= High @-@ level radioactive waste management =

High @-@ level radioactive waste management concerns how radioactive materials created during production of nuclear power and nuclear weapons are dealt with . Radioactive waste contains a mixture of short @-@ lived and long @-@ lived nuclides , as well as non @-@ radioactive nuclides . There was reported some 47 @,@ 000 tonnes of high @-@ level nuclear waste stored in the USA in 2002 .

The most troublesome transuranic elements in spent fuel are neptunium @-@ 237 (half @-@ life two million years) and plutonium @-@ 239 (half @-@ life 24 @,@ 000 years) . Consequently , high @-@ level radioactive waste requires sophisticated treatment and management to successfully isolate it from the biosphere . This usually necessitates treatment , followed by a long @-@ term management strategy involving permanent storage , disposal or transformation of the waste into a non @-@ toxic form . Radioactive decay follows the half @-@ life rule , which means that the rate of decay is inversely proportional to the duration of decay . In other words , the radiation from a long @-@ lived isotope like iodine @-@ 129 will be much less intense than that of short @-@ lived isotope like iodine @-@ 131 .

Governments around the world are considering a range of waste management and disposal options , usually involving deep @-@ geologic placement , although there has been limited progress toward implementing long @-@ term waste management solutions . This is partly because the timeframes in question when dealing with radioactive waste range from 10 @,@ 000 to millions of years , according to studies based on the effect of estimated radiation doses .

Thus , Alfvén identified two fundamental prerequisites for effective management of high @-@ level radioactive waste : (1) stable geological formations , and (2) stable human institutions over hundreds of thousands of years . As Alfvén suggests , no known human civilization has ever endured for so long , and no geologic formation of adequate size for a permanent radioactive waste repository has yet been discovered that has been stable for so long a period . Nevertheless , avoiding confronting the risks associated with managing radioactive wastes may create countervailing risks of greater magnitude . Radioactive waste management is an example of policy analysis that requires special attention to ethical concerns , examined in the light of uncertainty and futurity : consideration of ' the impacts of practices and technologies on future generations ' .

There is a debate over what should constitute an acceptable scientific and engineering foundation for proceeding with radioactive waste disposal strategies . There are those who have argued , on the basis of complex geochemical simulation models , that relinquishing control over radioactive materials to geohydrologic processes at repository closure is an acceptable risk . They maintain that so @-@ called " natural analogues " inhibit subterranean movement of radionuclides , making disposal of radioactive wastes in stable geologic formations unnecessary . However , existing models of these processes are empirically underdetermined : due to the subterranean nature of such processes in solid geologic formations , the accuracy of computer simulation models has not been verified by empirical observation , certainly not over periods of time equivalent to the lethal half @-@ lives of high @-@ level radioactive waste . On the other hand , some insist deep geologic repositories in stable geologic formations are necessary . National management plans of various countries display a variety of approaches to resolving this debate .

Researchers suggest that forecasts of health detriment for such long periods should be examined critically . Practical studies only consider up to 100 years as far as effective planning and cost evaluations are concerned . Long term behaviour of radioactive wastes remains a subject for ongoing research . Management strategies and implementation plans of several representative national governments are described below .

= = Geologic disposal = =

The International Panel on Fissile Materials has said :

It is widely accepted that spent nuclear fuel and high @-@ level reprocessing and plutonium wastes require well @-@ designed storage for periods ranging from tens of thousands to a million years , to

minimize releases of the contained radioactivity into the environment . Safeguards are also required to ensure that neither plutonium nor highly enriched uranium is diverted to weapon use . There is general agreement that placing spent nuclear fuel in repositories hundreds of meters below the surface would be safer than indefinite storage of spent fuel on the surface .

The process of selecting appropriate permanent repositories for high level waste and spent fuel is now under way in several countries with the first expected to be commissioned some time after 2017 . The basic concept is to locate a large , stable geologic formation and use mining technology to excavate a tunnel , or large @-@ bore tunnel boring machines (similar to those used to drill the Chunnel from England to France) to drill a shaft 500 ? 1 @,@ 000 meters below the surface where rooms or vaults can be excavated for disposal of high @-@ level radioactive waste . The goal is to permanently isolate nuclear waste from the human environment . However , many people remain uncomfortable with the immediate stewardship cessation of this disposal system , suggesting perpetual management and monitoring would be more prudent .

