March 17, 2017

Dear Colleague, Attached is a printed copy of my WM 2017 paper. I will send an electronic copy in a few days. (It is hard to insert the ice age figures that are readable into the middle of the text.)

I began the presentation of this paper only to the BOD of WMS on Sunday afternoon, March 4, 2017, technically outside the official meeting. I started with a *mea culpa,* that agreeing to dispose un-reprocessed used nuclear fuel, with major energy and resource values, was a major mistake in my career. My excuse, that I thought energy values and economics would prevent such disposal, has not materialized. But I think disposal of un-reprocessed spent fuel, is not credible. A local siting process will not find hydrology calculations extending thru 6 or 8 ice ages, credible.

In part because this paper may appear to upset the Presidential approval of disposing spent fuel in Yucca Mt., I did not present this paper to the BOD of WM Symposia, until after the meeting adjourned. While the message was well received the consensus was to wait until the next several echelons of DOE employees are confirmed by the Senate, before trying to change policy. (I also now believe, that just because SNF disposal is approved at Yucca Mt., it does not mean we have to do it. Yucca Mt could be used for the vitrified defense waste, but this should not be done initially, until it is done elsewhere first, perhaps under a local siting initiative like Carlsbad New Mexico, or near Hanford or Savannah river.)

In the meantime there are at least a half dozen issues that require coordination between EM, OCRWM, and NE to get what I called the 'broader context' for nuclear power moving, in other words a sustainable long term nuclear plan. There are certain facilities in the US that should not be returned to green field status. These include:

- The H-1 Canyon at Savannah River which needs a fuel chop leach module to process Zirconium clad high burnup (up to 75,000 MWD/T) LWR fuel.
- A place like INEL to build and operate a family of passively safe fast flux (breeder) reactors, to burn the higher actinides, while conducting on site recycle a la Argonne's and Henry Till's fuel. There need to be enough reactors to have meaningful feedback between 1,2,3,...n reactors on a 4 or six year cycle, to use engineering and construction expertise to the best effect.
- Places near Hanford and Savannah River that can demonstrate 'local siting' initiatives for nearly benign (hazardous for less than 10,000 year) waste. (There are many skeptics, but I personally think it can and should be tried with a locality informed and truly in charge)
- Some technology, perhaps it is deep borehole, to dispose of certain elements of partitioned waste, for example Ruthenium and Technetium, and perhaps Cesium and Strontium, that is partly or completely separated in processing defense waste, or is hard to incorporate in the vitrified waste, might be found suitable. (It might not need to be so 2-3,000 meters deep.)

If the logical choice is to conduct the next several decades of reprocessing small quantities of LWR fuel in H-1 canyon at Savannah River, (for waste disposal research and breeder reactor development) it does not make sense to build the small MRS facilities for shutdown LWR's at or near Yucca Mt., only to have to ship the fuel East to reprocess it eventually, (or build a reprocessing complex on.Lake Havasu, behind Hoover dam.

Best regards, Bob Williams

2/25/2017

Proposed New Start on HLW Disposal

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Summary

This paper proposes to restart the US HLW disposal program, at two sites, Hanford, and Savannah River. The recommendation is based on work between 1975 and 2001 on various elements of the US program, most recently Yucca Mt., while at EPRI. Several special committees, organizations, and individuals have written summaries of the US and International Programs. (1), (2) The author presents his own innovative, and constructive suggestions. In retrospect, this approach addresses many ideas of the Blue Ribbon Committee (BRC) [2] at a demonstration level, in the context of present laws.

The over all principle behind the recommendation is to make a New Start to the extent possible, and to simplify and segment the effort into small, mangeable, and realistic projects. The program is by analogy like a very long train, but a multi-dimensional one, that is stuck going up a very steep hill. One obvious solution, decouple various elements of the multi-dimensional train, and move them separately. Start with the easy ones first.

