What should the United States do with spent Nuclear Fuel?

BQOM 2521 - Decision Making in a Complex Environment
Fall 2009
The Katz Graduate School of Business

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October 19, 2009

Introduction

Investments in a range of electricity solutions will be required in the near future in order to meet the global and U.S. demand of future electricity. One solution that could play a substantional role in meeting this increased electricity demand is nuclear power. According to the International Atomic Energy Agency (IAEA) "predicts nuclear power production worldwide could double by 2030." The re-emergence of nuclear power which is expected to increase by 50 percent by 2030, is attracting significant attention politically, economically, and socially. One major issue that is debated is the management of spent fuel from nuclear power plants. The United States will only become more successful by finding solutions to process spent fuel. If the government can provide this solution, this could lead to a more favorable perception of nuclear energy.

Alternatives

The management of spent fuel we chose to assess is sending the fuel to Yucca Mountain, reprocessing the fuel, keep Dry Caskets (or Casks) onsite, and moving Dry Caskets to off-site facility. At this time in the nuclear industry, utilities currently keep the majority of the fuel in the spent fuel pools within the plant, while some are using dry casks on the grounds of the plant sites. Listed below is a brief description of each possible solution, along with some advantages, disadvantages, and additional information.

Yucca Mountain

In 1982 Congress passed the Nuclear Waste Policy Act to identify specific actions to resolve the national problem of what to do with waste from nuclear reactors and defense facilities. For 20 years many of the nation's top scientists and engineers have studied Yucca Mountain in Nevada to determine if this arid site would be a suitable location to develop the first repository for the disposal of radioactive waste. This repository is located in a desert on federal land adjacent to the Nevada Test Site in Nye County, Nevada. This location is approximately 80 miles northwest of Las Vegas Metropolitan area.

As of 2008, the U.S. has spent $9 billion on the project which made Yucca mountain one of the most studied pieces of geology in the world. The Department of Energy (DOE) estimates that the U.S. has over 100 million gallons of radioactive waste and 2,500 metric tons of spent fuel from production of nuclear weapons and from research activities in temporary storage.

The DOE was to begin accepting spent fuel at Yucca Mountain repository by January 31, 1998; however as of today it is still not open for waste storage. This project is a debated topic locally in the state of Nevada and nationally. There has been wide variety of lawsuits to stop the progress of this project. As of March 2009, the Energy Secretary Steven Chu told a Senate hearing "the Yucca Mountain site no longer viewed as an option" and federal funding has been significantly reduced.

Reprocessing

A favorable solution that is building strength to deal with spent nuclear fuel is a technique called "reprocessing." Reprocessing takes used or spent nuclear fuel and separates the uranium and plutonium from the highly radioactive fission products. The reprocessing facility will then use the plutonium and uranium to make new reactor fuel which reduces the amount of fresh uranium by about 20%. The French reprocessing company, Areva, claims that its method reduces the volume and longevity of the radioactive waste produced by nuclear power reactors.

In October 1976, due to the fear of nuclear weapons, President Gerald Ford issued a Presidential Directive to indefinitely suspend the commercial reprocessing and recycling of plutonium in the U.S. To prevent other non-nuclear weapon countries from reprocessing the U.S. government states “we don’t reprocess, you don’t need to either.” If the U.S. would want to reprocess again this would defeat the mission of preventing other countries to reprocess. This could lead to a better chance of other countries developing nuclear weapon programs.

Some of the disadvantages of reprocessing fuel is that it is several times more expensive than producing fresh uranium reactor fuel, although this doesn’t factor in the disposal costs of the fresh fuel. It is estimated that cost of for reprocessing fuel would range from .4 to .6 cents per kilowatt-hour. Reprocessing would increase the ease of nuclear proliferation, leading to the U.S. not having the capability to convince other countries to forgo technology used to make nuclear weapons. Another concern about reprocessing is after the process is complete, you still need storage and disposal of a small amount of radioactive waste. Reprocessing is currently a possible solution; however, more information and research needs to be done to decide if this is a feasible answer for the U.S.

Dry Cask On-Site

For many years nuclear power plants have stored used fuel in water pools at the utility site. As the utilities periodically change out approximately one-third of the fuel and have been placing them into these pools, the pools are now near capacity after decades of plant operation. This leads to dry casks becoming the current solution of spent fuel. Dry casks consist of a sealed metal cylinder containing the spent fuel enclosed with a metal or concrete outer shell. Then these casks are set on a concrete pad at the plant site.

Dry casks are considered to be safe and environmentally sound. Over the last 20 years, there have been no radiation releases which have affected the public, no radioactive contamination and no known or suspected attempts to sabotage spent fuel casks. These dry cask storage systems are designed to resist floods, tornadoes, projectiles, temperature extremes and other unusual scenarios. The NRC has various regulations and utilities must go through a standard licensing process to develop a storage system on the site property. Typically the NRC will conduct a technical review to ensure the design of the dry cask will be safe and secure for use at a broad range of nuclear power plant sites, although the storage duration is currently only for 20 years so this might not be a long-term solution with the current technology. Currently, spent fuel in dry storage casks are located at approximately 50 different locations across the United States.

