha particles emitted during its slow but steady radioactive decay. The combined physical properties of alpha particles (large mass and diameter, double positive charge) emitted by plutonium cause large amounts of energy to be transmitted from the alpha particles to living tissues when the particles travel through human or animal bodies and until the particles are absorbed. Typically over 100,000 ionisations of atoms and molecules might be caused by one alpha particle. Each such ionisation absorbs about 35 eV of energy from the alpha particle and results in electrons being released from some molecules in the living tissues and leaving behind positively charged atoms (radicals), and being absorbed by others. This process causes changes in the chemical structure in the area of the ionisations. Cells within about 10 microns of a plutonium-dioxide particle will be killed by this ionising radiation, whilst cells from 10 microns to 50 microns away are likely to have their genetic materials changed. Such changed cells are potential cancer cells. Cells that are not killed by the radiation may have various end results depending on how well or poorly the DNA is repaired and what sort of cell has been affected. The cells may become cancerous, weaken the body against infection (eg, in lymph nodes) or, in reproductive organs, cause birth defects. The alpha particles emitted by plutonium atoms which have lodged in bone (especially in the areas of the periosteum, endosteum and trabeculae) attack the radio-sensitive haematopoietic tissue in the bone marrow, leading to a reduction in the number of red blood corpuscles and serious effects on the body.

50 Large J H, *A Brief Assessment of the Possible Outcomes of a Terrorist Attack on the Cogema La Hague Nuclear Reprocessing Works*, October 2005

http://www.largeassociates.com/3137-a1.pdf

51 The substance qualifies as LDM if, during and following the tests, does not release an amount of activity greater than 100 times the A2 index in gaseous and particulate forms of up to 100 microns in diameter - *Requirements for Very Low Dispersible Material (VLDM)*, TC-946, F Lange, F Nitsche, F-W Collin and M Cosack, Working Paper No 11, IAEA Technical Committee Meeting, Vienna, 15-19 May 1995

52 Large J H, *Review of the Sea Transportation of Mixed Oxide Fuel: i) Transportation Risks and Hazards , ii) Physical and Dispersion Characteristics of MOX Fuel, iii) MOX Fuel, a UK Perspective*, Evidence to the New Zealand Government Foreign Affairs, Defence and Trade Select Committee, May 2001

http://www.largeassociates.com/R3063-MOX1.pdf …/ R3063-MOX2.pdf … / R3063-MOX3.pdf

Similarly, AMEC-NNC erroneously consider that the fissile material content of unirradiated MOX fuel is not suitable for fabrication into the fissile pit of an implosion type nuclear warhead and that it is difficult to separate and extract the plutonium from the sintered MOX pellets, although this has been challenged by a number of authoritative sources.[53,54,55] MOX fuel, which may[56] utilise so-called *reactor-grade* plutonium, is defined by the IAEA as a *Category 1* nuclear material [JHL52][36] solely on the basis of 'safeguards' issues.[57] Indeed, Hans Blix, the former Director-General of the IAEA has stated *"On the basis of advice provided to it by its Member States and by the Standing Advisory Group on Safeguards Implementation (SAGSI), the Agency considers high burn-up 'reactor grade' plutonium and in general plutonium of any isotopic composition with the exception of plutonium containing more than 80 percent Pu-238 to be capable of use in a nuclear explosive device. There is no debate on this matter in the Agency's Department of Safeguards"*.[58]

This assertion that plutonium yielded from irradiated light water reactor (PWR) fuel does not yield an isotopic quality that is suitable for use in a nuclear weapon [JHL75 & 77][59] is carried through to the **IMPLICATIONS FOR NUCLEAR PROLIFERATION**. Irrespective of this, AMEC-NNC's consideration of the Non-Proliferation Treaty (NPT) and Euratom extends the security consideration into the wider political arena which may not be directly relevant to the issues under review, and it is not clear what the lengthy narrative on the NPT is meant to convey [JHL61].

The section dealing with **HEALTH IMPACTS** is somewhat one-sided, considering as it does just the health detriment of normal operation and radioactive discharges. Remarkably, AMEC-NNC takes the opportunity to sideswipe at the stochastic (no-threshold) or LNT system adopted by the International Commission for Radiological Protection (ICRP). Presented as authoritative, the AMEC-NNC health impacts discourse is in fact somewhat lacking in its comprehensiveness, being not much more than an explanation of the radiological management regime presently in place in the United Kingdom.

The major shortcomings of this section are that

i) it fails to consider the case of *'what if'* an accident or terrorist event occurred that resulted in a radioactive release beyond the design basis;

ii) whether the emergency plans and countermeasures can, in the immediate and longer term aftermath of i), manage and mitigate the exposure and consequences;

iii) it does not assess the radiological legacy being left to future generations (from accumulating radioactive discharges, future decommissioning and the disposal of radioactive wastes);

iv) there is no account of the detriment carried by those who do not share in the 'benefits' of nuclear power (ie Eire, Norway and other non-nuclear power states);

and, for the purposes of assessing the safety and security of the role of nuclear power in the low carbon economy

v) it provides no comparison with other low carbon generators (and energy conservation measures) which, indeed, new build nuclear power might displace.

53 Barnaby F *Potential Terrorist Misuses of Plutonium and MOX*, Edited submission to the UK Government Energy Review, Oxford research Group, August 2002

54 Araujo, B F, Matsuda, H. T, Carvalho, E. I., and Araujo, I. C. 1992, *Plutonium removal by ion-exchange chromatography*, J. Radioanalyt. and Nuc. Chem.-Letters 165; 209-218

55 Mathur, J. N., Murali, M. S, Rizvi, G. H, Iyer, R. H., Michael, K. M., Kapoor, S.C., Ramanujam, A., Badheka, L. P. and Banerji, A. 1993, *Extraction chromatographic separation and recovery of plutonium from oxalate supernatant using CMPO*, J. Nuc. Sci and Technol. 30, 1198-1200.

56 The US and Russian Federation have agreed to each dispose of 34 tonnes of *weapons-grade* plutonium via conversion to MOX fuel for burning in commercial light water reactors – see footnote 43 for background information.

57 In other words, if AMEC-NNC's assertion that there is no military/terrorist use for reactor-grade plutonium is correct then why designate it INFCIRC 225 *Category 1* and have to go to all of the cost and inconvenience to transport in specially adapted radioactive material cargo ships that are heavily armed and crewed by armed police officers, and why does the United States Department of Energy classify it as a *Stored Weapons Standard* material for which it requires a greater degree of security and physical protection than that specified by IAEA INFCIRC 225/Rev 4 – see Section 4 of Ref 43 1).

58 Letter from Hans Blix, Director-General of the IAEA, to Paul Leventhal, NCI, November 1, 1990

59 The geometry of the US Trinity weapon detonated in the test of 1945 was capable detonating with a fissile pit fabricated in reactor-grade d-phase plutonium. In June 1994, U.S. Energy Secretary Hazel O'Leary declassified further details of a 1962 test of a nuclear device of the Trinity geometry using reactor-grade plutonium, which successfully produced a nuclear yield

Overall, a disappointing analysis on safety and security aspects of UK nuclear power plants and not, in my opinion, a definitive contribution to the Sustainable Development Commission's review of the role of nuclear power in a future low carbon economy.

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