Important Elements and Ideas

- Start where equipment and hardware are nearly in place and/or operating
- Nimby- Take advantage of the concern of those with waste in their backyard. Use local public concern to mobilize local support , it's better to dispose than to let it sit.
- Fly Below the Radar- The first program elements should be taken as ad hoc, safe, and conservative ways to start getting 90 % of the waste treated and disposed, on a reasonable schedule and at reasonable cost. This is site specific not a global precedent. The plan is to develop cooperative and compatible solution with environmental support.
- Spent Fuel and Reprocessed Waste - Set a clear line of demarcation between spent fuel (which will be dealt with later) and reprocessed waste, which has many desirable and simplifying characteristics.
- Spent fuel policy decision- Do not dispose spent fuel, but instead put it in long term safe storage, for several reasons: 1) preserve and ease recovery of the resource value with safe monitored storage 2) Make the repository a less attractive target for future vandals, warlords, or governments. Minimize the intrusion incentives.
- Minimize transportation of this first segment of the train. Find a suitable disposal site on or near Hanford, and on or near Savannah River for the more benign, more easily emplaced and licensed. Alternate sites in the near vicinity, perhaps adjacent states.

Programmatic Elements and suggestions-

For clarity the recommendation is to start with some of the waste at Hanford and Savannah River. Process plants are in advance stages, but segregate the product into more benign, and more challenging segments. Plan to surface store the more challenging waste until 5 years after operation of the first repositories at each location.

Remember that the objective is a NEW START, NOT a RESTART, NOT a RESET. The intent is to move previous functions into new organizations, with a few veterans but mostly younger, new, technically competent staff. This is not intended as a criticism of past organizations, per se. It implements the goal of a new slate, of leaving behind previous procedures and practices which may tend to over complicate, and over specify what needs to be done for the first segment of relatively simple to process and dispose radioactive waste. Management simplification results from a Defense Waste initiative.

Objectives & Simplifications

- **The Defense Nuclear Facility Safety Board (DNFSB) takes over specific roles previously handled by the NRC, and the ACNW**
- **Down the road a year or two, a new office (GW-EPA) of geology and groundwater, might take over the entire issue of ground water protection, fracking regulation, toxic and chemical waste, to achieve commonality in the geologic disposal requirements for all waste types. HLW should have an advantage over other wastes**
- **The National Academy of Engineering would be asked periodically for program review and program advice, in addition to NAS, in the spirit of getting engineering and construction oriented, as well as theoretical advice.**
- **State Government and Regional Representatives. Each Site, Hanford and Savannah River would receive US government funding for an entity like the Environmental Review Group in New Mexico. The new Hanford and Savannah River EEG's (HEEG, and SEEG) would have management but not technical oversight from a panel of three local governors, (WA. OR. ID and NC,SC, GA**
- **Sites and Site Selection- Each regional disposal effort would identify two or even possibly three sites that are suitable for the waste and waste package of the more benign waste segment. <u>The intent would be to keep all three sites operating, in each region, if they meet the agreed criterion, but be able to drop one.</u> Try to find at least one site on a federal reservation, to simplify land withdrawal issues.**
- **Disposal Criteria- Site specific, and repository specific criteria have been proposed in the past. (3), (4) However, If the zero release from the near field idea proves practical, tailoring the package for most locations is likely to be feasible. Geologic issues will relate to groundwater, and geology that precludes groundwater in the near field.**
- **Three or four multiple barriers, one of which the waste form, one of which the geology, one or two a redundancy on the waste form or geology. <u>Overall, near zero release from the near field under credible foreseeable states.</u>**

Caveat: - These steps intended as simplification, are generally within existing practice, and do not need a major legislative initiative, rather some site specific amendments, such as occurred for WIPP (3) and Yucca mountain.(4) Legislation may be needed for funding, and for the long range nuclear program context, discussed in a separate memo.

