(Not) Getting to "Go": Recent Experience in International Cooperation over the Management of Spent Nuclear Reactor Fuel

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Introduction[1]

Issues of nuclear waste management and disposal pose very serious problems in all countries with civilian nuclear power programs. Not only is there no acceptable way, in technological and political terms, of disposing of such wastes safely and permanently, no country has yet managed to build any sort of societal consensus behind approaches to the long term, or often even the interim, storage of radioactive wastes and spent nuclear reactor fuel. This is especially a problem with respect to the latter: around the world the cooling ponds next to reactors where spent fuel is initially stored after its removal from the reactor are filling up, leading firms to demand solutions from their governments or to seek out expensive and controversial alternatives, such as reprocessing. Nuclear waste management is also a highly politicized issue, and justifiably so, in many countries, with disputes over both content and process of policy making seemingly beyond resolution in many places. NIMBYism-"Not In My Back Yard"-predominates, but so does "reverse NIMBYism": there is substantial evidence that people not only don't want nuclear wastes in their own "backyards", but also that they don't want to transport or to export nuclear wastes to other communities or countries either. Moreover, nuclear waste storage and disposal sites in many cases are likely to be large, expensive and complex facilities, best situated in isolated areas. Yet, many small, densely populated countries run civilian nuclear power programs, and are unable to site or to afford their own waste management program.

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One approach to these problems that would seem appropriate is international cooperation, in particular the establishment of international sites where spent fuel from several countries could be shipped for storage or for final disposal. There has been a recent revival of interest in internationalizing spent fuel management, and a number of plans have been proposed by different groups, many of which put forward strong arguments in favor of such schemes; yet, despite the amount of time and energy devoted to this cause, none has yet been implemented. This paper outlines some of the factors that have inhibited the establishment of such international storage facilities to date and makes some tentative suggestions concerning approaches that might be taken to overcome these obstacles.

The first part of the paper discusses some of the basic issues involved in the internationalization of spent fuel management:

- First, it discusses the current status quo in civilian spent fuel management, looking at the amounts generated worldwide, at existing storage and reprocessing practices and at more qualitative issues, such as the risks spent fuel poses to the environment and to human health.
- Second, it examines why spent fuel management has become an international problem and considers some of the factors that provide the basis for and facilitate international cooperation in this area.
- The third part examines international spent fuel management schemes (usually regionally based sites serving a number of countries), their historical context, and the recent resurgence in interest in such plans.

Recent proposals for such schemes differ from earlier versions of this same notion in several respects. They are predicated on greater involvement of the private sector, often being advocated by individual or groups of entrepreneurs, and tend to place more emphasis

on civilian nuclear power management than on anti-proliferation goals. In turn, these plans have been put forward in a changing international security context, one that has facilitated more cooperation among the major powers, but also one that has led to more assertive nuclear independence-civilian and military--on the part of "smaller" powers. Finally, the debate over the continued utility of nuclear power rages on. Anti-nuclear activists are increasingly adopting high-profile tactics that span across national boundaries, while at the same time the nuclear industry has found renewed support in discussions of the role of nuclear power in a world subject to global warming as a result, in part at least, of the burning of fossil fuels.

I argue that while there is a strong case for an international regime that goes beyond the minimal goals of standardization, coordination, and information, the important question is why none has worked out in practice. Important factors here are the high levels of domestic opposition (demonstrated by recent "flashpoints" in the area of radioactive waste transportation), different national government interests and approaches, and other inhibiting factors. Subsequent sections address short to medium term actions that could ameliorate at least some of these problems to make an international solution a real possibility. They emphasize the need for an incremental approach to building consensus across the broad range of actors engaged or with an interest in this field. Finding the right balance of public and private involvement to ensure long-term responsible management and control as well as commercial viability is also extremely important.

Finally, I address the problems of finding host countries and sites, gaining public acceptance for opening such sites and the transportation of materials to them. Some of the lessons learned by the international community in addressing other international

environmental problems might well be put to use in this issue area.[2] Hence the policy suggestions are aimed primarily at an international target audience. In brief, this paper recommends that the best approach would be regionally based and governed, with particular emphasis on the commercial viability of such a program. To ensure basic safety, standardization of practices, and to facilitate monitoring of activities and improve the transparency of the international regime, an international rule structure needs to be established as well.

Spent Fuel Management: The Current Status Quo

Spent nuclear reactor fuel consists of "fuel elements that have been removed from nuclear reactors after use because they contain too little fissile and fertile material and too high a concentration of unwanted radioactive byproducts to sustain reactor operation" (Albright, Berkhout and Walker, 1997, p. xxv). It is made up of roughly 95% uranium 238 (U238) but also contains significant quantities of uranium 235 (U235) and plutonium (Pu), which add both to its radioactivity and to its economic and strategic value and when unloaded from the reactor it is highly radioactive and has an extremely high temperature. There are sharp differences of opinion as to whether Pu-containing spent fuel should be classified as a high-level radioactive waste-as is the case in the United States-or as an object of value, as it is in Russia and France; this debate has in fact driven much of the controversy over the relative merits of closed or open fuel cycles, to the extent that some think there is little utility

[2] One of the more obvious parallels with the issue of international management of spent reactor fuel is with the international trade in hazardous wastes and attempts at national and international levels to cope with increased volumes of hazardous wastes, as well as opposition to siting of disposal facilities. Thus, this paper draws out some of these parallels and some of the lessons (both positive and negative) that could be applied here.

in attempting to resolve this issue. However, despite differences of opinion on this matter, international and national policy communities are in agreement that spent fuel, being the first and one of the main forms of radioactive waste, is both dangerous and problematic, and what happens to it after its removal from reactors needs to be accorded high importance.

Spent fuel management poses practical and political problems at several different stages, including removal from power reactors, storage in at-reactor cooling ponds for periods ranging from a few months to years while elements cool down sufficiently for further handling, transportation, and long term storage, reprocessing and/or ultimate disposal. Its management is characterized by all the dilemmas facing regulators of high-level radioactive wastes plus some more of its own (Holdren 1992). Strict safeguards are needed, and are indeed employed to protect against accidents and other forms of mismanagement, but these are not infallible. Furthermore, the extremely long time horizons-up to hundreds of thousands, even millions of years-over which the fuel poses radioactive hazards are unparalleled in any other policy area, and entail planning beyond the expected lifetime of most political regimes and indeed of many geophysical systems.

In addition to the high risks spent fuel poses to local ecological systems and to human health, it occupies a crucial place for policy intervention in the nuclear fuel cycle: at the point where the outcomes of whatever decisions are taken (arguably) pose the highest weapons proliferation risks, depending on how the fuel is handled-for example, whether it is removed and stored, placed in a final repository, or reprocessed, and under what sort of security measures it is kept to prevent theft or diversion.[3] At-reactor storage, for example,

[3] While spent fuel in and of itself is not considered a high proliferation risk over the short term-which is why the Spent Fuel Standard is used for excess weapons-material disposition-if it is reprocessed, the resulting Pu and U235 are a direct proliferation risk: "every ton of fuel contains more plutonium than the 6.2 kilograms in the bomb that destroyed Nagasaki. Eighty-four thousand tonnes would contain about 800 tons of plutonium, or three times more than was present in the combined arsenals of the United States and the Soviet Union" (Carter

given its decentralized nature and the cost of controls, which might be too high for utility companies to bear on their own, is unlikely to be feasible over the long term. In turn, the point at which spent fuel is removed from the reactors is an effective one for anti-proliferation intervention by the relevant authorities: spent fuel rods are relatively easy to count, weigh and measure for later accounting.

Most nuclear power programs originally included the reprocessing of spent fuel to reclaim the valuable U235 and Pu, which could then be used to fuel reactors or indeed, in a few cases, for weapons manufacture .[4] Hence, most nuclear utility companies rely on small-scale, at-reactor storage, which was expected to be needed only in the short term while the fuel cooled before removal for reprocessing and direct (and final) disposal. However, reprocessing has fallen out of favor in many countries (with some notable exceptions-who themselves are rarely able to reprocess to full capacity),[5] and plans for long-term direct away

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and Pigford, 1998:58). Safeguards need to be maintained throughout the storage and disposal periods: "as the fuel cools and radiation decays, the diversion risk could increase as fissile materials become more accessible" (Albright, Berkhout and Walker, 1997:147).

[4] Normally, or at least openly, however, nuclear weapons countries tend to produce weapons materials in entirely separate facilities from those used to generate civilian nuclear power.

[5] The main reasons behind the decline in reprocessing are economic (continued availability of quantities of cheap uranium), and political (proliferation risks; pressure from the United States). The countries with domestic reprocessing facilities are: Great Britain, France, Russia (whose commercial reprocessing facilities--La Hague, Marcoule--run by the French firm Cogema, Windscale/Sellafield, and Chelyabinsk-65/Ozerskcarry out about 95% of civilian reprocessing), Japan (a small plant at Tokai as well as the proposed new plant at Rokashomora), India, and China (military). Plans for reprocessing are underway most notably in Japan. See Berkhout, 1997, and Seth, 1997 (http:/www.ieer.org/ieer/ensec/no-2/repromap.html). In the United States, reprocessing of small quantities of spent fuels restarted at the Savannah River site in 1996 despite official policy against reprocessing in general. The original purpose was to clean up materials remaining in the canyons, but proposals are afoot to keep at least some part of the facility open for reprocessing into the near term future. See "Nuclear Waste - Not!", an editorial from *The Christian Science Monitor,* April 7, 1997, and also Popova, 1997.

from-reactor (AFR) disposal of radioactive wastes have met with serious and widespread public opposition in practically every country where they have been put forward.[6]

Thus, despite the environmental, strategic, and economic significance of spent nuclear reactor fuel, its management across most countries remains decentralized, short term, and ad hoc. As the following section, which goes into some of the quantitative aspects of spent fuel generation and management worldwide, shows, the current status quo is best characterized as an international crisis waiting to happen: at-reactor storage sites that are full to capacity could lead either to a crisis in one country with international effects, or, cumulatively, a situation occurring in many countries simultaneously that will require rapid action on the part of the international community, action that ideally should have received forethought and planning.

Worldwide Spent Fuel Generation and Management: Some Numbers

Studies of countries' civil and military inventories of radioactive substances do not claim to be exact. However, they point toward the same trends: spent fuel generation, and hence, the amount in storage is continuing to increase world-wide, while storage and disposal capacities are, if anything, decreasing. Future storage capacities are in doubt.

Spent fuel was first discharged from commercial power reactors in the early 1960s. According to Albright, Berkhout and Walker (1997):

> "at the end of 1995, installed world nuclear capacity was 356 Gwe (gigawatts electric), having tripled over the previous 15 years. By then, the world's commercial reactors had discharged a total of some 166,000 tonnes of spent fuel, containing

[6] The possible exceptions here are Sweden and France, where discussions over a repository for HLW are still on-going. Also, Michael Kraft notes that Canada, Sweden and France have successfully sited low-level radioactive waste disposal sites (Kraft, 1996:134-135). For a summary of existing disposal, storage and reprocessing practices in countries with nuclear programs, see Table 1, and "Global Nuclear Waste Management and Disposal: Update, 1994." *Nukem*, February, 1995.

> nearly 990 tonnes of total plutonium. Spent fuel is currently arising at a rate of around 10,300 tonnes each year, containing around 70 tonnes of plutonium" (Albright, Berkhout and Walker, 1997:141).