Because some radioactive species have half @-@ lives longer than one million years , even very low container leakage and radionuclide migration rates must be taken into account . Moreover , it may require more than one half @-@ life until some nuclear materials lose enough radioactivity to no longer be lethal to living organisms . A 1983 review of the Swedish radioactive waste disposal program by the National Academy of Sciences found that country ? s estimate of several hundred thousand years ? perhaps up to one million years ? being necessary for waste isolation " fully justified . "

The proposed land @-@ based subductive waste disposal method would dispose of nuclear waste in a subduction zone accessed from land , and therefore is not prohibited by international agreement . This method has been described as a viable means of disposing of radioactive waste , and as a state @-@ of @-@ the @-@ art nuclear waste disposal technology .

In nature , sixteen repositories were discovered at the Oklo mine in Gabon where natural nuclear fission reactions took place 1 @.@ 7 billion years ago . The fission products in these natural formations were found to have moved less than 10 ft (3 m) over this period , though the lack of movement may be due more to retention in the uraninite structure than to insolubility and sorption from moving ground water ; uraninite crystals are better preserved here than those in spent fuel rods because of a less complete nuclear reaction , so that reaction products would be less accessible to groundwater attack .

= = Materials for geological disposal = =

In order to store the high level radioactive waste in long @-@ term geological depositories , specific waste forms need to be used which will allow the radioactivity to decay away while the materials retain their integrity for thousands of years . The materials being used can be broken down into a few classes : glass waste forms , ceramic waste forms , and nanostructured materials .

The glass forms include borosilicate glasses and phosphate glasses . Borosilicate nuclear waste glasses are used on an industrial scale to immobilize high level radioactive waste in many countries which are producers of nuclear energy or have nuclear weaponry . The glass waste forms have the advantage of being able to accommodate a wide variety of waste @-@ stream compositions , they are easy to scale up to industrial processing , and they are stable against thermal , radiative , and chemical perturbations . These glasses function by binding radioactive elements to nonradioactive glass @-@ forming elements . Phosphate glasses while not being used industrially have much lower dissolution rates than borosilicate glasses , which make them a more favorable option . However , no single phosphate material has the ability to accommodate all of the radioactive products so phosphate storage requires more reprocessing to separate the waste into distinct fractions . Both glasses have to be processed at elevated temperatures making them unusable for some of the more volatile radiotoxic elements .

The ceramic waste forms offer higher waste loadings than the glass options because ceramics have crystalline structure . Also , mineral analogues of the ceramic waste forms provide evidence for long term durability . Due to this fact and the fact that they can be processed at lower temperatures ,

ceramics are often considered the next generation in high level radioactive waste forms . Ceramic waste forms offer great potential , but a lot of research remains to be done .

= = National management plans = =

Finland , the United States and Sweden are the most advanced in developing a deep repository for high @-@ level radioactive waste disposal . Countries vary in their plans on disposing used fuel directly or after reprocessing , with France and Japan having an extensive commitment to reprocessing . The country @-@ specific status of high @-@ level waste management plans are described below .

In many European countries (e.g. , Britain , Finland , the Netherlands , Sweden and Switzerland) the risk or dose limit for a member of the public exposed to radiation from a future high @-@ level nuclear waste facility is considerably more stringent than that suggested by the International Commission on Radiation Protection or proposed in the United States . European limits are often more stringent than the standard suggested in 1990 by the International Commission on Radiation Protection by a factor of 20 , and more stringent by a factor of ten than the standard proposed by the U.S. Environmental Protection Agency (EPA) for Yucca Mountain nuclear waste repository for the first 10 @,@ 000 years after closure . Moreover , the U.S. EPA ? s proposed standard for greater than 10 @,@ 000 years is 250 times more permissive than the European limit .