<u>ACTION</u>

Step 1: <u>To avoid the two years plus a normal procurement takes,</u> I suggest the Prime Contractor at Hanford and Savannah River each get a sole source amendment to develop a disposal program in their region. A realistic assessment of action within present laws and structure, and needed amendments would be part of the scoping activity.

Step 2, 3...n. Experience demonstrates we cannot proceed without local approval, Executive support, and Congressional appropriations. I believe a program kept simple and direct may result in bi partisan support for the New Start projects.

Some type of funding for a consortium to submit a credible bid is also needed. The City Council, and the County Board of Supervisors will need technical backup from a University, perhaps a National Lab, and a local mining or oil company for pre-proposal work, and a bid.

<u>References-</u>

1) NWTRB 2014 to 2016 publications <u>https://nwtrb.gov/reports/reports/html</u>
2) Blue Ribbon Commission (2013) <u>https://www.energy.gov/ne/downloads/html</u>
3) WIPP criteria , 40CFR194
4) Yucca Mt. criteria , EPA 40CFR197, NRC 10CFR63

February 25, 2017

Subject: A Broader context for a New Start on HLW Disposal

Dear Colleague,

Summary
The purpose of this memorandum is to strongly urge a broader context be established for industry wide efforts to restart a program for High Level Waste Disposal. Both the Blue Ribbon Committee (1) and the Nuclear Waste Technical Review Board (2) have issued comprehensive reviews that recommend a renewed effort to find sites for High Level Waste Repositories, based on the support of the a local consensus for the repository siting process.

I believe the question of very long term disposal of un-reprocessed spent fuel in a HLW repository complicates the issue so seriously that the new Nuclear Waste Policy Act (NWPA II) will be no more likely to succeed than the NWPA of 1982. I strongly urge that the BRC and the NWPA review the inclusion of Spent Fuel Disposal, and for the time being at least eliminate SNF disposal from the question of finding and licensing a new repository site.

The broader context is in fact a long range plan for nuclear power development that provides a context for nuclear fuel reprocessing of high burnup LWR fuel, and a program for fast reactors that will utilize the plutonium recovered from the relatively limited quantities of reprocessed high burnup spent fuel.

The Board of WM Symposia can play an important role in developing a sufficient consensus to proceed with a new program that separates SNF from the repository siting and licensing issue. Here is a summary of why the change is needed, and what can still be done to keep nuclear repository technology alive and moving forward.

Three issue areas need to be considered. They are as follows:

- **Climate Change and future glacial and inter-glacial periods**
- **Effects of future exploitation of shale for oil and natural gas recovery**
- **The need for energy to recycle material now accumulating in the oceans, and to recycle less easily degraded material that a society of billions of people produces**

A longer term plan for the role of nuclear energy in a world where solar power, wind power, and bio fuels have a major role needs to be made more explicit.

Consideration of Climate Change requires a new look.

- **A change is needed because the technical community and the public are becoming increasingly aware of the likelihood of climate change.**

- Glaciation and interglacial periods have occurred on a 100,000 year cycle for the last 2 million years, with interglacial periods of 15-20,000 years, and glaciations of 80,000 years
- As water is stored in glaciers on land, significant changes in sea level, as much as 1000 feet, and consequent changes in hydrology and water chemistry on continents can occur.

- When the ice melts, as it is likely to do, there will almost certainly be major changes in climatology and ground water hydrology For example:
  - Melting glacier could re-charge the Ogalala aquifer now being depleted, that underlies much of the mid west.
  - Melting of glaciers could re-fill a new Lake Bonneville that existed where the Great Salt Lake and the Bonneville salt flats now reside.
- HLW disposal can address this issue by more reliance on the waste form, the multi barrier waste package, reduction of long lived hazardous isotopes, and less reliance on geology and nuclide migration calculations in ground water.

The long term effects of world wide exploration of oil shale, and the effect on geologic barriers are difficult to address.

- A case can be made that many if not most world wide shale deposits will be exploited in the next 100 to 200 years.
- Shale in some area can have a major effect on ground water flow and chemistry. It is better not to have to speculate on these effects in licensing a repository.