They estimate discharges between 1994 and 2010 at 177,320 tonnes. Table I shows the break-down by country of past and estimated future discharges of spent reactor fuel, as well as the main modes of storage/disposal in each country in the 1990s. The figures are based on the assumption that all reactors will operate smoothly for the rest of their lifetimes and do not take into account extension of reactor lives, currently unplanned new capacity, and/or early retirement of existing reactors (Albright, Berkhout and Walker, 1997:143-144).

Table 1: Past and Estimated Discharges of Spent Fuel from Nuclear Power Reactors, 1960-1993 and 1994-2010 (in tonnes; ordered by 1960-1993 generation) and National Spent Fuel Management Policies, 1990s

Country	Past discharges of spent fuel 1960-1993	Spent Fuel Discharges 1994-2000	Spent Fuel Discharges 2001-2010	Spent Fuel Management Policies, 1990s
United States	28 570	13 400	19000	S
UK	26040	6 700	8 120	R(D) + S
France	20 630	9 250	11 620	R(D) + S
Canada	18 950	10 070	17 830	S
Japan	10 580	8 070	9 080	R(F+D) + S
Russia	9 050	4 110	6 820	R(D) + S
Germany	6 420	3 550	3810	R(F) + S
Spain	3 490	1 760	1 320	R(F) + TB + S
Sweden	2 800	1 510	2 150	S
Ukraine	2 400	1 860	2 670	S + R(F)
South Korea	2 300	2 880	5 660	S
Argentina	1810	1460	2040	S
Italy	1780	370	0	R(F)
Belgium	1660	870	920	R(F) + S
Switzerland	1370	690	560	R(F) + S
Taiwan	1350	990	980	S
India	1050	1560	4 750	R(D) + S
Finland	1 030	520	510	S
Lithuania	870	1440	1290	S
Bulgaria	860	400	770	TB + S
Slovakia	570	450	750	S + TB
Hungary	480	480	370	S + TB
Armenia	350	0	0	TB
Czech Republic	320	320	350	TB + S
Netherlands	280	100	80	R(F) + S
South Africa	260	230	340	S
Slovenia	170	110	110	S
Pakistan	130	60	120	S
Brazil	60	170	320	S
Mexico	60	300	250	S
China	0	400	650	S
Total	**145, 690**	**74, 080**	**103,240**	

Source: Albright, Berkhout and Walker, 1997, Tables 5.2, 5.3 and 5.4 (from SPRU Spent Fuel and Plutonium Database, 1994); Table 6.1. S = interim storage (either at or away from reactor); R(D) = reprocessing (domestic); R(F) = reprocessing (foreign); TB = fuel returned to supplier under "take-back" arrangements.

Table 1 shows that roughly 325,000 tons of spent fuel (containing over 2000 tons of Pu) will have been generated worldwide by 2010.[7] Albright, Berkhout and Walker estimate that over two thirds of this total will remain in storage-i.e. not be reprocessed (p. 147). Six countries dominate worldwide spent fuel generation: the United States, France, Russia, Japan, Great Britain, and Canada.[8] However, a large number of other countries also generate significant quantities of spent fuel, especially at the lower end of the scale. In terms of general trends, there has been a notable increase in estimated spent fuel generation across Asia; spent fuel generation Russia and parts of Eastern Europe is also increasing (dependent on planned RBMK reactors coming on-line), while West Europe generation figures remain constant. They conclude that "spent fuel will continue to accumulate at a rate of 9,000 - 10,000 tonnes per year for the next two decades" (Albright, Berkhout and Walker, 1997:147).[9]

The second part of Table 1 shows national spent fuel management policies as they stand in the 1990s. No permanent geologic disposal facilities are operational anywhere, and the earliest any planned long-term repositories are supposed to come on-line is projected to be 2010, at the Yucca Mountain site in Nevada: a goal unlikely to be reached.[10] Many

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[7] The corresponding totals for Pu generation from power reactors are:
1961-1993: 846 200 kg.
1994-2000: 537 440 kg.
2001-2010: 741 320 kg.

[8] This depends, to an extent, on reactor type: the Canadian CANDU reactors, for example, expel proportionately more spent fuel than other reactor types (Albright, Berkhout and Walker, 1997:144-5). For a broader discussion of different types of reactor, see Wolfson, 1993, chapter 8.

[9] A figure backed up by other estimates: for example, "[s]hould present and planned nuclear plants continue to operate, the world would require one radioactive waste repository (holding 70,000 tons) *every nine years*" (Kraft, 1996, citing Hafele, 1990; emphasis in text).

[10] The Swedish Nuclear Fuel and Waste Management Company, or SKB, is also working towards siting a deep repository for spent fuel, and indeed already has some AFR storage capacity. For more information, see www.skb.se/eng/default.htm. For a discussion of nuclear waste management practices and consensus building

countries are still in the initial search phase looking for long term repositories; others have abandoned this search entirely.[11]

Table 1 also shows that transboundary movement of spent fuel, chiefly for reprocessing elsewhere, either under commercial contracts or long-existing take-back arrangements, is really quite common.[12] Albright, Berkhout and Walker predict that the main changes likely to occur after 2000 are that the countries of Eastern Europe, which have historically sent their spent fuel back to the former USSR, are likely to lose that option or have to pay high prices for it. With respect to reprocessing, practices are under fire. The United States halted civilian reprocessing in 1976, and in countries with existing reprocessing facilities, plants are not running to capacity. In Japan, the only country where a large new facility is planned, serious problems with financing, safety and public acceptance are arising.[13] In turn, the continuance of open, rather than closed fuel cycles (that is, without reprocessing) is further encouraged by the relative availability and low market price in historic and absolute terms, of uranium at present.[14]

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in Sweden, see Löwgren, 1993, and, more recently "Business: A Nuclear Waste", *The Economist,* July 11, 1998, pp. 64-65, on public opinion, politics and nuclear power in Sweden.

[11] For reference, the term "repository" usually refers to long term or permanent geologic (hence underground) facilities. International proposals usually concern more temporary above-ground storage facilities. However, sometimes the terms are used interchangeably, a practice the author also sometimes follows.

[12] Table 1 omits one set of transboundary movements of radioactive wastes, and one which is not often discussed in the international relations part of the relevant literature: the hosting of nuclear (and other) waste disposal sites on Native American reservations in the United States, also an issue in other countries where indigenous peoples are given sovereign control over areas of land. This is a highly contentious issue: however, according to *The US News and World Report* in 1993, "16 tribes-and four sparsely populated rural countries in the West-have applied for or have received federal grants to get into the nuclear waste business" ("trashing the reservations?' *US News and World Report,* January 11, 1993, p. 24). Such proposals continue to this day (e.g. "New Prosperity Brings New Conflict to Indian Country", The New York Times, March 8, 1998). The significance of these practices, and the conflict they arouse for internationalizing spent fuel management is high, and is discussed in the final section of this paper.

[13] See von Hippel and Jones, 1997.

[14] Uranium is now of an order of ten-fold cheaper, in real terms, than it was in the late 1970s.

Exact figures on existing spent fuel storage capacities are hard to find: firms have, unfortunately, proprietary rights to this information. However, anecdotal evidence suggests that the situation is becoming critical in many countries: utilities have re-racked fuel rods almost as much as possible; the situation is especially acute in Taiwan, South Korea, Germany, and the United States, and it is likely that most storage facilities will reach capacity over the next ten to twenty years.[15] A paper presented at the 1993 Uranium Institute Symposium by C. K. Anderson states that:

> over the next twenty years, 140,000 tonnes of new spent fuel will be generated worldwide. Full capacity of existing reprocessing plants together with away from reactor storage (AFR) facilities and free at-reactor pool capacity could in theory accommodate all but 25,000 tonnes. However, reprocessing is only expected to accommodate 30 000 tonnes while AFR cannot be expected to deal with more than 50 000 tonnes over the next ten years, leaving 45 000 tonnes outstanding [and stored at the reactors]. (Anderson, 1993)

Takáts et al (1993) show AFR worldwide storage capacities in operation in 1992 of 47,373 tonnes. Pierre Goldschmidt, in a paper presented at the 1995 Uranium Industry Symposium, paints a more optimistic picture of policies in Western Europe to manage the back-end of the fuel cycle:

> each nuclear station obviously has its own spent fuel storage facility, sometimes of fairly high capacity. In addition, across Western Europe there are 12 AFR (away from reactor) storage facilities of various types with a cumulative capacity of about 40,000 tonnes. These facilities use both wet and dry storage technologies, include both underground and surface siting and make use of both modular and fixed capacity approaches ... European reprocessing capacity is in excess of 3500 tonnes/year". (Goldschmidt, 1995)

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[15] For example, nuclear utilities in the United States are starting to sue the federal government after the Department of Energy reneged on its pledge to take custody of spent fuel as of January 31, 1998. Both Maine Yankee and Florida Power and Light have filed claims for damages in the hundreds of millions of dollars in subsequent months ("DOE sued for not taking nuclear waste." *The Energy Report*, June 15, 1998). The DOE's view of its responsibilities under the Nuclear Waste Policy Act is somewhat different: it sees itself as having no

Whatever the exact situation, it is clear, however, that most nuclear power generators will soon face, if they are not already facing, a crisis in terms of storing their spent fuel over the long term, especially given the political and economic factors now stacked against reprocessing. It is probably also true that spent fuel in large quantities would be a good deal less dangerous stored in a smaller number of specially constructed facilities at AFR sites than in smaller quantities at a large number of harder to monitor at-reactor facilities. However, this means that there will need to be a large shift in the existing status quo, which would-if only by drawing attention to a problem that has quietly existed for many years-give rise to much controversy, for example, by introducing new (and unknown) technologies, raising transportation issues and so on. This point will be elaborated on in subsequent sections.

Why has spent fuel management become an international problem?

Nuclear power generation and waste management has (unlike hazardous waste management) always been considered an issue for international concern because of its security dimensions, although that concern has not played out into a strong international management regime as yet. These issues have both transboundary and "local-cumulative" aspects as international problems: transboundary in the sense that problems arising in one country can affect another; local-cumulative in that while a problem might only have local effects, by virtue of it being common in many areas, there is a cumulative impact on the whole system. For example, in addition to issues surrounding the transboundary movement of radioactive substances, accidents in one country can severely affect others. Local

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obligation to physically take custody of the spent fuel. However, the court system has yet to fully resolve this question.

cumulative issues arise in that countries share similar waste management problems, and the accumulation of radioactive wastes in all countries with nuclear programs could eventually have an aggregate effect on the global environment. These factors have only become clearer over time, and, unfortunately, through experience:

- The 1986 Chernobyl disaster demonstrated beyond a doubt that nuclear accidents have cross-boundary effects.
- No country, save the United States and Russia, is self-sufficient right through the nuclear fuel cycle in terms of supplying their own uranium, generating energy. and dealing with wastes or reprocessing -- and even those countries may not be over the long term. Many countries, for example, lack adequate storage facilities. As a result, transboundary movements of radioactive substances have been common throughout the history of nuclear energy. Examples include the reprocessing of fuel from West European countries and from Japan in Britain and France, United States take-back of research reactor fuel, and now-changing take-back agreements between the former Soviet Union and the states in Eastern and Central Europe that were its satellites.[16]
- Nuclear energy programs are being expanded in East and Southeast Asia: in particular, Japan, China, Taiwan and South Korea are building or planning new reactors, while Indonesia has now shelved (but could reactivate) plans for its own reactor. These plans have implications not only for regional security, but also for the need to construct adequate management infrastructures across the region.

[16] See, for example, Mark Hibbs, "For Eastern Europe's Research Reactors..." *Nuclear Fuel*, April 6, 1998.