The countries that have made the most progress towards a repository for high @-@ level radioactive waste have typically started with public consultations and made voluntary siting a necessary condition . This consensus seeking approach is believed to have a greater chance of success than top @-@ down modes of decision making , but the process is necessarily slow , and there is " inadequate experience around the world to know if it will succeed in all existing and aspiring nuclear nations " .

Moreover , most communities do not want to host a nuclear waste repository as they are " concerned about their community becoming a de facto site for waste for thousands of years , the health and environmental consequences of an accident , and lower property values " .

= = = Asia = = =

= = = = People 's Republic of China = = = =

In the Peoples Republic of China , ten reactors provide about 2 % of electricity and five more are under construction . China made a commitment to reprocessing in the 1980s ; a pilot plant is under construction at Lanzhou , where a temporary spent fuel storage facility has been constructed . Geological disposal has been studied since 1985 , and a permanent deep geological repository was required by law in 2003 . Sites in Gansu Province near the Gobi desert in northwestern China are under investigation , with a final site expected to be selected by 2020 , and actual disposal by about 2050 .

= = = = Republic of China = = = =

In the Republic of China , nuclear waste storage facility was built at the Southern tip of Orchid Island in Taitung County , offshore of Taiwan Island . The facility was built in 1982 and it is owned and operated by Taipower . The facility receives nuclear waste from Taipower 's current three nuclear power plants . However , due to the strong resistance from local community in the island , the nuclear waste has to be stored at the power plant facilities themselves .

= = = = India = = = =

Sixteen nuclear reactors produce about 3 % of India ? s electricity , and seven more are under

construction . Spent fuel is processed at facilities in Trombay near Mumbai , at Tarapur on the west coast north of Mumbai , and at Kalpakkam on the southeast coast of India . Plutonium will be used in a fast breeder reactor (under construction) to produce more fuel , and other waste vitrified at Tarapur and Trombay . Interim storage for 30 years is expected , with eventual disposal in a deep geological repository in crystalline rock near Kalpakkam .

= = = = Japan = = = =

In 2000 , a Specified Radioactive Waste Final Disposal Act called for creation of a new organization to manage high level radioactive waste , and later that year the Nuclear Waste Management Organization of Japan (NUMO) was established under the jurisdiction of the Ministry of Economy , Trade and Industry . NUMO is responsible for selecting a permanent deep geological repository site , construction , operation and closure of the facility for waste emplacement by 2040 . Site selection began in 2002 and application information was sent to 3 @,@ 239 municipalities , but by 2006 , no local government had volunteered to host the facility . K?chi Prefecture showed interest in 2007 , but its mayor resigned due to local opposition . In December 2013 the government decided to identify suitable candidate areas before approaching municipalities .

The head of the Science Council of Japan ? s expert panel has said Japan 's seismic conditions makes it difficult to predict ground conditions over the necessary 100 @,@ 000 years , so it will be impossible to convince the public of the safety of deep geological disposal .

= = = Europe = = =

= = = = Belgium = = = =

Belgium has seven nuclear reactors that provide about 52 % of its electricity . Belgian spent nuclear fuel was initially sent for reprocessing in France . In 1993 , reprocessing was suspended following a resolution of the Belgian parliament ; spent fuel is since being stored on the sites of the nuclear power plants . The deep disposal of high @-@ level radioactive waste (HLW) has been studied in Belgium for more than 30 years . Boom Clay is studied as a reference host formation for HLW disposal . The Hades underground research laboratory (URL) is located at ? 223 m in the Boom Formation at the Mol site . The Belgian URL is operated by the Euridice Economic Interest Group , a joint organisation between SCK ? CEN , the Belgian Nuclear Research Centre which initiated the research on waste disposal in Belgium in the 1970s and 1980s and ONDRAF / NIRAS , the Belgian agency for radioactive waste management . In Belgium , the regulatory body in charge of guidance and licensing approval is the Federal Agency of Nuclear Control , created in 2001 .