The energy needs of the world of the future need to be considered

- The world inhabited by 10 or 20 Billion people under some scenarios will likely have much greater requirements for central station, base load power to meet needs to recycle the materials of a high technology society.
- Fresh water production and transport will likely require more, not less energy. The needs for power for water transport, water purification, fertilizer synthesis, and public and material transportation suggest to me a world that is not entirely driven by solar, wind, and bio fuels.
- The accumulation of all kinds of waste and garbage in the ocean will drive the need for energy for more complete garbage treatment and recycle. It is does not seem likely that all materials of a complex society can be built in such a ways that materials are recycled by natural processes.

A civilization and society that can afford an international space station, and a planned manned trip to Mars can and should have a robust, multi reactor, multi national breeder reactor program. Burning long lived actinides for waste disposal can help justify the research program for different types of breedersand fast flux reactors, with inherent safe shutdown, even if they are not quite mills/kwhr 'competitive.'

Since orbital variations are predictable,[5] computer models that relate orbital variations to climate can predict future climate possibilities. Two caveats are necessary: that anthropogenic effects (human-assisted global warming) are likely to exert a larger influence over the short term; and that the mechanism by which orbital forcing influences climate is not well understood. Work by Berger and Loutre suggests that the current warm climate may last another 50,000 years.[6]

See also

- Climate
- Cyclostratigraphy
- Geologic time scale
- Glacial history of Minnesota
- Glacier
- Greenhouse and Icehouse Earth
- Ice age
- Interglacial and Interstadial periods
- Last Glacial Maximum
- last glacial period
- Milankovitch cycles
- Precession (astronomy)
- Quaternary glaciation
- Snowball Earth
- Timeline of glaciation
- Yarkovsky effect
- YORP effect

References

1. J. Severinghaus; E. Brook (1999). "Abrupt Climate Change at the End of the Last Glacial Period Inferred from Trapped Air in Polar Ice". *Science.* **286** (5441): 930–4. doi:10.1126/science.286.5441.930. PMID 10542141.
2. Bralower, T.J.; Premoli Silva, I.; Malone, M.J. (2006). [Abstract Summary *Leg 198 Synthesis : A Remarkable 120-m.y. Record of Climate and Oceanography from Shatsky Rise, Northwest Pacific Ocean*] Check `|url=` value (help). Proceedings of the Ocean drilling program. p. 47. doi:10.2973/odp.proc.ir.198.2002. ISSN 1096-2158. Retrieved April 9, 2014.
3. Christopher M. Fedo; Grant M. Young; H. Wayne Nesbitt (1997). "Paleoclimatic control on the composition of the Paleoproterozoic Serpent Formation, Huronian Supergroup, Canada: a greenhouse to icehouse transition". *Precambrian Research.* Elsevier. doi:10.1016/S0301-9268(97)00049-1.
4. Miriam E. Katz; Kenneth G. Miller; James D. Wright; Bridget S. Wade; James V. Browning; Benjamin S. Cramer; Yair Rosenthal (2008). "Stepwise transition from the Eocene greenhouse to the Oligocene icehouse". *Nature Geoscience.* Nature. doi:10.1038/ngeo179.
5. F. Varadi; B. Runnegar; M. Ghil (2003). "Successive Refinements in Long-Term Integrations of Planetary Orbits" (PDF). *The Astrophysical Journal.* **592**: 620–630. Bibcode:2003ApJ...592..620V. doi:10.1086/375560.
6. Berger A, Loutre MF (2002). "Climate: An exceptionally long interglacial ahead?". *Science.* **297** (5585): 1287–8. doi:10.1126/science.1076120. PMID 12193773.