Dry Cask Off-Site

The Dry Cask Off-Site option would take the spent nuclear waste and take it to designed locations away from nuclear power plants. This follows the same design as on-site dry casks and must meet the same requirements. However, people may feel that there is a better security precaution and would lead less terrorist threats. This solution would separate the power plant providing electricity from the dangerous nuclear waste, although a secure transportation infrastructure would need to be developed to each of these regional storage sites.

The Model

The model that we chose to create was a BOCR Model. The model focuses on one main goal, which is the best solution for the storage of spent nuclear fuel from the perspective of the U.S. government. This is then linked to Benefits, Opportunities, Costs, and Risks as the merits of the decision process.

Figure 1: General BOCR Model

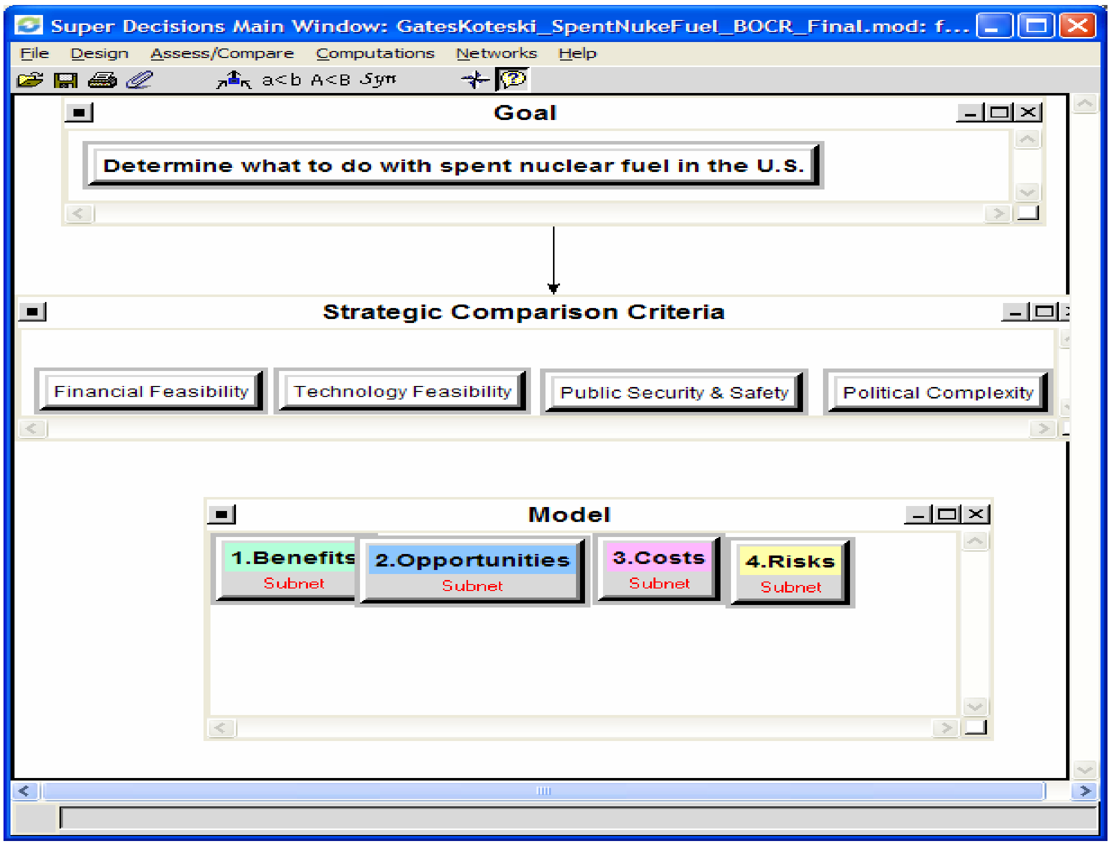


Table 1: BOCR Merit Priorities

Merit	Priorities Ranking
Benefits	0.2322
Opportunities	0.2322
Costs	0.2791
Risks	0.2564

BOCR Sub Criteria

Every BOCR cluster had Economic, Political, and Social benefits. The most prominent control criteria were determined and subsequent subnets were created. The figures below show the breakdown of the subnets.

BENEFITS	**OPPORTUNITIES**
ECONOMIC Employment Efficiency POLITICAL Worldwide Benefits Government Control SOCIAL Short Term Long Term	ECONOMIC Private Company Growth Growth Around Project POLITICAL Regional Government National Government SOCIAL Local Benefits
COSTS	**RISKS**
ECONOMIC Operation Implementation POLITICAL Regional Government National Government SOCIAL Public Impact	ECONOMIC Project POLITICAL Planning Liability SOCIAL Security Transportation Environment