= = = = Finland = = = =

In 1983 , the government decided to select a site for permanent repository by 2010 . With four nuclear reactors providing 29 % of its electricity , Finland in 1987 enacted a Nuclear Energy Act making the producers of radioactive waste responsible for its disposal , subject to requirements of its Radiation and Nuclear Safety Authority and an absolute veto given to local governments in which a proposed repository would be located . Producers of nuclear waste organized the company Posiva , with responsibility for site selection , construction and operation of a permanent repository . A 1994 amendment to the Act required final disposal of spent fuel in Finland , prohibiting the import or export of radioactive waste .

Environmental assessment of four sites occurred in 1997 ? 98 , Posiva chose the Olkiluoto site near two existing reactors , and the local government approved it in 2000 . The Finnish Parliament approved a deep geologic repository there in igneous bedrock at a depth of about 500 meters in 2001 . The repository concept is similar to the Swedish model , with containers to be clad in copper and buried below the water table beginning in 2020 . An underground characterization facility ,

Onkalo spent nuclear fuel repository , was under construction at the site in 2012 .

= = = = France = = = =

With 58 nuclear reactors contributing about 75 % of its electricity , the highest percentage of any country , France has been reprocessing its spent reactor fuel since the introduction of nuclear power there . Some reprocessed plutonium is used to make fuel , but more is being produced than is being recycled as reactor fuel . France also reprocesses spent fuel for other countries , but the nuclear waste is returned to the country of origin . Radioactive waste from reprocessing French spent fuel is expected to be disposed of in a geological repository , pursuant to legislation enacted in 1991 that established a 15 @-@ year period for conducting radioactive waste management research . Under this legislation , partition and transmutation of long @-@ lived elements , immobilization and conditioning processes , and long @-@ term near surface storage are being investigated by the Commissariat à l ? Energie Atomique (CEA) . Disposal in deep geological formations is being studied by the French agency for radioactive waste management , L 'Agence Nationale pour la Gestion des Déchets Radioactifs , in underground research labs .

Three sites were identified for possible deep geologic disposal in clay near the border of Meuse and Haute @-@ Marne , near Gard , and at Vienne . In 1998 the government approved the Meuse / Haute Marne Underground Research Laboratory , a site near Meuse / Haute @-@ Marne and dropped the others from further consideration . Legislation was proposed in 2006 to license a repository by 2015 , with operations expected in 2025 .

= = = = Germany = = = =

Nuclear waste policy in Germany is in flux . German planning for a permanent geologic repository began in 1974 , focused on salt dome Gorleben , a salt mine near Gorleben about 100 kilometers northeast of Braunschweig . The site was announced in 1977 with plans for a reprocessing plant , spent fuel management , and permanent disposal facilities at a single site . Plans for the reprocessing plant were dropped in 1979 . In 2000 , the federal government and utilities agreed to suspend underground investigations for three to ten years , and the government committed to ending its use of nuclear power , closing one reactor in 2003 .

Within days of the March 2011 Fukushima Daiichi nuclear disaster , Chancellor Angela Merkel " imposed a three @-@ month moratorium on previously announced extensions for Germany 's existing nuclear power plants , while shutting seven of the 17 reactors that had been operating since 1981 " . Protests continued and , on 29 May 2011 , Merkel 's government announced that it would close all of its nuclear power plants by 2022 .

Meanwhile , electric utilities have been transporting spent fuel to interim storage facilities at Gorleben , Lubmin and Ahaus until temporary storage facilities can be built near reactor sites . Previously , spent fuel was sent to France or the United Kingdom for reprocessing , but this practice was ended in July 2005 .

= = = = Russia = = = =

In Russia , the Ministry of Atomic Energy (Minatom) is responsible for 31 nuclear reactors which generate about 16 % of its electricity . Minatom is also responsible for reprocessing and radioactive waste disposal , including over 25 @,@ 000 tons of spent nuclear fuel in temporary storage in 2001 .