Categories: Glaciology

Glacial period

From Wikipedia, the free encyclopedia

A glacial period (alternatively glacial or glaciation) is an interval of time (thousands of years) within an ice age that is marked by colder temperatures and glacier advances. Interglacials, on the other hand, are periods of warmer climate between glacial periods. The last glacial period ended about 15,000 years ago.[1] The Holocene epoch is the current interglacial. A time when there are no glaciers on Earth is considered a greenhouse climate state.[2][3][4]

Contents

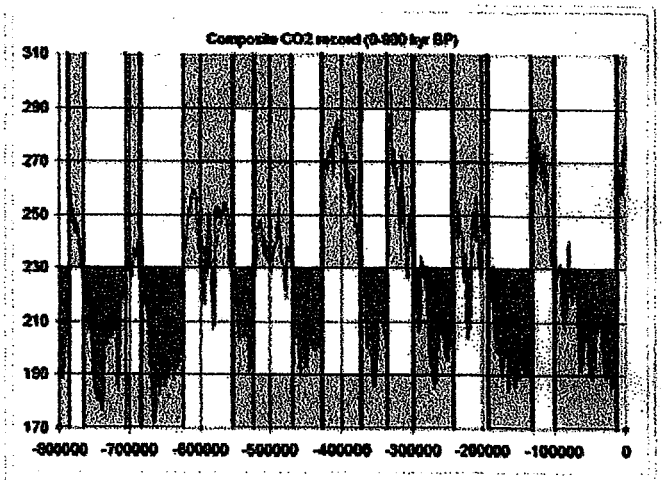
Look up ***glaciation*** in Wiktionary, the free dictionary.

Quaternary ice age

Within the Quaternary glaciation (2.58 Ma to present), there have been a number of glacials and interglacials.

Last glacial period

The last glacial period was the most recent glacial period within the current ice age, occurring in the Pleistocene epoch, which began about 110,000 years ago and ended about 15,000 years ago.[1] The glaciations that occurred during this glacial period covered many areas of the Northern Hemisphere and have different names, depending on their geographic distributions: *Wisconsin* (in North America), *Devensian* (in Great Britain), *Midlandian* (in Ireland), *Würm* (in the Alps), *Weichsel* (in northern central Europe), *Dali* (in East China), *Beiye* (in North China), *Taibai* (in Shaanxi) *Luojishan* (in Southwest Sichuan), *Zagunao* (in Northwest Sichuan), *Tianchi* (in Tianshan Mountains) *Qomolangma* (in Himalaya), and *Llanquihue* (in Chile). The glacial advance reached its maximum extent about 18,000 BP. In Europe, the ice sheet reached northern Germany.



Glacial and interglacial cycles as represented by atmospheric CO_2, measured from ice core samples going back 800,000 years. The stage names are part of the North American and the European Alpine subdivisions. The correlation between both subdivisions is tentative.

Next glacial period

Since orbital variations are predictable,[5] computer models that relate orbital variations to climate can predict future climate possibilities. Two caveats are necessary: that anthropogenic effects (human-assisted global warming) are likely to exert a larger influence over the short term; and that the mechanism by which orbital forcing influences climate is not well understood. Work by Berger and Loutre suggests that the current warm climate may last another 50,000 years.[6]

See also

- Climate
- Cyclostratigraphy
- Geologic time scale
- Glacial history of Minnesota
- Glacier
- Greenhouse and Icehouse Earth
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- Milankovitch cycles
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- Quaternary glaciation
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- Timeline of glaciation
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5. F. Varadi; B. Runnegar; M. Ghil (2003). "Successive Refinements in Long-Term Integrations of Planetary Orbits" (PDF). *The Astrophysical Journal.* **592**: 620–630. Bibcode:2003ApJ...592..620V. doi:10.1086/375560.
6. Berger A, Loutre MF (2002). "Climate: An exceptionally long interglacial ahead?". *Science.* **297** (5585): 1287–8. doi:10.1126/science.1076120. PMID 12193773.