- Countries with nuclear power programs face common problems, for example, public opposition to siting proposals and waste transportation, and developing and utilizing technology (whose high cost makes joint ventures appealing).

These international dimensions of the issue underscore the case for international cooperation over spent fuel and radioactive waste management. However, many further factors impinge on this process, and on how cooperative responses are designed and implemented; factors that are the subject of the next section. Cooperation in this area involves more than governments alone coordinating or changing policies to fit mutually determined goals (the standard definition of cooperation): the prevalence and influence of non-state and private actors-particularly, the civilian nuclear power industry and antinuclear groups-have shaped much of what has happened over this issue in recent years. The next section investigates some of the factors that facilitate cooperation among state and private actors (the nuclear industry in particular) in the international management of spent reactor fuel and discusses some of the international schemes proposed in recent years.

International Spent Fuel Management Schemes from the 1950s to the Present: An Historical Perspective

1. Facilitating Factors and International Support

Into this context of mismatch between spent fuel generation and disposal capacity worldwide has come a variety of actors who, over time, have proposed and/or introduced a variety of schemes for international or transnational management of spent reactor fuel. These plans offer different suggestions for the shape, scope, and goals of an international nuclear

waste management regime. Most focus on developing a regional or international network of sites, but other options are also possible, such as setting up an international standards and monitoring regime, a multinational storage corporation, or an international spent fuel organization (Dunn and Carey, 1998; Table 3, p. 17).

Many factors would appear to facilitate the formation of international cooperative agreements for the management of spent nuclear reactor fuel. First, there are relatively few direct stake-holders in this issue area (especially in comparison with hazardous waste generation), and thus fewer actors involved in the regulatory process. The nuclear industry is quite small, consisting of several large utility firms, all of which can be readily identified. Privatization and the introduction of competition in nuclear power generation is likely to enhance trends towards industry consolidation, for example, reducing the number of operators in the United States from roughly 40 to 4 or 5 (in an extreme case). Nuclear power generators have an interest in joint management, and the industry has a long tradition of intervention by, for example, national governments and the IAEA.

Another factor limiting the number of actors involved is that relatively few countries have civilian nuclear programs: thirty one, according to the IAEA. In the countries that do have nuclear programs, nuclear power usually falls under the auspices of central agencies, not local ones. This again compares with the management of hazardous wastes, where the extent to which regulatory powers are decentralized among many agencies and levels of government has posed management and coordination problems in many countries. This is not to say, of course, that there are not other actors with a stake in this matter, including international organizations, such as the IAEA, the IEA, and the European Union; carrier firms and the insurance industry, and public interest groups and NGOs. However, there are fewer ultimate <u>targets</u> of regulation in this area than is the case in many other areas of public policy.

Second, some institutional structures are already in place that could provide building blocks for a spent fuel management regime. These include the IAEA Safeguards regime, the Convention on the Physical Protection of Nuclear Materials, and the 1997 IAEA Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Dunn and Carey, 1998)." There are also agreements drawn up in other areas--notably the Basel Convention on the Transboundary Movement of Hazardous Wastes and Their Disposal that could be relevant here. The European Atomic Energy Community (EURATOM), established in 1957, is an example of regional nuclear power management. It differs from the IAEA in that its member states are bound by broader legal treaty obligations, it technically owns commercial nuclear materials, and it has a monitoring role in terms of nuclear safety (Blowers, 1991:43-4). Its experience and success over the years have been mixed however, especially as nuclear power issues have become more politicized in Europe. Most recently its role has been to regulate bilateral nuclear commerce between the US and EURATOM members; this agreement was re-signed in 1996, giving European countries more control over US-origin materials and equipment (Medeiros, 1996). Also, there has always been a high level of international intervention in civilian nuclear power industries-at least among the non-nuclear weapons states-and some of the national barriers to international regulation that we see, for example, in the management of the hazardous waste trade have never arisen: there is little dispute, for example, over the definition of spent fuel.

Third, there are strong mutual economic interests in joint management of spent fuel, in terms of reaping advantages of economies of scale and cost-sharing measures. Since storage is cheaper than reprocessing, storage facilities can compete with reprocessors in

[17] There are also IAEA schemes for boosting waste management capacities and infrastructures in less industrialized states. For general IAEA activities in the field of fostering good radioactive waste management worldwide, see Semenov (1992) and Chen (1992)

getting business from utilities, thus generating huge revenues for a host country. Fourth, and finally, there are common international political interests in controlling spent fuel, shared notably by the nuclear weapons states and those interested in restricting state and non-state weapons proliferation.

At the same time, there are high levels of support from several different quarters for some form of international spent fuel management regime. The IAEA backs plans for international and regional repositories, especially for countries with small nuclear programs, as evidenced by reports from working group meetings in June and December 1997. It sees its role as developing appropriate licensing, safety, and standardization guidelines. There is also evidence of support from the major nuclear players, especially from Russia and Western European countries, notably Germany. The US government still needs to be convinced-it is following a policy of "wait and see' =but it leans towards such ideas, especially a Southeast or East Asian regional scheme, while such proposals are definitely backed by countries with smaller nuclear programs and by sectors of the nuclear industry.

Unlike some other international environmental agreements, the participation of the United States, or at least its acquiescence in any scheme that emerged is important, given that nearly all spent fuel in East Asia and a substantial fraction in Western Europe is subject to US consent requirements, meaning that it can't be sent to any international facility without US approval. However, whether or not the US would have to take the lead role in negotiations is a lot less clear-cut.

In fact, this issue area displays some potential for the emergence of "lead states", that is, states that are not necessarily the most influential in international politics but that set the standards for, and drive the formation of, international agreements. Such actors have been

Key in the emergence of successful international environmental regimes: the role of the Scandanvian states in the long range transboundary air pollution (LRTAP) negotiations is a case in point (Porter and Brown, 1995). In the global management of nuclear materials, it would seem that countries with large nuclear programs and with a big stake in transboundary aspects of nuclear management and the long term viability of nuclear power-such as Japan, the United Kingdom or France-could, if they chose, take a lead role in bringing other states to the table, and in determining the terms of an international cooperative arrangement.

2. History of International Cooperation over Spent Fuel Management

Schemes and proposals for the management of the civilian nuclear power industry have a long history, going back to the 1946 Baruch Plan and Eisenhower's 1953 Atoms for Peace proposal, which led to the establishment of the IAEA and the start of the safeguards regime that remains in place today. Most proposals sought to combat weapons proliferation problems at a time when nuclear power was still seen to be the wave of the future in terms of energy generation.

Once the IAEA had been established, and hopes for the dismantling of nuclear weapons had ended by the start of the Cold War, interest in these ideas faded until the 1970s, when a combination of factors such as the oil shock of 1973 once again led to a series of investigations into different possibilities for international and regional spent fuel management (Berkhout, 1994). Few of these-especially the multilateral schemes-were ultimately implemented over the long term, a development Berkhout ascribes primarily to concern over the violation of national sovereignty.

Box 1: Examples of Early Transnational Spent Fuel Management Schemes

- Eurochemic: a collaborative R&D exercise involving most of the non-nuclear weapons states in western Europe (notably Germany) and France, and set up under the auspices of the OECD's Nuclear Energy Agency. In 1966 a Eurochemic-operated demonstration reprocessing plant opened in Belgium, which processed LWR fuels from the participants between 1970 and 1974. However, it collapsed after both France and Germany withdrew (Berkhout and Walker, 1991:554-555).
- Reprocessing agreements, along with take-back clauses, in Western and Eastern Europe.
- Bilateral arrangements for the return of spent research reactor fuel, primarily back to the United States, originally for reprocessing, but now stored.
- IAEA proposals, e.g. regional nuclear fuel cycle centers (RFCC; 1975). The IAEA also examined possibilities for international spent fuel management in a working group convened between 1979 and 1982.
- "Energy Islands"; first studied at the International Institute for Applied Systems Analysis, Vienna, Austria (under Wolf Häfele) in the early 1970s.

In the last 10 years or so, interest in these ideas has once again been revived. Several factors have contributed to this process. First, the Chernobyl disaster of 1986 led to a greater concern with international safety standards, communication, and harmonization. Second, the nuclear utilities themselves are demanding that governments fulfill their promises for more, and more permanent AFR storage space-suffering "nuclear constipation", according to Janberg 1997. Third, the end of the Cold War has generated a more cooperative international security environment, at least among the former superpowers, not to mention additional, and shared, burdens of dealing with excess fissile materials. Fourth, there has been a recent revival of interest in the utility of nuclear energy in the face of global climate change.

In turn, there have been several initiatives from different quarters for some form of internationalized spent fuel management, of which only two (IMRSS and regional pacts) could be said to have much life left in them, although it is possible that other initiatives are in the process of formation. There is a distinct demarcation between "site-based" initiatives (i.e. locate a suitable site first, then worry about governance), versus those that are "regime based" (i.e. set up operational rules, codes of practice, safeguards, then find a site or a willing host). Many international regulations and treaties also govern this area: existing agreements, especially through the IAEA, national governments, the EU, the International Maritime Organization and others work towards establishing and maintaining effective safeguards and safety standards at civilian power plants and ensuring the safe transportation of nuclear wastes.

3. An Overview of Current Proposals for International Spent Fuel Management Arrangements

Recently proposed schemes for internationalizing spent fuel management vary along a number of important dimensions, as shown in Table 2. These include:

- Scope of the scheme with respect to the fuel cycle: covering just spent fuel, or the whole cycle, or just one aspect, such as transportation.
- Scope of the scheme with respect to the number of countries involved: it may be a series of national initiatives, or a bilateral agreement, a regional pact, or an international scheme. Related issues concern the locus of control, which may be centralized, as in a series of regional sites governed by a central international body, or decentralized, as in

cases where, as the IAEA December 1997 Report recommends, the laws and regulations of the host country apply.

- Funding and management: schemes may be public-run by governments or international organizations, or private-run by nuclear utilities or entrepreneurs, or some combination of the two. A related and very real controversy is over whether or not ownership of the materials should be transferred from the generating country or utility. Proponents of no transfer of ownership prefer that it remain with the depositing countries or utilities, with host countries bearing responsibility for managing the sites. Utilities on the other hand would prefer that ownership is transferred, thus removing their long-term liability. Hence, nuclear power generators often prefer schemes that lease them the fuel in the first place, then take it back.
- Goals: schemes may be put forward with non-proliferation/ anti-terrorism, often antireprocessing goals to the fore or environmental goals (solving the waste problem), commercial goals, or again, some combination. In addition, they can be aimed towards helping out smaller countries and/or the large nuclear powers, specifically, the nuclear weapons states, notably Russia, whose problems in managing its nuclear legacy are extremely apparent across a number of levels.
- Time scale: may be framed as interim storage or permanent disposal. Again, arrangements may vary according to rules for retrievability of wastes.