Strategic Criteria

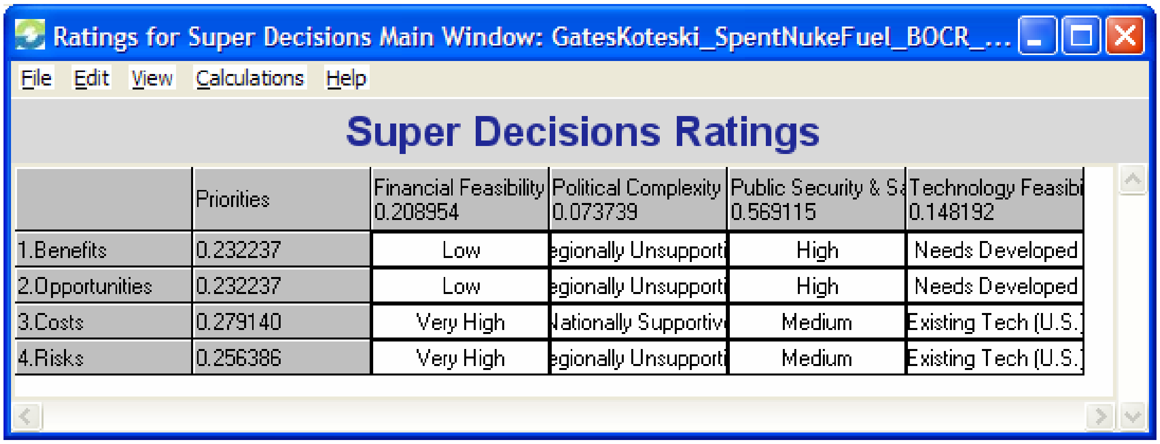
The Strategic Criteria chosen for this analysis on a solution for nuclear waste were *Financial Feasibility*, *Technology Feasibility*, *Public Security and Safety*, and *Political Complexity*. These were all perceived to be significant considerations that must be factored into any solution for nuclear waste in the U.S. These criteria were pair-wised compared against another to develop priorities for each, which are shown below:

Table 2: Criteria Priorities

Criteria	**Priorities Ranking**
Public Security and Safety	0.59612
Financial Feasibility	0.20895
Technology Feasibility	0.14819
Political Complexity	0.07374

Ratings Model

The Strategic Criteria discussed above was used to rate the merits (Benefits, Opportunities, Costs, and Risks) using a Ratings model in SuperDecisions to get the priorities for each. The results of the Ratings model are shown in the following figure, which shows similar priorities for each of the merits.


Ratings for Super Decisions Main Window: GatesKoteski_SpentNukeFuel_BOCR_...

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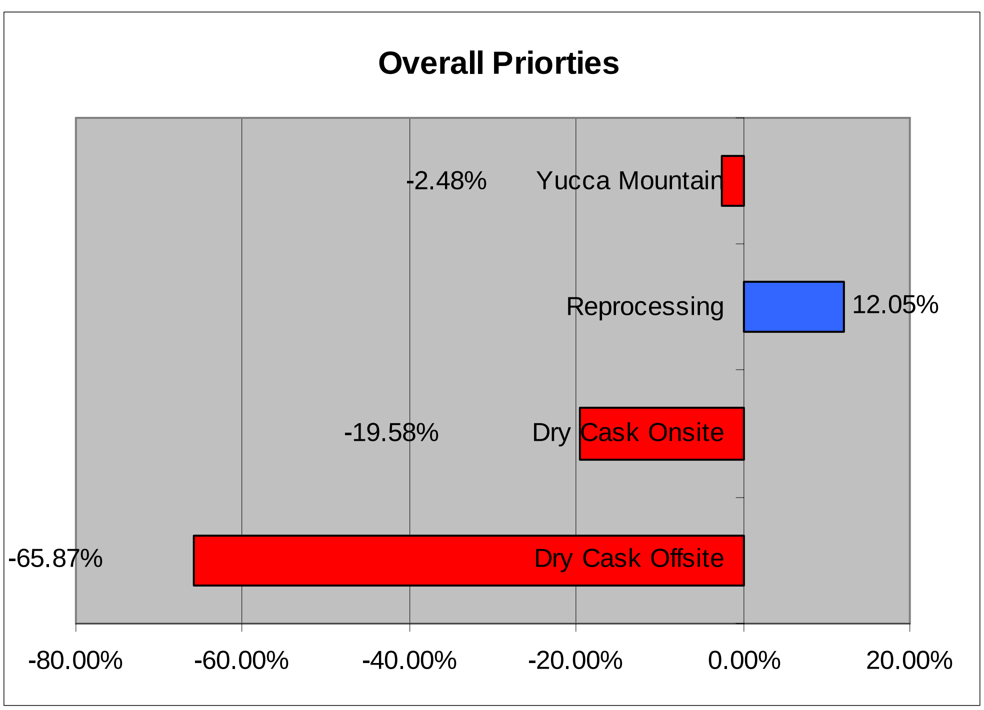
Super Decisions Ratings

	Priorities	Financial Feasibility 0.208954	Political Complexity 0.073739	Public Security & S 0.569115	Technology Feasibi 0.148192
1.Benefits	0.232237	Low	egionally Unsupporti	High	Needs Developed
2.Opportunities	0.232237	Low	egionally Unsupporti	High	Needs Developed
3.Costs	0.279140	Very High	Nationally Supportiv	Medium	Existing Tech (U.S.)
4.Risks	0.256386	Very High	egionally Unsupporti	Medium	Existing Tech (U.S.)