Categories: Glaciology

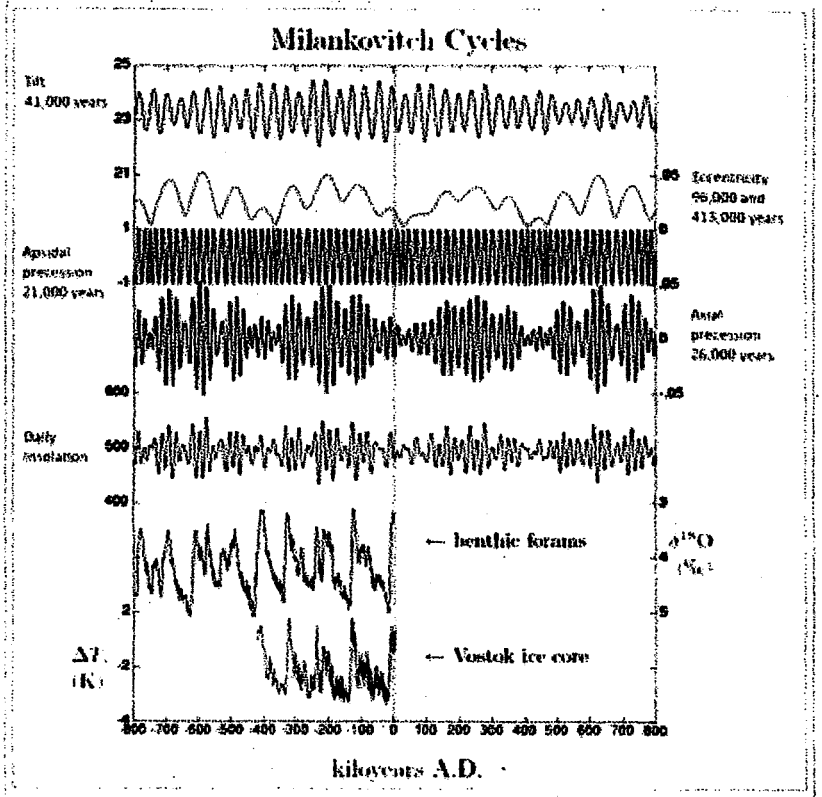
Milankovitch cycles

From Wikipedia, the free encyclopedia

Milankovitch cycles describes the collective effects of changes in the Earth's movements upon its climate, named after Serbian geophysicist and astronomer Milutin Milanković, who in the 1920s had theorized that variations in eccentricity, axial tilt, and precession of the Earth's orbit determined climatic patterns on Earth through orbital forcing.

The Earth's axis completes one full cycle of precession approximately every 26,000 years. At the same time, the elliptical orbit rotates more slowly. The combined effect of the two precessions leads to a 21,000-year period between the astronomical seasons and the orbit. In addition, the angle between Earth's rotational axis and the normal to the plane of its orbit (obliquity) oscillates between 22.1 and 24.5 degrees on a 41,000-year cycle. It is currently 23.44 degrees and decreasing at a rate of about 0.013° per century.

Similar astronomical theories had been advanced in the 19th century by Joseph Adhemar, James Croll and others, but verification was difficult due to the absence of reliably dated evidence and doubts as to exactly which periods were important. Not until the advent of deep-ocean cores and a seminal paper by Hays, Imbrie, and Shackleton, "Variations in the Earth's Orbit: Pacemaker of the Ice Ages", in *Science* (1976)[2] did the theory attain its present state.



Past and future Milankovitch cycles. VSOP allows prediction of past and future orbital parameters with great accuracy.
Shows variations in: obliquity (axial tilt) in blue (ε).
eccentricity in green (*e*).
longitude of perihelion in purple (ϖ).
Precession index in dark red ($e \sin(\varpi)$), which together with obliquity, controls the seasonal cycle of insolation.[1]
– Calculated daily-averaged insolation at the top of the atmosphere in black ($\overline{Q}^{\text{day}}$), on the day of the summer solstice at 65° N latitude.
– *Benthic forams* in dark red and – *Vostok ice core* in dark green show two distinct proxies for past global sea level and temperature, from ocean sediment and Antarctic ice respectively.
The vertical gray line shows current conditions, at 2 ky A.D.