Table 2 (at end) discusses and compares three of the main sets of proposals that have emerged or been widely discussed during the last five years of so. Briefly, IMRSS (Internationally Monitored Retrievable Storage System)-the brainchild of Wolf Häfele and Chauncey Starr-specifically proposes setting up a new international organization and regime (separate from but linked to the IAEA), before finding selected sites that would

operate as "fuel banks" for depositing countries. It is not the only such arrangement proposed.[18] The U.S. Fuel and Security Group advocates the reverse approach, fording a site first then establishing rules. However, it is widely considered to have foundered on this very aspect, having had no success either in gaining the support of the United States, or in finding an island willing to accept a nuclear waste storage facility.[19]

Possibly the most important discussions occurring right now are over the formation of some sort of nuclear cooperation agreement in the Asia-Pacific region. Nuclear power is set to expand in Asia over the next ten to twenty years, if economic conditions allow. Japan hopes to extend its nuclear power capability by 60-75% over the next twelve years or so, China has announced plans for a ten-fold expansion of its nuclear power generation over the same period (it currently has three operational reactors and two under construction). South Korea is also planning to expand, and Taiwan, in one of the more controversial recent policy moves in this area, has announced its intention to ship 60,000 drums of low level radioactive waste to North Korea.[20] As things stand at present, countries are already facing similar set of problems, including financing, setting up safety and other management infrastructures, gaining public acceptance for plans, and, of course, managing spent fuel and other sorts of

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[18] Dunn and Carey (1998) analyze the most recent thinking on this subject, identifying two other "IMRSS-like" regimes: "internationalizing a network of national storage sites on a regional basis or supporting a multinational spent fuel storage corporation" (p. 16), and analyzing the "value-added' 'for the United States in supporting these at this time, as well as the relevant constraints. Another regional storage facility suggestion has been forwarded by an international working group headed by P. J. Bredell, of the Atomic Energy Corporation of South Africa, Ltd., and a variety of representatives from Germany, Australia and China (see Bredell and Fuchs, 1997).

[19] For an account of the United States Fuel and Security saga (including the quest for a suitable island site) and the somewhat colorful backers of the scheme, see Ken Silverstein, "Nuclear Burial in the Pacific: Plans for Nuclear Waste Dump on a Pacific Island." *The Progressive*, (November 1997), p. 32 on.

[20] Figures from Olsen and Lincoln, 1997. For an overview of existing spent fuel and radioactive waste management practices in East and Southeast Asia, see Choi, 1996:12-20.

radioactive wastes. Various proposals for regional cooperative arrangements have been put forward in the last five or six years, which vary in terms of their scope and extent.[21]

Track II level discussions for some sort of regional arrangement are on-going within the forum of the Council for Security Cooperation in the Asia-Pacific (CSCAP).[22] While it is unlikely that an overarching regional organization will be formed at any point in the near future, especially given prevailing economic uncertainty in the region, participants have recognized a need to work towards certain short term goals, including joint spent fuel management, especially among the northeast Asian states, and also including information sharing and facility monitoring throughout the region.

Two factors stand out as driving the process in its current stage, in addition to more long-standing concerns, such as openness and transparency (arising from security concerns), and worries about safety in some countries. First, Japan needs to find a different solution to its spent fuel management problems as reprocessing becomes increasingly problematic. Second, private corporations are now seen to have a key role to play in this area; their willingness and perceived ability to participate in the process has lent a new impetus to negotiations. It also seems likely that the degree of regional integration in this part of the world, while nowhere near as high as that pertaining in Western Europe, would help reinforce these efforts. Questions remain, though, as to whether such a regional arrangement would be driven more by political and security or economic and commercial goals. Recent reports suggest also that there are strong differences of opinion among the key participants: for

[21] See Choi, 1997, Manning, 1997, Speier and Chow, 1996, and Cossa, 1996 for a discussion of some of the options related to an Asiatom scheme. For an opposing view, see Dr. J. Takagi, "Nuclear Power is No Future Energy to Asian Countries." Produced by the Citizens' Nuclear Information Center, Japan, 1997 (full text at www.jca.ax.apc.org/cnic/english/topics/nuke-and-asia.html).

example, between Korea, which would prefer simply an Asian nuclear safety coordination organization, and Japan, which favors the broader Asiatom idea.[23]

Factors Inhibiting the Implementation of International Spent Fuel Management Initiatives

The question now becomes: if some form of international spent fuel management is such a sensible idea, why hasn't it happened, and what are the major obstacles to achieving such a goal? This is a question that is rarely asked in the advocacy literature, and the answers can be extremely instructive. As one analyst puts it: "The historical record of the past decades is littered with the acronyms of defunct proposals for an internationalized back end fuel cycle.... Not only have these not materialized; it appears that at the back end of the fuel cycle internationalization is actually on the retreat ... Stalemate and procrastination seem to be a general phenomenon of fuel cycle policy everywhere" (Hackel, 1997:271-2). His suggestion-that responsibility for running such schemes should be taken away from states and put into the hands of the nuclear utilities-should be treated with some caution. However, his analysis raises some interesting questions concerning "negative internationalization", or the roll-back of international involvement in the back end of the fuel cycle and these are insights worth exploring.

There are at least five sets of factors that can be easily identified as inhibiting the development of an international spent fuel management regime or regimes: (1) starting with

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[22] Part of this analysis is based on notes from the meeting of CSCAP's working group on Pacatom/Asiatom proposals in Washington DC on May 8 1998. Track II level discussions are those occurring between nongovernmental groups and organizations. Government officials often attend such talks, but usually as observers.

[23] Mark Hibbs, Nuclear Watch Report, May 8, 1998 (www.nyu.edu/globalbeat).

the hardest to address, widespread political and public opposition to siting of storage facilities (as illustrated by the controversies raised in several highly publicized recent cases of nuclear waste and spent fuel transportation); (2) differences in national interests and practices; (3) sovereignty concerns; (4) compliance and transparency concerns; and (5) the extremely long time horizons involved.

(1) Political opposition to siting and transportation: NIMBYism and "reverse NIMBYism ": It is probably almost impossible to over-estimate the extent of domestic opposition in most countries to anything related to radioactive waste disposal-opposition that would only be heightened by the prospect of serving as the world's "nuclear dumping ground". Mistrust of official abilities to adequately manage the risks posed by nuclear wastes is endemic and often deserved. There are high levels of opposition to transport of radioactive substances within countries and across national boundaries from a wide variety of constituencies, including domestic interest groups, international NGOs, sub-national political entities, and in some cases, national governments. For example, Germany, Sweden, and Canada all have laws prohibiting the permanent movement of radioactive wastes beyond their national boundaries. In addition, several regions of the world, notably many of the Pacific Island nations, have prohibited the transport and dumping of radioactive substances into and within their territorial bounds, and Russia has barred permanent import for storage or disposal (although transport through its territory and importation for reprocessing are both still allowed). Many anti-nuclear activist groups are following a strategy of concerted opposition with the aim of "choking" the nuclear power industry with its own waste, refusing to discuss alternative solutions to waste disposal problems while power plants are still operating.

Several recent events involving nuclear waste transportation and disposal have given rise to much publicity, public outcry, and controversy and have made the issue a much more salient one for international authorities (see Box 2). Of these flashpoints, one-the most recent shipment of Japanese spent fuel to France for reprocessing, and the subsequent return of high-level wastes to Japan-is most obviously international in character.[24] It also illustrates the tangle of domestic, international, political and economic issues involved in, and the degree and scope of, opposition to the international transportation of highly radioactive materials. Although more such shipments are planned, and they have been going on for many years, it is becoming harder and harder to carry them out in the face of escalating international and domestic opposition.

Two of the other cases identified here-the protests in Germany over the shipment of radioactive waste for storage near Gorleben and problems over the siting and operation of the Yucca Mountain site in Nevada-have at the very least high levels of symbolism, not to mention ramifications, for policy in other countries. The German case, for example, has both direct and indirect implications for nuclear politics among its neighbors, especially Britain and France (Blowers and Lowry, 1997). Directly, a fair proportion of the contested waste consists of repatriated HLW from reprocessing in Britain and France: if Germany cannot find some sort of domestic compromise, those wastes will have to remain abroad. Indirectly, the politics of nuclear protest in Germany are "a component in a much wider conflict involving France and the UK and, in conjunction with other developments, affecting the future of the

[24] According to the Nuclear Control Institute, "more than 3,000 canisters of vitrified nuclear waste are to be returned to Japan from France and Britain. There were 28 canisters in the first shipment in 1996,40 canisters in the second shipment in 1997 and 60 canisters in the 1998 shipment. Future shipments will carry 150 canisters. At least 15 to 30 shipments are likely over a 15 year period" (Tamer, 1998). In the reverse direction, "Tokyo plans eventually to ship 7,100 tonnes of spent fuel to France and Britain for reprocessing into 30 tonnes of fuel grade plutonium, yielding 3,000 tonnes of waste" (Reuters, 13 October 1997). Note that the latter figure only includes high-level waste.

Industry world wide [being] indicative of new forms, of political protest that are emerging elsewhere" (Blowers and Lowry, 1997:149).

The final and most recent case, the shipment of Georgian spent fuel from Tblisi to Scotland for reprocessing does, however, offer a small amount of hope for how such transfers might be handled in ways that meet with public acceptance. However, as noted below, the situation does not end with the arrival of the shipment at its destination. Problems have often continued to arise-including, somewhat drastically, some radical safety questions arising at Dounreay, as well as revelations about levels of radioactivity leaking from the casks used to transport spent fuel both from France to Germany and from France to Japan. This illustrates the need for continued vigilance on the part of watchdog groups and regulatory authorities, as well as the need to engage in active and participatory learning about processes and practices of nuclear transportation.

Box 2: Recent Controversies in the International Transportation of Nuclear Materials

Japanese Plutonium: The Voyage of the Pacific Swan

On January 23, 1998, the third shipment of high-level radioactive waste to Japan left France on the British-flagged ship, The Pacific Swan. This ship is operated by Pacific Nuclear Fuels, a company run by British Nuclear Fuel Ltd., Cogema, and 10 Japanese nuclear utilities, which specializes in marine transportation of radioactive substances. It was carrying 60 canisters of vitrified nuclear waste, each of which weighed about half a ton, destined for storage at a facility in Rokkasho village, in Aomori Prefecture in northeastern Japan. Its route was kept secret prior to departure, having been openly opposed by governments in the Caribbean and the Pacific. Approval for the safety of the cargo and its transportation had been obtained from the French and Japanese governments, the IAEA, and the International Maritime Organization, and extensive security precautions were in place (e.g. clearing the Panama Canal, 24 hour expert teams on call, etc.). However, in addition to government opposition, the shipment was opposed extremely vocally by the Washington-based Nuclear Control Institute and Greenpeace International, both of which are concerned with the physical safety of the ship and the containers in the event of accident, and with the possibility of terrorist attack. Shadowing the shipment throughout, Greenpeace activists managed to board the ship on its entry to the Panama Canal on February 6, generating a large amount of adverse international publicity for the transporting authorities.

Finally, on its arrival in Japanese waters in early March, it was blocked for 4 days from docking and off-loading its cargo by a combination of local farmers and activists and the governor of the local prefecture, although ultimately unloading was allowed to take place.

Gorleben: Nuclear Transportation in Germany

Germany relies on nuclear power for about 30% of its electricity needs (based on 1995 figures). After ultimately futile attempts to develop reprocessing facilities, and with strong opposition to the export of nuclear wastes abroad, the government turned to plans to develop a temporary storage site and more permanent underground facilities in Gorleben, Lower Saxony. These plans, however roused serious opposition, and in March 1997, 30,000 riot police were needed to protect the first shipment of nuclear waste from Bavaria and Baden-Wdrttemberg north to Gorleben at a cost of more than $57 million, as well as extensive public disruption and sabotage of the railway lines by protesters ("Nuclear Row hits Meltdown", The Guardian, March 1, 1997). Following these events, Lower Saxony officials-in the face of state-wide and national elections-declared a moratorium on further shipments of wastes or spent fuel to Gorleben, and instead German waste management policy has shifted to a new site, near Ahaus on the Dutch-North Rhine-Westphalian border (Hibbs, 1998). The first shipment to Ahaus reached the site in late March 1998, causing the same level of protests and indeed violence along the way. Then in May 1998, shipments were halted following the discovery of contamination from casks used to ship wastes from France back to Germany. Thus, a long-term solution to the German nuclear waste problem remains to be found, and there is unlikely to be any consensus over what to do with Germany's spent fuel and radioactive wastes in the near future.