Russia has a long history of reprocessing spent fuel for military purposes , and previously planned to reprocess imported spent fuel , possibly including some of the 33 @,@ 000 metric tons of spent fuel accumulated at sites in other countries who received fuel from the U.S. , which the U.S. originally pledged to take back , such as Brazil , the Czech Republic , India , Japan , Mexico , Slovenia , South Korea , Switzerland , Taiwan , and the European Union .

An Environmental Protection Act in 1991 prohibited importing radioactive material for long @-@

term storage or burial in Russia , but controversial legislation to allow imports for permanent storage was passed by the Russian Parliament and signed by President Putin in 2001 . In the long term , the Russian plan is for deep geologic disposal . Most attention has been paid to locations where waste has accumulated in temporary storage at Mayak , near Chelyabinsk in the Ural Mountains , and in granite at Krasnoyarsk in Siberia .

= = = = Sweden = = = =

In Sweden , as of 2007 there are ten operating nuclear reactors that produce about 45 % of its electricity . Two other reactors in Barsebäck were shut down in 1999 and 2005 . When these reactors were built , it was expected their nuclear fuel would be reprocessed in a foreign country , and the reprocessing waste would not be returned to Sweden . Later , construction of a domestic reprocessing plant was contemplated , but has not been built .

Passage of the Stipulation Act of 1977 transferred responsibility for nuclear waste management from the government to the nuclear industry , requiring reactor operators to present an acceptable plan for waste management with " absolute safety " in order to obtain an operating license . In early 1980 , after the Three Mile Island meltdown in the United States , a referendum was held on the future use of nuclear power in Sweden . In late 1980 , after a three @-@ question referendum produced mixed results , the Swedish Parliament decided to phase out existing reactors by 2010 . In 2010 , the Swedish government opened up for construction of new nuclear reactors . The new units can only be built at the existing nuclear power sites , Oskarshamn , Ringhals or Forsmark , and only to replace one of the existing reactors , that will have to be shut down for the new one to be able to start up .

The Swedish Nuclear Fuel and Waste Management Company . (Svensk Kärnbränslehantering AB , known as SKB) was created in 1980 and is responsible for final disposal of nuclear waste there . This includes operation of a monitored retrievable storage facility , the Central Interim Storage Facility for Spent Nuclear Fuel at Oskarshamn , about 150 miles south of Stockholm on the Baltic coast ; transportation of spent fuel ; and construction of a permanent repository . Swedish utilities store spent fuel at the reactor site for one year before transporting it to the facility at Oskarshamn , where it will be stored in excavated caverns filled with water for about 30 years before removal to a permanent repository .

Conceptual design of a permanent repository was determined by 1983 , calling for placement of copper @-@ clad iron canisters in granite bedrock about 500 metres underground , below the water table in what is known as the KBS @-@ 3 method . Space around the canisters will be filled with bentonite clay . After examining six possible locations for a permanent repository , three were nominated for further investigation , at Osthammar , Oskarshamn , and Tierp . On 3 June 2009 , Swedish Nuclear Fuel and Waste Co. chose a location for a deep @-@ level waste site at Östhammar , near Forsmark Nuclear Power plant . The application to build the repository was handed in by SKB 2011 .

= = = = Switzerland = = = =

Switzerland has five nuclear reactors that provide about 43 % of its electricity . Some Swiss spent nuclear fuel has been sent for reprocessing in France and the United Kingdom ; most fuel is being stored without reprocessing . An industry @-@ owned organization , ZWILAG , built and operates a central interim storage facility for spent nuclear fuel and high @-@ level radioactive waste , and for conditioning low @-@ level radioactive waste and for incinerating wastes . Other interim storage facilities predating ZWILAG continue to operate in Switzerland .

The Swiss program is considering options for the siting of a deep repository for high @-@ level radioactive waste disposal , and for low & intermediate level wastes . Construction of a repository is not foreseen until well into this century . Research on sedimentary rock (especially Opalinus Clay) is carried out at the Swiss Mont Terri rock laboratory ; the Grimsel Test Site , an older facility in crystalline rock is also still active .