Contents

Attachment -Program Elements summarized.

1. **Defense Waste Processing and Siting can proceed**
   - **A repository Site Selection, Licensing and Disposal program similar to the idea in the "New Start on HLS disposal paper" can and should still proceed. Attachment 1. But a simpler process than another NWPA(II) is needed.**
   - **Some support for NRC to agree to site specific criteria with greater reliance on the waste form, and muliti barrier waste canisters and near field engineering is needed. Both WIPP and Yucca Mountain have set precedents for site specific criteria. New sites for defense waste should also have such criteria in my opinion without the hoopla of an NWPA (II).**
   - **The incentives for localities to agree to and support siting also need to be spelled out. Incentives much greater than Payments in Lieu of Taxes for other federal sites are not justified. The jobs are an important inducement, and the hazard, in the first several hundred years is less than many other elements of society such as international airports or regional oil refineries.**
   - **Funds to pay for preparation of a proposal to the government, submitted on behalf of a region with a university, National Lab, and oil drilling or mining company may be a needed for a credible local siting process.**

Go slow on Yucca Mountain - Politics

- **What to do about Yucca Mountain will be among the first questions asked. I argue that consideration of alternate sites for Savannah River waste, and Hanford waste may be part of a compromise to minimize transcontinental shipping. Down the road, Yucca Mountain might then become viable.**

Process High Burnup Commercial Fuel for a fast flux (Breeder) reactor program

- **A demonstration program to reprocess small quantities of higher exposure commercial spent fuel, to vitrify it, and to confirm that small quantities of nearly insoluble sludge can be dealt with is most likely required.**
- **The separated plutonium and other actinides can and should be used in a demonstration program for a fast flux passively safe reactor. Recall that the demonstrated safe shutdown of EBR-2 with simulated station blackout, was over shadowed by the Chernobyl accident in 1986.**
- **Conduct limited demonstration tests of processing of high burnup BWR and PWR fuel (the range of fuel exposure of 25,000 MWD/T to 75,000 MWD/T.) It would be very worthwhile to determine if France or other national programs have such data. The issues include ability to completely dissolve the high exposure fuel, and the ability to suitably vitrify, or other wise solidify / vitrify/ treat any nearly insoluble residues.**
- **Uncertainties in future hydrology and geochemistry related to the effects of climate change are likely to require greater reliance on the near field, the multi- barrier waste form, its package and near field barrier (s). This will reduce the reliance on climate change predictions, and associated hydrology and geochemistry extrapolations.**

- **The processed waste form can (and perhaps should) have eliminated essentially all beneficial resources (Uranium, rare earths, platinum metals, as well as heat generating Cesium and Strontium) to minimize the ease of location and attractiveness for future human intrusion. An assumption has been that a future intruder (archeologists, geologist, war lords, miners, even a government or a sub-national group of terrorists) would be smart enough not to destroy the protections built into the repository.**

  What about the not too smart future war lord who wants to recover material by solution mining? I believe a hard look at this question is needed to motivate a hard look at minimizing the resource value of the buried material.

In the difficult public policy environment of the 1970"s and 1980's, was the issue of geologic disposal of un-reprocessed Spent Nuclear Fuel too quickly dealt with? I think it was, and deserves another look in the context of a multi-decade, long range nuclear program.

References.

Attachment 2- Brief History of 1970-1980's challenges that led to Including Spent Fuel Disposal in a HLW repository.

Summary

There were many ongoing concerns and challenges within and around the nuclear industry in the 1970's and 1980's. Looking back in 2017 from the perspective of 50 years, the author believes the decision to include un-reprocessed spent fuel in geologic disposal in a HLW repository was not sufficiently considered, and at least for the time being should be dropped from any new repository site selection and licensing program.