Yucca Mountain: Political Disputes in Setting up a Long-Term Storage Facility

Yucca Mountain, in the Nevada desert, is being investigated by the United States government to be the first long-term geologic repository for high-level radioactive waste from civilian reactors and the nuclear weapons complex. It represents the first attempt by a nuclear power to set up a long-term disposal facility for radioactive waste. However, the choice of site and its construction have run into all sorts of problems; currently slated to begin accepting wastes in 2010, it is unlikely that even that goal will be reached. In the meantime, government efforts to transport even low-level nuclear wastes is meeting with high levels of opposition from groups en route. Criticisms of the choice of site, and timetable, are based on a variety of factors, including doubts about the long-term geological stability of the area, the durability of proposed construction materials and design, and the nature and extent of public consultation undertaken by the Department of Energy (Carter & Pigford, 1998; Flynn et al, 1997; see also Kraft, 1996).

Recent Controversies, continued

Shipments of Spent Fuel from the Republic of Georgia to Britain

In April 1998, a shipment of highly enriched uranium and spent fuel was flown from Thlisi, Georgia to Britain for reprocessing at the Dounreay plant in Scotland. It contained 5 kg of radioactive materials in total, including less than a kilo of spent fuel. The operation was a joint United States-British-Georgian venture designed to prevent the materials falling into the hands of terrorists or other "rogue" powers. Opposition groups, including the Scottish Nationalist Party and anti-nuclear groups protested the use of Scotland as a nuclear "dumping ground", the length of time the materials would be in storage, and the secrecy under which the operation was planned; however, these voices turned out to be in the minority. The plan was to only announce the shipment after it had arrived at Dounreay; however, when the story appeared in advance in the *New York Times*, the British government was forced to scramble to announce the shipment before its arrival ("Nuclear Leaks are Bad News", by Marcus Linklater, *The Times*, April 23 1998). Most media reports and some prominent groups, including Scotland Against Nuclear Dumping, publicly acknowledged that transporting these materials out of Georgia was indeed the best alternative, although they remained critical of the way in which the deal had been hidden from the public, favoring open discussion in advance. On the other hand, had the shipment been considerably larger, it is doubtful there would have been the same level of support for the scheme.

A serious quandary arising from the above problems with location and transport is the so-called "host-site paradox" in designating a site for an international spent fuel storage facility: given the level and extent of public opposition to transport and disposal of radioactive wastes, it is likely that no state that would agree or volunteer to host an international repository would be agreed upon as a candidate by the rest of the world. Likewise, no site chosen as suitable by the rest of the world would be likely to agree to host such a repository. An IAEA Experts Report published in 1994 on regional repositories outlined some requirements for a host country (Berkhout, 1994: 22-3), including that it must already have an established nuclear and radioactive waste management infrastructure and a large land mass. The main barriers are, however, political; while an advanced industrialized democracy-as opposed to an authoritarian state-would probably be the candidate of choice for most nuclear powers, given nuclear politics in most of these countries, siting a repository there would not be feasible. This might, however, not be the case in terms of regional sites-as in the Asiatom proposals. Regional, as opposed to international, solutions make more

sense in this sort of situation as in a regionalized system, it is usually the case that countries share more of a common identity, or common norms, and are more likely to trust other nations in cases such as this, thus facilitating cooperation. Furthermore, it has often historically been the case that animosities have been more intense at a regional than at an international level, Western Europe being a case in point; Japan and Korea being another. However, rather than animosities inhibiting cooperation within a given region, cooperation over these sorts of issues, especially if fostered by more powerful allies of the countries concerned, could have the ultimate effect of reducing tensions in the region and in fact facilitating cooperation and regional stability over the longer term.

(2) Differences in national governmental interests and practices: The interests, policies, and existing approaches to nuclear power generation differ widely among governments, even within the set of the major nuclear players in ways that would almost certainly preclude both traditional inter-governmental modes of negotiations, and agreement on an international course, or courses, of action that would both be voluntarily entered into by signatory states and be relatively efficient.

For example, it seems highly unlikely that most states with an existing reprocessing capacity will be persuaded to give it up: there are also significant conflicts over whether spent fuel is a waste or an object of value. There are also identifiable and significant differences in national interests and preferences for an international spent-fuel repository or storage site over and above differences of opinion over the utility of reprocessing. For example, the United States' approach originates primarily from a non-proliferation standpoint, while West European countries have primarily commercial interests in such proposals (Bredell, 1997). Russia is another interesting case: in order to forego reprocessing, an extremely important plank in its nuclear policy, it (unlike the countries without

reprocessing facilities who would presumably be willing to pay to get rid of the spent fuel) would probably have to receive some form of compensation, for example, for lost employment. Japan, too, would have to be dissuaded from its advocacy of the nuclear option to provide it with its long desired energy independence.

Resolving these conflicts of interests in the context of traditional inter-governmental negotiations and treaty requirements would be extremely difficult, and it is unlikely that many of the proposed schemes-especially the international (as opposed to regional) ones would satisfy all contending interests while also remaining cost-efficient in the eyes of all participants. However, there is more hope that a commercially driven process and one that was opened up to participation of non-governmental actors (within the context of international guidelines), could get around some of these differences.

(3) Concerns over national sovereignty: Sovereignty issues are key because of the symbolic importance of nuclear programs for many countries, not only their military aspects (as the recent testing of nuclear weapons by India and Pakistan attests), but also economic, as in establishing self-sufficiency in energy generation. The overriding concern of states with national political priorities and problems-negative internationalization in Hackel's terms-- is very likely to lead to stalemate in terms of international negotiations. This might prove especially to be the case for the world-wide civilian nuclear power industry, which has in its 50 year history been the subject of large amounts of intervention by national and international authorities, and therefore be more bound by political than by economic priorities.

(4) Compliance and information gathering *and dissemination:* These are two primary concerns of theories of international cooperation: in order to enter into a cooperative international agreement, states need assurances that others will also comply. In turn, any agreement drawn up needs to contain adequate incentives for states to do this. Also, there

need to be provisions for adequate transparency, data availability and exchange (on relevant generation figures, as well as state compliance) .[25] Similarly, there are additional technical issues to be overcome in setting up international rather than regional sites: for example, standardization of practices, and communication issues, and even language barriers (Bredell, 1997).

(5) Very long time horizons: As mentioned earlier, time horizons for the storage and disposal of radioactive substances measure from-the thousands to the millions of years. At the very least, even an interim storage site would outlast the actual lifetimes-let alone the political life-of most political leaders. This issue can be addressed through appeals to include measures in an international regime that would allow for fixed-term contracts, flexibility of response, and retrievability of wastes in response to changes in international political and/or economic circumstances.

Recommendations for the Short to Medium Term: International Political Will and Regional Schemes

1. Is international cooperation worth the effort?

In light of the above constraints, it is not necessarily obvious that international cooperation, or the internationalization of the back end of the fuel cycle, is indeed the optimum solution to spent fuel management problems. As John Holdren argues, "certainly a part of the difficulty with radioactive wastes in the United States up until now has been due

[25] For a discussion of regime transparency: its importance, different types, means of achieving, and facilitating and constraining factors, see Mitchell, 1998.

to the diversity of levels of political organization-local, regional, state, national-that need to agree on a solution; in this situation, adding another (international) layer is not likely to help" (Holdren, 1992:256). Brian Wynne, discussing the institutional features of hazardous waste management in an argument that could apply to nuclear waste management, suggests in a similar vein, that "the technical harmonization and consistency of local costs and implementation practices needed for regulation at the international level is intrinsically limited by national institutional factors" (Wynne, 1987:35). In other words, national-level differences constrain the option set for international regulators in ways that make the desirability of cooperation problematic at best. The sorts of national level differences relevant here include not only differences in fuel cycle management (on-the-ground spent fuel management practices do not themselves differ extensively from country to country), but also the ways that cooperative agreements are viewed politically, and subsequently negotiated, ratified and implemented.

Thus, any analysis of the possibilities for cooperation in this area has to carefully examine the rationale for such cooperation, to find out the answers to two questions in particular: first, is the added complexity (if indeed that is the case) of international cooperation outweighed by benefits? Second, is it at all feasible to remove spent fuel management to some sort of international authority regardless of the domestic political circumstances that could constrain the removal of regulatory authority to a higher body? There are clear warning signs against the establishment of a grand multinational or international scheme that does not recognize and respect the above constraints.

In turn, these arguments, as well as those in favor of a more "macro" approach than existing, uncoordinated national level approaches, underlie the support for a step-by-step, regional approach to international management of spent fuel. Such an approach would help

minimize some of the costs-e.g. costs of negotiation-associated with international schemes and could be built upon existing linkages among countries in the region, for example, through regional trade and security agreements and other integrative frameworks. Such an approach could also be more responsive to specific local needs, demands, and conditions, for example the level of maturity of local fuel cycles, the sorts of infrastructures already in place for waste management, and the specific problem situations that could arise in a given area and that would need resolution.

These factors and others are discussed in the following section, which examines some of the short to medium term activities that could be undertaken to shift the current existing political balance against internationalizing spent fuel management and to introduce a measure of flexibility into the way the nuclear waste problem is treated internationally. It should, however, be stressed that no long-term solution that adequately addresses the problem of public opinion and participation seems remotely close; how to achieve this solution is in fact the major question nuclear policy makers are trying to address. What follows are suggestions that both seem feasible given current conditions and that could help break down the existing political deadlock. I try to avoid framing the debate in terms of pitting technical or economic factors against political (or, as some put it, if you solve one set, the others will follow). Instead, I would suggest, these are better seen as interactive, or co-determining. The next section, therefore, discusses some of the situational factors that need to be dealt with prior to setting up actual facilities. The section following that examines some of the more specific, although related questions to do with scheme design.

2. Short to Medium Term Objectives and Prescriptions

a. Current Activities-The Role of the IAEA: The IAEA held a meeting of the Technical Committee on the Technologies and Safety Aspects of a Regional Spent Fuel Facility in December 1997, as part of an on-going process of low-level talks on this issue. The report of this meeting outlines its own desired role and some of the technical factors involved in setting up regional storage facilities and highlights factors important in shaping public acceptance of schemes. Two brief results of their survey on these factors are worth mentioning. First, public opinion appears to be less concerned by long run issues (such as the half life of plutonium) than other factors (such as health and economic effects, e.g. property values), and second, personal risks (presumably health and safety) appear to outweigh proliferation concerns. These sorts of studies are extremely important in crafting solutions here, and more are needed. The IAEA sees itself playing an important role in advocating the establishment of regional storage facilities, especially for countries with small amounts of spent fuel. It plans to work in the near-term future on developing guidelines for such facilities and developing standardized handling techniques for high-level waste.

b. Getting the issue onto national political agendas: Absent a serious international disaster in the area of spent fuel management (an event to be avoided at all costs), getting national authorities on board (or getting the issue beyond working group level) poses some problems for advocates of an international or regional plan. Pressure needs to be exerted from both above (e.g., IAEA level) and below (non-governmental stakeholders, such as the utilities and societal pressure groups) or, as mentioned earlier, by a pioneering "lead state" willing to take unilateral measures in the long-term interests of encouraging international cooperation. Participation by a variety of countries, which would have to be on a voluntary basis, would best be encouraged using a carrot, rather than a stick approach-for example, showing exporting governments a way out of a serious domestic political impasse, and

allowing host states (if such is to be the case) to profit fully from taking on such a burden. The constructive use of side-payments and issue-linkage remains under-explored in this area.