Results

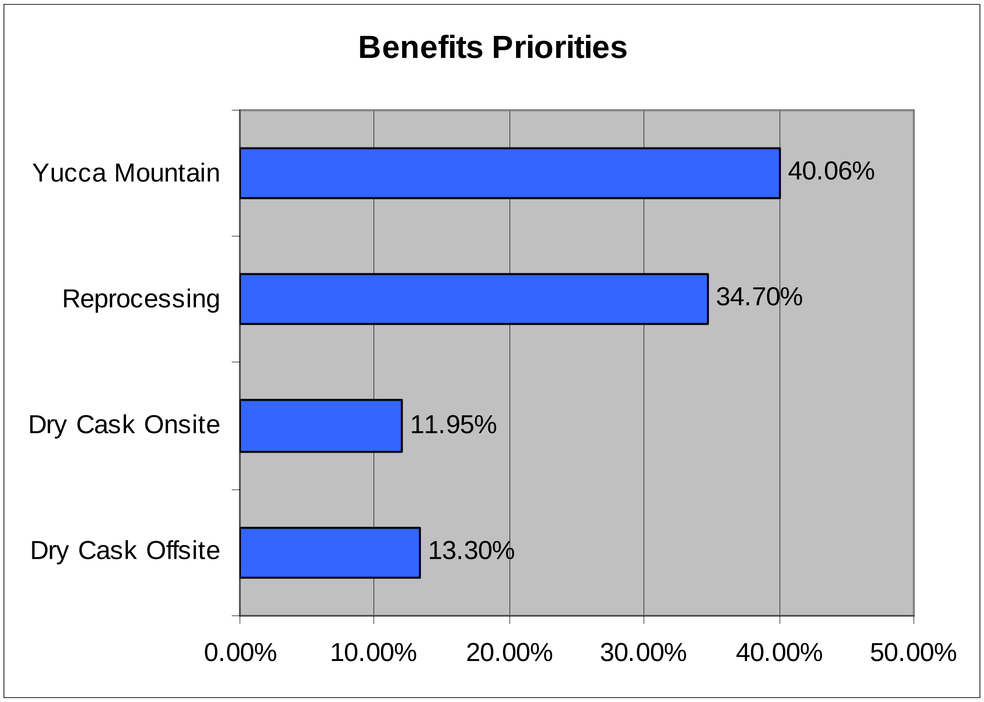
Overall, the fully synthesized model supports the *Reprocessing* alternative to solve the Spent Nuclear Fuel problem. The control criteria of Benefits and Opportunities ranked *Yucca Mountain* ahead of *Reprocessing* as the number one choice. Although, for the other merits of Cost and Risk, *Yucca Mountain* showed to be less advantageous when compared to *Reprocessing*. This is likely to be the reason that *Reprocessing* was chosen to be the best overall choice when compared to *Yucca Mountain*.



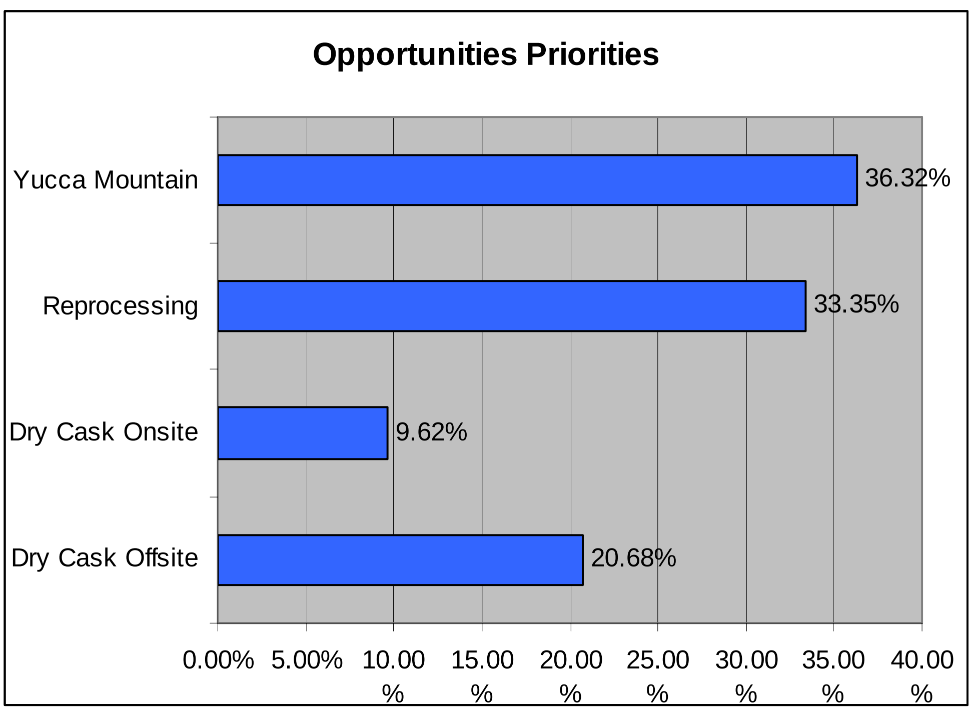
Note that *Yucca Mountain* is a strong second place when compared to the other alternatives. This alternative may provide many of the same benefits; however, when looking at the BOCR priorities it would be a greater cost and risk for the government in the solution for spent nuclear fuel.