The past history and rationale for including un-reprocessed spent fuel (URSF) in the repository program developed in 1975 thru 1986 are briefly summarized. The problem that was not sufficiently considered at the time was what I will label "the million year problem." The reprocessing concerns leading to the decision to dispose URSF were numerous:

- **Problems at the 300 MT/yr West Valley Reprocessing Plant**
- **Problems with potential environmental release from the 1500 MT/yr AGNS plant under construction and undergoing licensing hearings.**
- **Concerns regarding economic Viability of the small GE reprocessing plant near the Dresden Illinois nuclear plant site.**
- **The findings of the 2 year Technical Alternatives Study (3) that there was no 'technical fix' to accomplish a diversion resistant or diversion proof nuclear fuel cycle. Administrative controls and nuclear material accountancy, (safeguards) are required. The International Nuclear Fuel Cycle Evaluation (INFCE) confirmed this finding. (4)**
- **The costs for spent fuel reprocessing currently made uranium or plutonium fuel recycle more costly than once thru fuel cycles using enriched natural uranium feed.**
- **Long term monitored retrievable storage was safe, economic, and feasible for 60 years, or even longer, as found in the NRC's Nuclear Waste Confidence Proceeding, and periodic renewals (5) (6)**
- **Disposal of un-reprocessed spent fuel appeared feasible, safe and effective, for those that insisted on an end point for the fission products from nuclear power generation. The 1978 Swedish KBS-2 study presented a very complete engineering study of disposal of spent fuel in metal casks with the fuel imbedded in a metal matrix and was convincing. (6)**

The concerns related to the two OPEC oil embargoes, and the delays in nuclear plant construction beginning in 1979 due to the Three Mile Island II accident, followed by the 1986 Chernobyl accident presented major challenges.

The net effect, the greater attractiveness of un-reprocessed spent fuel to potential intruders, and the much longer term hazard were not sufficiently considered, at least in the opinion of this author.

Sent: Thursday, March 23, 2017 8:35 AM
Subject: GHG heating due to melting of the permafrost in Siberia and elsewhere ACRE

Fellow retirees, Especially Bryce, There is a program that is analogous to Nova (on PBS) that is the HBO response or competitor to Nova. I think the KOCH brothers also sponsor this. It is called VICE and has run for 5 years.

For those of you on COMCAST here is how you access what is called VICE. (I admit this is a very strange name)

1. Go to movies with the XFINITY button.
2. Go to HBO as a network
3. Go to the end of HBO to VICE as a program name
4. The program of interest is in series 5, episode 3

The episode of interest starts about 3 minutes into the 30 minute program. It begins with two people walking thru an area of the arctic where there is permafrost. They go out onto a lake. They light a small torch to ignite gas, and then start poking holes in the ice.

As the poker goes thru the ice, a blast of methane gas is released that shoots 8 or ten feet into the air, and just about singes the hair off of the 2 person party.They have an interesting dialog for the next fifteen minutes. They argue that as the permafrost melts, there is subsidence that forms lots of lakes, and also releases carbon that microbes eat and turn into methane.

a) The y argue that grass on the permafrost lets the ground stay deeply frozen to -35 degrees, but that forest land is warmer, and the ground is only frozen to minus 15 degrees.

b) They argue that the process is already almost auto catalytic, that the permafrost will be melted, and as it melts the process will get worse and worse, melting more of the arctic permafrost.

c) They argue the best way to fix this is with large herds of big animals like bison or wooly mammoths, because they tear down forests to get more grass land. This all sounds very strange.

d) They cite some data on heating from JPL (Jet Propulsion labs) that says the amount of Carbon releasable by this mechanism is four times bigger than the amount of carbon dioxide released by man made means (to date or when I am not sure) The available cargon they argue is **1.8 Trillion tons per X compared to 350 Billion tons per X.**

Bryce, have you followed this issue at all??? They show or talk about some JPL data that predicts 6 or 8 or 10 degrees of warming if the permafrost melts.