In this case, careful attention also needs to be paid to problem-framing and the different ways this can be used to persuade different national governments to participate. As argued above, good spent fuel management is crucial from the perspectives of both international security (the prevention of theft or diversion of the material towards weapons-making) and environmental safety (radioactive waste management).[26] Commercial viability (see below) also helps. Analyses suggest (although there is no firm data on this subject) that while public opinion is more concerned about the environmental ramifications of spent fuel (mis)management, many national governments-and notably the United States, whose participation or at least acquiescence in any scheme would be important, though not necessarily crucial-see the issue in security terms (Dunn and Carey, 1998; IAEA 1997 Report).

The issue then becomes whether or not different sets of demands (e.g. for security-based or environment-based, or "small-country"-oriented solutions) would generate very different international regimes, and if so, whether that would limit the use of flexibility in problem framing. For example, a security-based regime might dictate just few sites or a single international site, while an arrangement designed to help smaller countries might entail siting facilities in parts of the world in close proximity to these countries, areas likely to be less politically stable. This is a question that would have to be resolved as negotiations get underway; however, if anything, this argument strengthens the case for regional sites or

[26] Arguments as to whether spent fuel should be referred to as "waste" or as "spent fuel" run both ways. For example, some say that the latter, a more technical term, would be more acceptable to a wider variety of constituencies, while others suggest using the term waste conveys a more accurate depiction of the problem to be solved.

networks of sites that can be designed to suit local needs. On the other hand, regimes might usefully be designed to address an array of issues and problems in a given region of the world: one recent draft proposal suggests building a facility in the Russian Far East that could simultaneously deal with Russian excess fissile materials and Japanese, South Korean, and Taiwanese spent fuel, via storage and MOX fuel fabrication facilities.[27]

c. Limited Cooperation-Functions: In this case, it might be desirable, at least in the short term, to limit the scope of cooperation over spent fuel management to certain, limited functions, which can be agreed on and implemented fairly easily. This in turn could be the basis for extending cooperation to other parts of the fuel cycle. Monitoring of spent fuel generation and the safety of existing sites, information-sharing and exchange visits among the participating countries are all within the bounds of existing possibilities, even across large groups of countries, involving most or all states with civilian nuclear power programs. For instance, Olsen and Lincoln (1997) suggest a region-wide airborne radiation monitoring scheme as a good place to start for the Asia-Pacific region. Another suggestion, albeit unlikely to be cost-efficient, would be just to deal with research reactor fuel, which exists in many countries in tiny but still extremely dangerous quantities (see Table 1). In several cases (in Eastern Europe as well as the newly industrialized countries), there is also a strong need to strengthen domestic capacities and infrastructures to comply with these sorts of terms, a role that can be taken on by the wealthier, more technologically advanced countries.

d. Limited Cooperation- Scope: Along the same lines, and as much of the argument so far has suggested, cooperation that is limited in terms of the number of countries involved (although governed by a limited international framework for monitoring and standard setting)

[27] Personal communication with Matthew Bunn, July 13, 1998.

could be another way out of the impasse. Regionalization, in terms of economic and political alliances, is a common and increasing trend internationally, and while Western Europe has been strongest in this respect, the foregoing discussion of Asiatom shows that these ideas are taking root elsewhere. East-Central Europe and the former Soviet states are another set of countries where a regional approach is needed and would make sense, especially in light of Russia's unwillingness to continue to take back spent fuel from its former allies, at least for free. [28]

The most obvious rationale for a regional approach is to take advantage of geographical proximity and existing regional ties in other areas. The existence too of some form of regional identity (shared norms for example) might make decisions as to whether or not to host a site a lot easier. Choi (1997) develops the regional compact approach in more detail, identifying a possible regional breakdown based on existing and possible new arrangements. [29] In turn, agreements between countries could start out on the bilateral level and move to multilateral: the accord between Brazil and Argentina over sharing information about their respective nuclear materials and activities is a good example of the sort of bilateral initiative that could be extended outwards to include other countries. On the other hand, care must be taken not to assume that cooperative practices that took a long while to mature in Europe can be easily applied in other situations.

[28] This of course raises the issue of where East-Central Europe should belong in the international scheme of things: whether it should be grouped with the countries of the former Soviet Union, with Western Europe, or in a group of its own. This is a decision likely to be made as the result of larger political processes, most importantly, the ultimate decisions made over enlargement of the EU.

[29] The areas he examines for "regional compact" potential are: the NAFTA countries; ABACC (ArgentineBrazilian Agency for Accounting and Control of Nuclear Materials) and other South American countries; Scandinavia; EURATOM; Russia and Eastern Europe; the Middle East; South Asia, and ASEAN/East Asia (Choi, 1997).

e. Transportation Issues: The above discussion of the controversies surrounding Japanese plutonium, Gorleben, and Yucca Mountain show just how salient, and highly-loaded nuclear transportation issues are in both national and international political arenas. It would seem, judging by these cases, that practically no level, no matter how high, of technical reassurance, expertise or expense will counter these concerns and the opposition they generate. These concerns have been heightened further by the revelation in May 1998 of contamination from casks used to ship spent fuel from Germany to France that led to the refusal of the German police to continue to guard shipments and indeed to the suspension of these shipments for the time being.[30] These revelations were matched in Sweden in July 1998, and by information revealed about Japanese shipments.[31] Therefore the solution, if there is one, must lie elsewhere. However, it seems this could be a good, more limited policy area to begin addressing the public acceptance dilemma.

Some hope in this area from recent experience comes from the transportation of spent fuel from Tblisi to Scotland, even despite the problems at Dounreay that led to a pioneering fast-breeding reactor at the site being closed in June 1998.[32] The U.S. decision to restart the take-back of "foreign" research reactor fuel, which initially caused much controversy, but ultimately gained support of a wide variety of groups, also shows some positive movement in this area.[33] Despite worries about the secrecy under which the Dounreay operation was

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[30] See Mark Hibbs, "With German Transports Suspended, Reactors Face Specter of Closure", Nuclear Fuel, June 1, 1998, p. 5.

[31] "Sweden Also Finds Contamination Problems with SF Transport Casks", Nuclear Waste News, July 9, 1998

[32] "British Close Controversial Nuclear Plant at Astronomical Cost", Christian Science Monitor, June 8, 1998

[33] These shipments represent the restarting of Reduced Enrichment for Research and Test Reactors (RERTR) Program, first begun in 1978, but which in 1996 had lapsed for eight years. An anti-proliferation program, it sought to replace US-owned LIEU in foreign research reactors (where it had been used for medical purposes and scientific research) with low enriched uranium, thereby also converting reactors and repatriating the HEU. Fuel is due to be returned from 42 countries, coming into the U.S. through Concord Naval Weapons Station,

planned there was, ultimately, a recognition across the full range of parties that the benefits-materials security-from this action outweighed the risks. Whether or not this represents the "thin end of the wedge", however, depends on the extent the relevant authorities are able to use lessons from this example to defuse opposition, and are able to begin building public trust and confidence in transportation safety measures.

f. Learning from other international regimes: Much has been learnt about addressing international environmental issues from a multilateral perspective in recent years, as the global environmental governance structure has matured and gained in complexity, and it is likely that some lessons might fruitfully be applied to the spent fuel management issue. Spent fuel management shares with many global environmental issues both highly technical as well as political aspects. Government representatives are required to negotiate in the presence of a multitude of national interests and with the strong involvement of non-state actors and face many of the same problems of implementation and policy instrument choice as with other environmental regulatory agreements. Furthermore, the iterative convention-protocol approach that has been adopted in most international environmental negotiations could well be applied in this instance.

Two immediate comparisons that come to mind are first, the Basel Convention on the Transboundary Movement of Hazardous Wastes and Their Disposal, which governs the North-South waste trade, and second, the various policies and directives of the EU with respect to hazardous waste transfers among its member states. Both these sets of regulations share a concern with protecting especially the less industrialized countries from the risks posed by wastes from other countries: the terms of the Basel Convention explicitly ban North

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near San Francisco on the West Coast and Charleston Naval Weapons Station in the East, to be shipped to the Idaho National Engineering Laboratory and the Savannah River Site respectively. At least one of these shipments, through Concord, was successfully completed in July 1998.

to South waste transfers, and the EU directives seek to implement the principle of self-sufficiency in waste management. Some of the lessons that can be learnt from these regimes are useful in learning what to avoid: both, for example, have been stuck on questions of how to harmonize waste definitions and how to gather complete and accurate information, as well as having inadequate resources to monitor parties' actions and to enforce terms of the agreements. They have proved highly controversial, with one of the key stumbling blocks to effective implementation being the extent to which wastes, especially those that can be recycled, actually have economic value and should, therefore be treated as goods rather than as potentially harmful externalities. Finally, they fail to take into account some of the problems underlying the waste trade: for example, the veritable crisis situation in many industrialized countries, as waste generation figures continue to rise in the absence of minimization policies and/or new facilities (O'Neill, 1998). On the other hand, their emphasis on establishing thorough licensing procedures for transporters and disposal facilities and assigning liability, in particular to protect transit states can provide important precedents for the nuclear area .[34]

3. Questions to be answered in scheme design

a. Site vs. *regime arguments:* Several sets of dilemmas are involved in this debate. Broadly speaking, it is likely that setting up rules and some sort of transnational governance

[34] One analysis suggests that policies underlying management of hazardous and of radioactive wastes could be linked: "hazardous wastes could benefit not only from the methods of nuclear waste treatment, but also from the policies of nuclear waste management, which emphasize planning, international cooperation and the welfare of future generations" (Louka, 1994:99). Many, including the author, would disagree with this statement However, especially in the light of increased toxicity and longevity of many hazardous wastes, there is a case for treating them in similar fashion.

structure for spent fuel transportation and safety would be more likely to succeed than finding a host site first, and would possibly help overcome the host site paradox. This approach is also more likely to be followed under traditional methods of inter-state negotiations-a path not necessarily the most likely to be taken here as the role of private economic actors becomes more important.

Although this paper advocates regional networks or facilities with a regional locus of control, there is also a strong case for some type of global governance structure, at least to ensure a certain amount of standardization of safety and monitoring procedures, as well as to facilitate the sharing of relevant information across countries. There are, however, arguments for and against a single international disposal site. While probably easier to safeguard than a number of sites (although with much higher costs from capture by, for example, terrorist groups), and benefiting from economies of scale, a single site could also lead to higher overall transportation costs and would be less likely to be accepted by a potential host nation, any of which would most likely wish to avoid becoming the world's only nuclear dump site.[35]

Finally, the thorny question of what would constitute a good set of characteristics for a regional disposal site or host nation would have to be resolved. This question was raised earlier on in the context of the host site paradox. While most spent fuel generating states would probably prefer a politically stable and economically prosperous country, one with a good infrastructure and effective governance, this is quite probably an unlikely outcome, unless truly effective guarantees can be undertaken by whomever controls the site. There are other suggestions, however, one being that disposal facilities could be located either in under

[35] Although some advocate the single-site approach, using the argument that the international community would be highly unlikely to be able to negotiate more. The opinion here, however, is that depends on a range of factors, in particular what mode of governance would be chosen.

populated areas (e.g., the Gobi Desert), or even in existing ecological disaster areas. How acceptable either of those would be, however, remains to be seen.