Below are the overall priorities for each of the BOCR subnets:

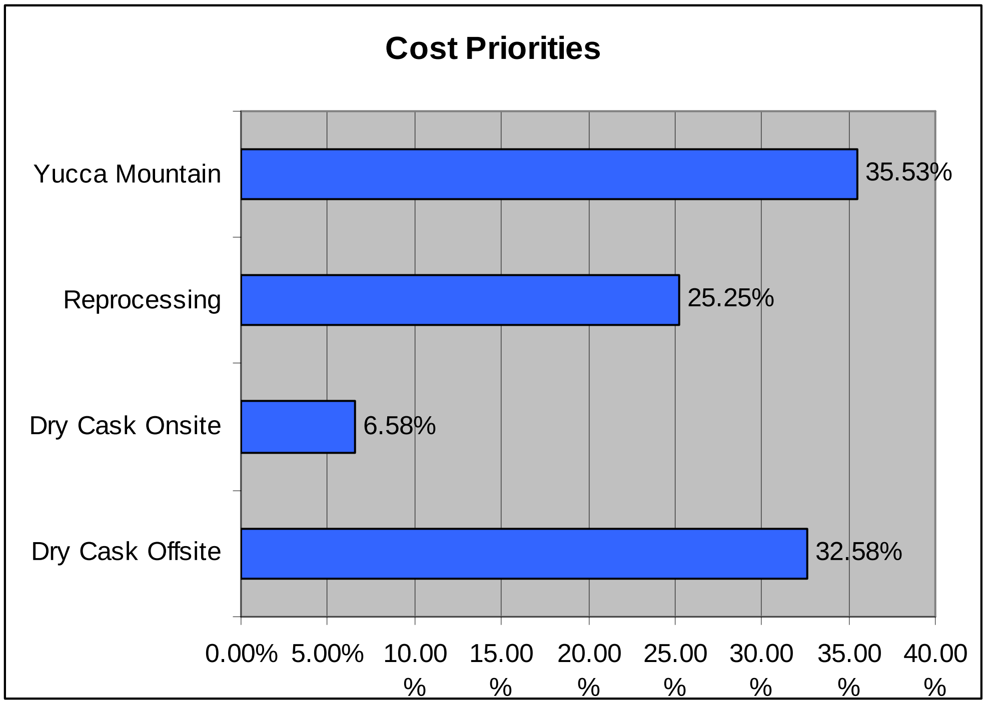
The Benefit specific synthesis model prioritizes the alternatives in the order as follows:



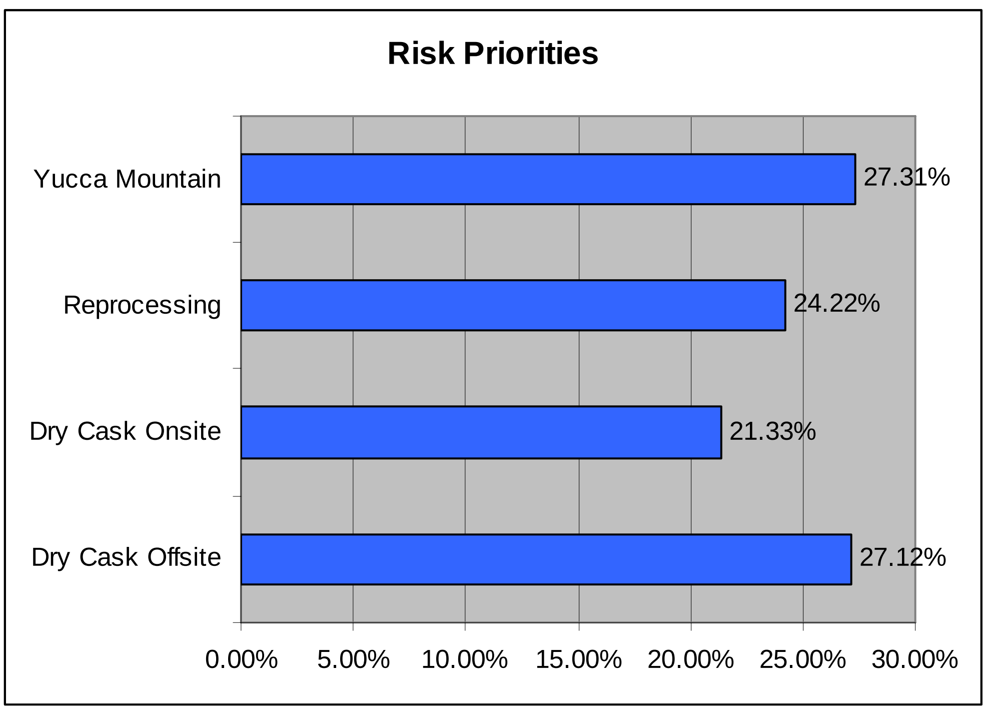
The Opportunities synthesis model prioritizes the alternatives as follows:



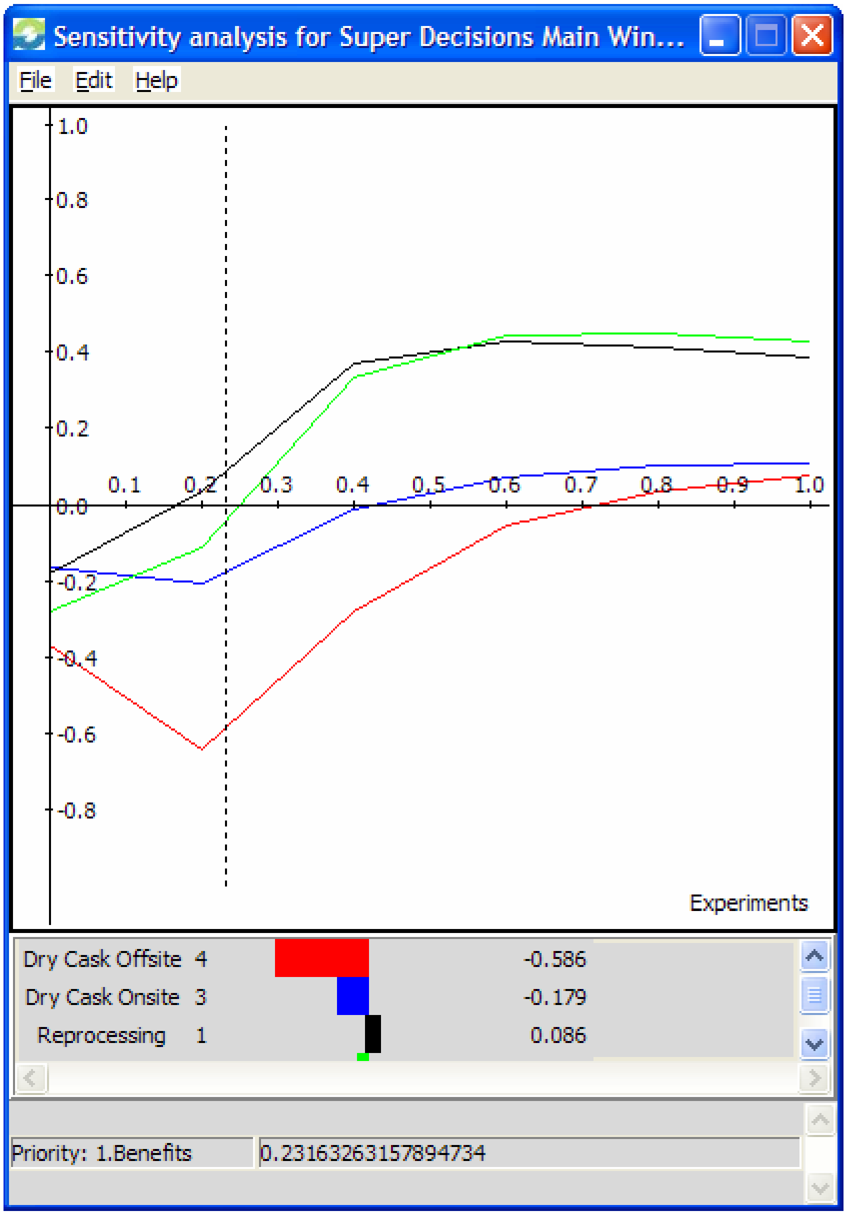
The Cost synthesis model prioritizes the alternatives as follows:



The Cost synthesis model prioritizes the alternatives as follows:

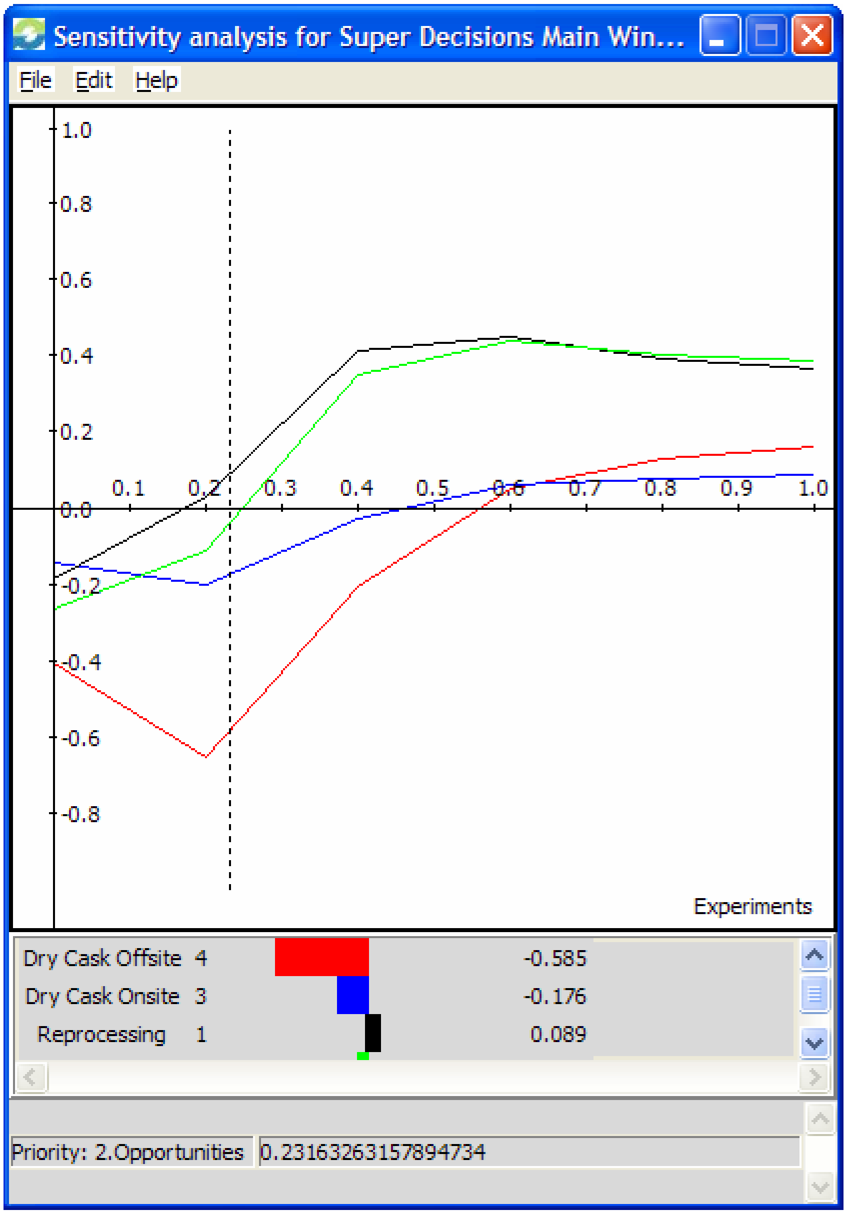


Benefits Sensitivity



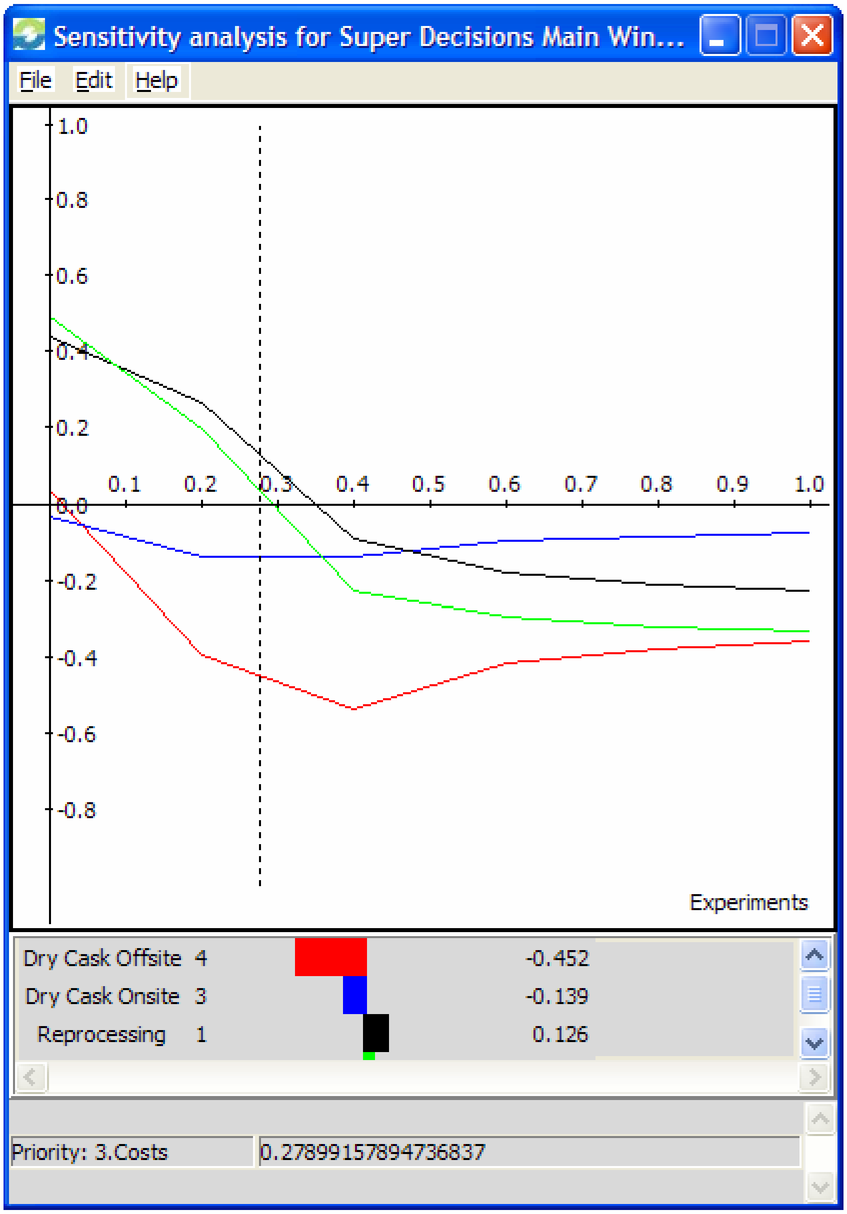
The outcomes for the various alternatives are stable after approximately a 0.55 priority weighting for Benefits. Both *Yucca Mountain* and *Reprocessing* follow the same trends, but *Yucca Mountain* is likely to eventually take over if more emphasis is placed on Benefits due to the perceived advantages in national security and control over the waste.