= = = = United Kingdom = = = =

Great Britain has 19 operating reactors , producing about 20 % of its electricity . It processes much of its spent fuel at Sellafield on the northwest coast across from Ireland , where nuclear waste is vitrified and sealed in stainless steel canisters for dry storage above ground for at least 50 years before eventual deep geologic disposal . Sellafield has a history of environmental and safety problems , including a fire in a nuclear plant in Windscale , and a significant incident in 2005 at the main reprocessing plant (THORP) .

In 1982 the Nuclear Industry Radioactive Waste Management Executive (NIREX) was established with responsibility for disposing of long @-@ lived nuclear waste and in 2006 a Committee on Radioactive Waste Management (CoRWM) of the Department of Environment , Food and Rural Affairs recommended geologic disposal 200 ? 1 @,@ 000 meters underground . NIREX developed a generic repository concept based on the Swedish model but has not yet selected a site . A Nuclear Decommissioning Authority is responsible for packaging waste from reprocessing and will eventually relieve British Nuclear Fuels Ltd. of responsibility for power reactors and the Sellafield reprocessing plant .

= = = North America = = =

= = = = Canada = = = =

The 18 operating nuclear power plants in Canada generated about 16 % of its electricity in 2006 . A national Nuclear Fuel Waste Act was enacted by the Canadian Parliament in 2002 , requiring nuclear energy corporations to create a waste management organization to propose to the Government of Canada approaches for management of nuclear waste , and implementation of an approach subsequently selected by the government . The Act defined management as " long term management by means of storage or disposal , including handling , treatment , conditioning or transport for the purpose of storage or disposal . "

The resulting Nuclear Waste Management Organization (NWMO) conducted an extensive three @-@ year study and consultation with Canadians . In 2005 , they recommended Adaptive Phased Management , an approach that emphasized both technical and management methods . The technical method included centralized isolation and containment of spent nuclear fuel in a deep geologic repository in a suitable rock formation , such as the granite of the Canadian Shield or Ordovician sedimentary rocks . Also recommended was a phased decision making process supported by a program of continuous learning , research and development .

In 2007 , the Canadian government accepted this recommendation , and NWMO was tasked with implementing the recommendation . No specific timeframe was defined for the process . In 2009 , the NWMO was designing the process for site selection ; siting was expected to take 10 years or more .

= = = = United States = = = =

The Nuclear Waste Policy Act of 1982 established a timetable and procedure for constructing a permanent , underground repository for high @-@ level radioactive waste by the mid @-@ 1990s , and provided for some temporary storage of waste , including spent fuel from 104 civilian nuclear reactors that produce about 19 @.@ 4 % of electricity there . The United States in April 2008 had about 56 @,@ 000 metric tons of spent fuel and 20 @,@ 000 canisters of solid defense @-@ related waste , and this is expected to increase to 119 @,@ 000 metric tons by 2035 . The U.S. opted for Yucca Mountain nuclear waste repository , a final repository at Yucca Mountain in Nevada , but this project was widely opposed , with some of the main concerns being long distance transportation of waste from across the United States to this site , the possibility of accidents , and

the uncertainty of success in isolating nuclear waste from the human environment in perpetuity . Yucca Mountain , with capacity for 70 @,@ 000 metric tons of radioactive waste , was expected to open in 2017 . However , the Obama Administration rejected use of the site in the 2009 United States Federal Budget proposal , which eliminated all funding except that needed to answer inquiries from the Nuclear Regulatory Commission , " while the Administration devises a new strategy toward nuclear waste disposal . " On March 5 , 2009 , Energy Secretary Steven Chu told a Senate hearing " the Yucca Mountain site no longer was viewed as an option for storing reactor waste . " Starting in 1999 , military @-@ generated nuclear waste is being entombed at the Waste Isolation Pilot Plant in New Mexico .