Recent approaches in the field of hazardous and radioactive waste politics and policy discuss the importance of allowing potential host communities volunteer their services: perhaps a way in which an international site could be established, with countries, rather than communities, volunteering services. A recent edited volume (Munton, 1996) examines in some detail processes of voluntary negotiation over waste disposal site selection and the (mixed but encouraging) success that these have had in siting hazardous and nuclear waste facilities, especially in comparison with the older approaches such as "Decide, Announce, Defend", in breaking down the NIMBY deadlock at least in some cases and building institutional credibility in ways that lead to lasting consensus across actors.[36] The lessons these draw from experiences around the world are applicable, though probably not wholly so, to the siting of an international facility.[37]

One of the reasons why voluntary siting processes are less applicable in the case of international spent fuel management is that evidence presented in this volume suggest that communities who agree to host a site often stipulate that they will not accept wastes from other jurisdictions within the same country, let alone wastes from abroad (Rabe, Gunderson and Harbage, 1996:93). Second, complex and, most likely, heated negotiations would also have to be carried out over transportation of wastes across international borders and other states' territory. Third, and this is a general argument often raised against these approaches, many object on the grounds that outcomes are likely to be inequitable, whereby poorer

[36] While also noting the need for cross-national studies on these issues (Kraft, 1996:134-135).

[37] In particular, see Kraft (1996) in this volume on HLW, who, among other things, stresses the need to take contextual, or case specific factors into account when looking at possible siting options for a HLW repository.

countries are most likely to volunteer. This question, of how interests and preferences are shaped here, and whether volunteerism is real or not is a hugely controversial issue and remains to be resolved. It is, however, one that brings an array of third parties, such as NGOs, into such disputes. All three of these weaknesses can be seen in direct analogy with cases of transfer of nuclear wastes to sovereign Native American territories in the United States, and are likely to be transferred and possibly exacerbated, in the absence of institutional factors, to such practices at higher international levels.[38]

b. Commercial Viability and Compliance Incentives: Finding the right public-private mix is crucial to the success of an international spent-fuel management regime and would in particular alter existing incentive structures for both regime compliance and effectiveness. There are strong arguments to suggest that spent fuel schemes will only work if the commercial incentives are there that make it more profitable for private fines to run or participate in such a scheme instead of relying on increased reprocessing or maintaining the existing status quo. These incentives would ensure that utilities would want to participate and would enable host governments to generate enough revenue and/or employment to make taking on the burden worthwhile. According to one rough estimate, reprocessing contracts run at about $800 per kg of heavy metal, compared with spent fuel storage at $300 per kg.[39] Even adding in the costs of safeguards and transportation, there are likely to be huge profits

[38] See, in particular, "Prosperity Brings New Conflict to Indian Country," and "Backlash Growing as Indians Make a Stand for Sovereignty." The New York Times, March 8 and 9, 1998, byline Timothy Egan. The former discusses the decision of the Goshute Tribe in Utah to bid for a civilian nuclear waste disposal site, and the opposition this gave rise to on the part of the Utah state government and various environmental groups. See also Brook, 1998.

[39] Of course, many factors come into play at this point. For example, different options for spent fuel storage (e.g. dry cask vs. pool) alter the calculations. See, for example, Rojas de Diego, 1990 on this.

here, given the rate at which spent fuel has been generated (see Table 1).[40] Furthermore, the currently historically low price of uranium provides a further incentive for continuing the open fuel cycle.

While a vital factor in the acceptability of such schemes would be their profitability, and private actors, such as the nuclear utilities, uranium mining firms, and entrepreneurs are already playing an important role in ongoing negotiations, any waste disposal issue is too fraught with possible market failures and informational asymmetries to be left entirely in private hands. In addition the days when bilateral reprocessing contracts were the sole province of the actors involved who would profit directly from such transactions are long-gone in today's international political climate. It is also necessary to take other factors such as long-term profitability, insurance issues, and liability into account. Hence, some sort of public-private balance needs to be worked out, with carefully delineated roles for state, international, and non-state stakeholders in the issue area.

c. Scope of the Fuel Cycle: So far, the discussion presented here has revolved around finding a way of internationalizing the back end of the fuel cycle while also discussing some options for minimal coordination of activities as a way of instigating broader cooperation over the longer term. However, some proposals-e.g. for an Asian regional pact-have also raised the issue of internationalizing the complete fuel cycle, and others that of leasing and buying back fuel to utilities. Full internationalization of the fuel cycle is most often discussed in countries that are just now establishing or expanding their nuclear power

[40] Estimates from conversation with Matthew Bunn, March, 1998. Other comparisons differ. For example, one analysis compares two studies: a 1994 OECD study interpreted by Cogema, and one from the German Association of Electricity Generators, both of which show the undiscounted, back-end costs of reprocessingrecycle options vs. storage-direct disposal. The former shows little difference between the two options, while the latter shows the costs associated with a closed fuel cycle as roughly twice that of an open cycle, although it is unclear the extent to which government subsides for reprocessing, for example, are included in these estimates (Berkhout, 1997b).

generation. It is certainly the case that other parts of the fuel cycle have not internalized the environmental costs of dealing with high level wastes and spent fuel-as in the cheap price of uranium worldwide, which reflects primarily its availability and ease of extraction.[41] This price in turn discourages reprocessing, thus further allowing the accumulation of spent fuel. These issues are complex and should form part of the discussions on international nuclear management. Although they do not necessarily imply a need for complete internationalization of the cycle, rather individual nuclear power programs need to take a more holistic view of their activities and impacts.

d. Time horizons: Again, there is no particular "right" answer as to what constitutes the appropriate time frame for any spent fuel storage scheme. However, as the above discussion of recent proposals shows (see Table 2), there exists a range of different opinions as to how long a spent fuel storage scheme should operate and whether it should be permanent, interim, or with the time frame determined by some exogenous factor, such as a revival in reprocessing or the emergence of new technologies .[42] If a permanent option is chosen, then serious consideration must be given as to how the materials can be safeguarded for the extreme length of time for which they will be dangerous. If storage is interim, then it must be made clear when, and under what conditions (e.g., development of reprocessing capacity, or the emergence of new waste disposal technologies) the fuel will be released back to its original or to new owners.

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[41] Thanks to Stacy VanDeveer for this point

[42] Professor Atsuyuki Suzuki refers to this letter as "strategic" storage, neither interim nor permanent, but which recognizes spent fuel not as a waste but as an object of some strategic and economic value. From a talk given at a meeting of United States and Japanese experts on nuclear matters, Belfer Center for Science and International Affairs, Harvard University, February 3, 1998 (A. Suzuki, 1998).

Conclusions and Areas for Further Research

Despite the seriousness of spent nuclear reactor fuel management problems worldwide, the amount of activity and ideas currently being generated, and the facilitating factors and general finding in favor of international cooperation in this area, progress towards finding a long-term international solution to the management of spent reactor fuel is, and is likely to remain, extremely slow. This paper advocates taking an incremental, or step-by-step, approach towards building an international regime or regimes to manage spent fuel, entailing short to medium term activities towards finding a solution to the storage crisis facing many nuclear operators and, similarly, attempting to change the array of domestic and international factors impeding a solution, thus forging some sort of consensus across different groups of stakeholders in this issue area. It recommends a regional approach to international spent fuel management, following that suggested in discussions in Asian forums. Regional sites would be managed at that level to enhance flexibility, but within the context of an international framework agreement (perhaps under IAEA auspices) to maintain common standards and to increase flows of information. The paper also concurs with much recent analysis that a strong commercial aspect, including involvement at all levels by private actors, would be an important incentive for such schemes to work, and for countries to agree to be hosts.

It must be stressed that the factors discussed above constitute only the first steps towards finding a solution to the world's nuclear waste management problems. One of the biggest challenges faced by advocates and managers of an international regime would be to forge a broad-based and lasting consensus, obtaining trust from the publics of exporting and

receiving countries and consent from groups that oppose transboundary radioactive waste shipments, as demonstrated in the above discussion of voluntary siting approaches. To do this entails a firm commitment to a lengthy process of negotiation, not only as the regime is established, but throughout its implementation, and a much greater commitment to openness on the part of participating firms and governments than has to date been the case. Exactly how these commitments can be institutionalized and what factors drive the making of public opinion in this area is a much needed topic for future research, which could use as its base the extensive literature on risk communication and analysis that has grown up here.[43] It would also be useful to examine other issue areas where public and private actors have had to negotiate over issues with complex and highly controversial technical and/or socio-political aspects to see what, if anything could be learnt by actors and groups from both sides.

A second area for related research would be into specific "problem" areas of the world with respect to spent fuel management, in addition to the East Asia and Pacific regions. In particular, there is a pressing case for examining how the former Soviet bloc countries are handling their waste management commitments, and how this could be improved with help from the international community in the near future. Similarly, there are few rigorous cross-national comparisons of the politics of nuclear waste and spent fuel management;[44] it would be useful to fill this gap.

Finally, one of the main trends in this area is the increased and very important involvement of private economic and other non-state actors in an issue traditionally seen as having been kept under close governmental control. Private firms and commercial interests

[43] For some recent examples of works on public trust of governments that discuss nuclear issues, see Kasperson et al, 1998, La Porte and Metlay, 1996, and Greenberg et al, 1997.

[44] Although see Blowers et al, 1991, for a comparison of nuclear waste politics in Western European countries and the United States.

are now seen as necessary in solutions to international and national nuclear power problems, including the safe transportation and storage of spent reactor fuel, and at the national level, increased industry deregulation is changing the baseline for public-private interaction in this issue area. Important themes here would include identifying the main actors involved in international activities related to the fuel cycle and to radioactive waste management, their role and their relative clout; the extent to which private actors really are more capable than government agencies of taking on responsibility for managing such dangerous substances, and how private economic actors address their relationship with opponents, such as antinuclear activists, and the increasingly global environmental (and anti-nuclear) movement. Much interesting work also remains to be done on the rise of the global anti-nuclear movement and its political impact. Shedding light on these questions would very much aid those who seek to understand how such an important issue can adequately be addressed in international forums.

List of Acronyms

AFR	Away From Reactor
CANDU	Heavy Water Reactors - Canadian Model
CSCAP	Council for Security Cooperation in the Asia-Pacific
EU	European Union
EURATOM	European Atomic Energy Community
HLW	High-Level Radioactive Waste
IAEA	International Atomic Energy Agency
IEA	International Energy Agency (OECD)
IMRSS	Internationally Monitored Regional Storage System
MOX	Mixed Oxide Fuel
NIMBY	Not In My Back Yard
OECD	Organization for Economic Cooperation and Development
RBMK	Graphite-Moderated Nuclear Reactor (USSR)

Table 2: Recently Proposed Schemes for International Spent Fuel Management

Scheme	Personnel and Dates /Status	Fuel Cycle Scope	International Scope and Locus of Control	Funding/ management	Goals	Timescale
IMRSS[a]	Chauncey Starr/ Wolf Häfele 1993 - present	Spent Fuel only	Regional centers administered internationally by an IAEA-affiliated organization	"Fuel Bank" via domestic tax; some commercial activity. No transfer of ownership	Anti-proliferation Pro nuclear power	Interim; not permanent
US Fuel and Security	Coalition of private entrepreneurs, led by Alex Copson 1996 - present (embattled)	Would lease fuel to the utilities and take back spent fuel	One Pacific island; US - Russia focus, but international potential	Private (joint venture with MinAtom).[b] Support of uranium companies	Anti-Proliferation Commercial	Long-term storage
Asiatom-type schemes	Multiple advocates; 1994 - present	Full cycle or just SF	Regional Control	Regional forum (governmental)	Environmental Commercial Anti-proliferation	Long-term

[a] Internationally Monitored Retrievable Storage System. See Häfele and Starr, 1998, and Häfele, 1996.