Opportunities Sensitivity



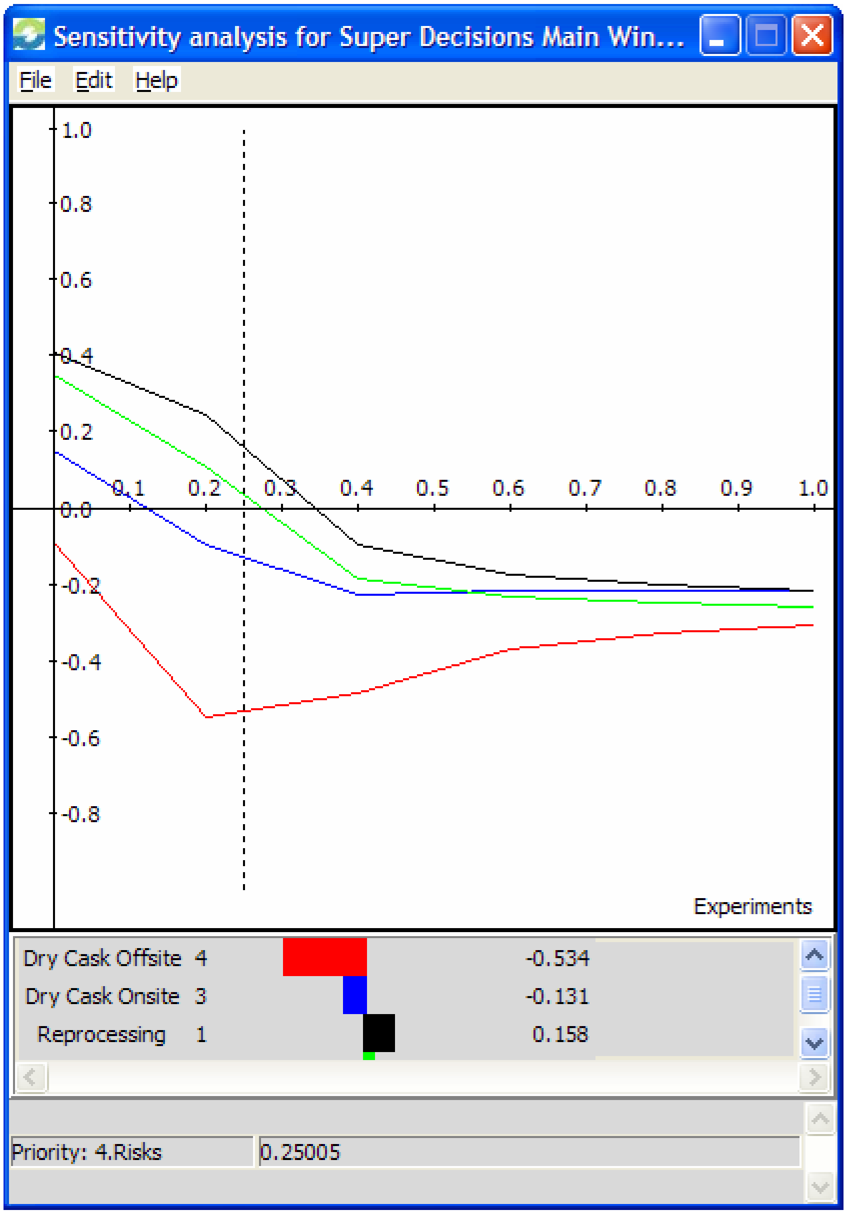
The *Yucca Mountain* and *Reprocessing* alternatives follow similar trends for Opportunities when compared to Benefits. The *Dry Cask Offsite* alternative makes a large decrease when higher priority is placed on Opportunities, which could be attributed to the business growth and political attention that the various sites would attract.

Cost Sensitivity



The sensitivity on Cost shows stable results after a priority of approximately 0.47. The *Reprocessing* alternative is rated the highest at the current priority of ~0.28 due to less reliance on government funding for the project, since it is expected that a privately held company would assume the majority of the costs. However, when more emphasis is placed on Cost, the *Dry Cask Onsite* alternative proves to be the best option, which is due to the very low economic costs since this is essentially the "status quo" alternative.

Risk Sensitivity



The *Reprocessing* alternative yields the best results when mitigating risk according to the sensitivity above. This could be as a result of less political pressure and risk, since the primary source of funding could be from the private sector.

Conclusion

The best option for the disposal of spent nuclear fuel will continue to be debated until a solution that meets all social, economic, and political concerns is found. All the various solutions that we discussed have strengths and weaknesses, which often become even more complicated when the politics and public perception in the U.S. are considered. Until the government can make a decision that meets all the regulations with a high approval rate of the general public, this will be a continually discussed issue as the nuclear renaissance continues to grow. However, the experience we have from working in the nuclear industry indicates that reprocessing spent nuclear fuel is a viable solution of the future in the U.S., and many lessons can be learned from France in this area since reprocessing has been used for many years.

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