In a Presidential Memorandum dated January 29 , 2010 , President Obama established the Blue Ribbon Commission on America ? s Nuclear Future (the Commission) . The Commission , composed of fifteen members , conducted an extensive two @-@ year study of nuclear waste disposal , what is referred to as the " back end " of the nuclear energy process . The Commission established three subcommittees : Reactor and Fuel Cycle Technology , Transportation and Storage , and Disposal . On January 26 , 2012 , the Commission submitted its final report to Energy Secretary Steven Chu . In the Disposal Subcommittee ? s final report the Commission does not issue recommendations for a specific site but rather presents a comprehensive recommendation for disposal strategies . During their research the Commission visited Finland , France , Japan , Russia , Sweden , and the UK . In their final report the Commission put forth seven recommendations for developing a comprehensive strategy to pursue :

Recommendation # 1

The United States should undertake an integrated nuclear waste management program that leads to the timely development of one or more permanent deep geological facilities for the safe disposal of spent fuel and high @-@ level nuclear waste .

Recommendation # 2

A new , single @-@ purpose organization is needed to develop and implement a focused , integrated program for the transportation , storage , and disposal 1 of nuclear waste in the United States .

Recommendation # 3

Assured access to the balance in the Nuclear Waste Fund (NWF) and to the revenues generated by annual nuclear waste fee payments from utility ratepayers is absolutely essential and must be provided to the new nuclear waste management organization .

Recommendation # 4

A new approach is needed to site and develop nuclear waste facilities in the United States in the future . We believe that these processes are most likely to succeed if they are :

Adaptive ? in the sense that process itself is flexible and produces decisions that are responsive to new information and new technical , social , or political developments .

Staged ? in the sense that key decisions are revisited and modified as necessary along the way rather than being pre @-@ determined in advance .

Consent @-@ based ? in the sense that affected communities have an opportunity to decide whether to accept facility siting decisions and retain significant local control .

Transparent ? in the sense that all stakeholders have an opportunity to understand key decisions and engage in the process in a meaningful way .

Standards- and science @-@ based ? in the sense that the public can have confidence that all facilities meet rigorous , objective , and consistently @-@ applied standards of safety and environmental protection .

Governed by partnership arrangements or legally @-@ enforceable agreements with host states , tribes and local communities .

Recommendation # 5

The current division of regulatory responsibilities for long @-@ term repository performance between the NRC and the EPA is appropriate and should continue . The two agencies should develop new , site @-@ independent safety standards in a formally coordinated joint process that actively engages and solicits input from all the relevant constituencies .

Recommendation # 6

The roles , responsibilities , and authorities of local , state , and tribal governments (with respect to facility siting and other aspects of nuclear waste disposal) must be an element of the negotiation between the federal government and the other affected units of government in establishing a disposal facility . In addition to legally @-@ binding agreements , as discussed in Recommendation # 4 , all affected levels of government (local , state , tribal , etc .) must have , at a minimum , a meaningful consultative role in all other important decisions . Additionally , states and tribes should retain ? or where appropriate , be delegated ? direct authority over aspects of regulation , permitting , and operations where oversight below the federal level can be exercised effectively and in a way that is helpful in protecting the interests and gaining the confidence of affected communities and citizens .

Recommendation # 7

The Nuclear Waste Technical Review Board (NWTRB) should be retained as a valuable source of independent technical advice and review .

= = = International repository = = =

Although Australia does not have any nuclear power reactors , Pangea Resources considered siting an international repository in the outback of South Australia or Western Australia in 1998 , but this stimulated legislative opposition in both states and the Australian national Senate during the following year . Thereafter , Pangea ceased operations in Australia but reemerged as Pangea International Association , and in 2002 evolved into the Association for Regional and International Underground Storage with support from Belgium , Bulgaria , Hungary , Japan and Switzerland . A general concept for an international repository has been advanced by one of the principals in all three ventures . Russia has expressed interest in serving as a repository for other countries , but does not envision sponsorship or control by an international body or group of other countries . South Africa , Argentina and western China have also been mentioned as possible locations .

In the EU , COVRA is negotiating a European @-@ wide waste disposal system with single disposal sites that can be used by several EU @-@ countries . This EU @-@ wide storage possibility is being researched under the SAPIERR @-@ 2 program .