[b] Note the support of Russia's atomic energy agency, Minatom. The Bellona Foundation, a nuclear watchdog group based in Northern Europe, surmises that Minatom will use the predicted refusal of the US to support this scheme to push for plans for developing its own storage facility at Novaya Zemlya See Bellona Foundation, "Pacific Nuclear Waste Project Goes One Further." August 27, 1997 (www.bellona.no/e/index.htm#News)

References

Albright, David, Frans Berkhout, and William Walker. *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies.* Oxford: SIPRI/Oxford University Press, 1997.

Anderson, C. K. "Interim Spent Fuel Management." Paper presented at the Uranium Institute 1993 Symposium.

Berkhout, Frans. "The International Civilian Reprocessing Business." *Energy and Security,* No. 2, (January/October 1997a) (www.ieer.org).

Berkhout, Frans. "The Economics of Reprocessing." *Energy and Security* No. 2, (January/October 1997b) (www.ieer.org).

Berkhout, Frans. "International Spent Fuel Storage." Draft Report, December 1994.

Berkhout, Frans and William Walker. "Spent Fuel and Plutonium Policies in Western Europe: The Non-Nuclear Weapon States." *Energy Policy,* (July/August, 1991), pp. 553-566.

Blowers, Andrew, and David Lowry. "Nuclear Conflict in Germany: The Wider Context." *Environmental Politics* 6.3 (1997): 148-155.

Blowers, Andrew, D. Lowry, and B. Solomon. *The International Politics of Nuclear Waste*. London: Macmillan, 1991.

Bredell, P. J. "A System for Regional Spent Fuel Storage." Presented at the IAEA Technical Committee Meeting on the Technologies and Safety Aspects of a Regional Spent Fuel Storage Facility, Vienna, Austria, December 1-4, 1997.

Bredell, P. J. and H. D. Fuchs, "International Cooperation with regard to Regional Repositories for Radioactive Waste Disposal." Presented at the IAEA Symposium on the Nuclear Fuel Cycle and Reactor Strategies: Adjusting to Realities, Vienna, Austria, June 3-6, 1997.

Bunn, Matthew, and John P. Holdren. "Managing Military Uranium and Plutonium in the United States and the Former Soviet Union." *Annual Review of Energy and the Environment* 22 (1997): 403-86.

Carter, Luther J. and Thomas H. Pigford. "Getting Yucca Mountain Right." *The Bulletin of the Atomic Scientists,* (March/April 1998), pp. 56-61.

Chen, Candace Y. "Radioactive Waste Management: An International Perspective." *IAEA Bulletin* 34:3 (1992), pp. 7-15.

Choi, Jor-Shan. *A Regional Compact Approach for the Peaceful Use of Nuclear Energy; Case Study: East Asia. CISAC Working Papers.* Stanford, CA: Center for International Security and Arms Control, Stanford University, 1997.

Cossa, Ralph (Ed.). *Asia-Pacific Multilateral Nuclear Safety and Non-Proliferation: Exploring the Possibilities.* A CSCAP Working Group Special Report, Pacific Forum/CSIS, December 1996.

Dunn, Lewis A. and Stephen Carey. "Internationalizing Spent Fuel Storage: Concepts, Issues, and Options." Report prepared by the Science Applications International Corporation, February 25, 1998.

Flynn, James, Roger E. Kasperson, Howard Kunreuther, and Paul Slavic. "Overcoming Tunnel Vision: Redirecting the United States High-Level Nuclear Waste Program." *Environment,* April 1997, pp. 7-11, 25-30.

Goldschmidt, Pierre. "The back-end of the nuclear fuel cycle in Europe: A story of achievement." Summary of talk given at the Nuclear Energy Institute in Washington in January 1995 (from Uranium Institute).

Greenberg, Michael, et al. "Bombs and Butterflies: A Case Study of the Challenges of Post-Cold War Environmental Planning and Management for the United States Nuclear Weapons Sites." *Journal of Environmental Planning and Management* 40.6 (1997): 739-750.

Hackel, E. "Internationalization of the Back End of the Nuclear Fuel Cycle: Problems and Prospects." Presented at the IAEA Symposium on the Nuclear Fuel Cycle and Reactor Strategies: Adjusting to Realities, Vienna, Austria, June 3-6, 1997.

Hafele, Wolf and Chauncey Start. "Proposal for an Internationally Monitored Retrievable Storage System (IMRSS)." Notes from a talk prepared for G8 Expert Meeting on Plutonium, March 30, 1998.

Hafele, Wolf. "The Concept of an Internationally Monitored Retrievable Storage System." Presented at the Uranium Institute Symposium, London, August 1996.

Hafele, Wolf. "Energy from Nuclear Power." From *Energy for Planet Earth,* edited by Scientific American, 95-105. New York: W. H. Freeman, 1990.

Hibbs, Mark. "With German Transports Suspended, Reactors Face Specter of Closure." *Nuclear Fuel,* June 1, 1998.

Hibbs, Mark. "For Eastern Europe's Research Reactors, No Russian Takeback, Spent Fuel Relief." *Nuclear Fuel,* April 6, 1998.

Hibbs, Mark. "Stage for German Waste Conflict Shifting from Gorleben to Ahaus." *Nucleonics Week,* February 5, 1998.

Holdren, John P. "Radioactive Waste Management in the United States: Evolving Policy Prospects and Dilemmas." *Annual Review of Energy and the Environment* 17 (1992): 235-59.

International Atomic Energy Agency, Report on the IAEA Technical Committee Meeting to collect and evaluate information on the Technologies and Safety Aspects of a Regional Spent Fuel Storage Facility, Vienna, Austria, December 1-4, 1997 (E-mail correspondence from H. P. Dyck).

Kasperson, Roger E., Dominic Golding, and Jeanne X. Kasperson. *Risk, Trust and Democratic Theory. Weatherhead Center for Science and International Affairs Seminar Series on International Environmental Politics.* Harvard University: 1998.

Kraft, Michael E. "Democratic Dialogue and Acceptable Risks: The Politics of High-Level Nuclear Waste Disposal in the United States." *Hazardous Waste Siting and Democratic Choice.* Ed. Don Munton. Washington: Georgetown University Press, 1996.

Janberg, Klaus. "Regional Spent Fuel Storage Facilities." Presented at the IAEA Technical Committee Meeting on the Technologies and Safety Aspects of a Regional Spent Fuel Storage Facility, Vienna, Austria, December 1-4, 1997.

La Porte, Todd R., and Daniel S. Metlay. "Hazards and Institutional Trustworthiness: Facing a Deficit of Trust." *Public Administration Review* 56.4 (1996): 341-347.

Louka, E. *The Transnational Movements of Hazardous and Radioactive Wastes. Orville H. Schell Jr. Center for Human Rights Occasional Papers.* New Haven: Yale University Press, 1992.

Löwgren, Marianne. "Nuclear Waste Management in Sweden: Balancing Risk Perceptions and Developing Community Consensus." *Problems and Prospects for Nuclear Waste Disposal Policy.* Eds. Eric B. Herzik and Alvin H. Mushkatel. Westport, CT: Greenwood Press, 1993.

Manning, Robert A. "PACATOM: Nuclear Cooperation in Asia." *The Washington Quarterly* 20.2 (1997): 217-232.

Medeiros, Evan S. "U.S: EURATOM nuclear accord enters into force; trade resumes. *Arms Control Today* 26.2 (1996): pp. 25 on.

Mitchell, Ronald B. "Sources of Transparency: Information Systems in International Regimes." *International Studies Quarterly* 42.1 (1998): 109-130.

Munton, Don, ed. *Hazardous Waste Siting and Democratic Choice*. Washington: Georgetown University Press, 1996.

Olsen, John N., and Richard C. Lincoln. "Potential Nuclear Cooperative Measures for Safety, the Environment and Nonproliferation in East Asia." working paper, Cooperative Monitoring Center, Sandia National Laboratories, New Mexico. (www.cmc.sandia.gov/issues/papers/971404c)

O'Neill, Kate. "Out of the Backyard: The Problems of Hazardous Waste Management at a Global Level." *Journal of Environment and Development* 7.2 (1998): 138-163.

Popova, Lydia. "International Implications of United States Reprocessing." *Energy and Security* No. 2, (January/October 1997) (www.ieer.org).

Porter, Gareth, and Janet Welsh Brown. *Global Environmental Politics, 2nd Edition.* Boulder: Westview, 1995.

Rabe, Barry G., William C. Gunderson, and Peter T. Harbage. "Alternatives to NIMBY Gridlock: Voluntary Approaches to Radioactive Waste Facility Siting in Canada and the United States." *Hazardous Waste Siting and Democratic Choice.* Ed. Don Munton. Washington: Georgetown University Press, 1996.

Rojas de Diego, Jose. "Economics of Spent Fuel Storage: A description of the methodology developed by the IAEA for analyzing costs." *IAEA Bulletin* 32.3 (1990): 34-38.

Semenov, B. A. "Disposal of Spent Fuel and High-Level Radioactive Waste: Building International Consensus", *IAEA Bulletin* 34:3 (1992), pp. 2-6.

Seth, Anita. "Reprocessing: Where and How." *Energy and Security* No. 2, (January/October 1997) (www.ieer.org).

Silverstein, Ken. "Nuclear Burial in the Pacific: Plans for Nuclear Waste Dump on a Pacific Island." *The Progressive*, (November 1997), p. 32 on.

Speier, Richard H., and Brian G. Chow. *Asiatom: Proposals, Alternatives and Next Steps.* RAND, 1996.

Starr, Chauncey. "Review of the Internationally Monitored Retrievable Storage System (IMRSS). " Notes from a talk given in Washington DC, January 8, 1997.

Suzuki, Atsuyuki. "Towards a More Flexible and More Robust Nuclear Fuel Cycle Program in Japan." Talk prepared for a meeting of United States and Japanese experts on nuclear policy, Belfer Center for Science and International Affairs, Harvard University, February 3, 1998.

Takagi, Dr. J. "Nuclear Power is No Future Energy to Asian Countries." produced by the Citizens' Nuclear Information Center, Japan, 1997 (full text at www.jca.ax.apc.org/cnic/english/topics/nuke-and-asia.httnl).

Takats, F., A. Grigoriev, and I.G. Ritchie. "Management of spent fuel from power and research reactors: International status and trends." *IAEA Bulletin* 35:3 (1993), PP- 1822.

Tanzer, Sharon. "The Most Important Questions and Answers about the Nuclear Waste Shipment." The Nuclear Control Institute, January 1998 (http://www.igc.apc.org/nci).

von Hippel, Frank, and Suzanne Jones. "The Slow Death of the Fast Breeder." *The Bulletin of the Atomic Scientists* 53.5 (1997); 46-51.

Wolfson, Richard. *Nuclear Choices: A Citizen's Guide to Nuclear Technology*. Cambridge: MIT Press, 1993.

Wynne, Brian, ed. *Risk Management and Hazardous Waste: Implementation and the Dialectics of Credibility*. Berlin: Springer-Verlag, 1987.