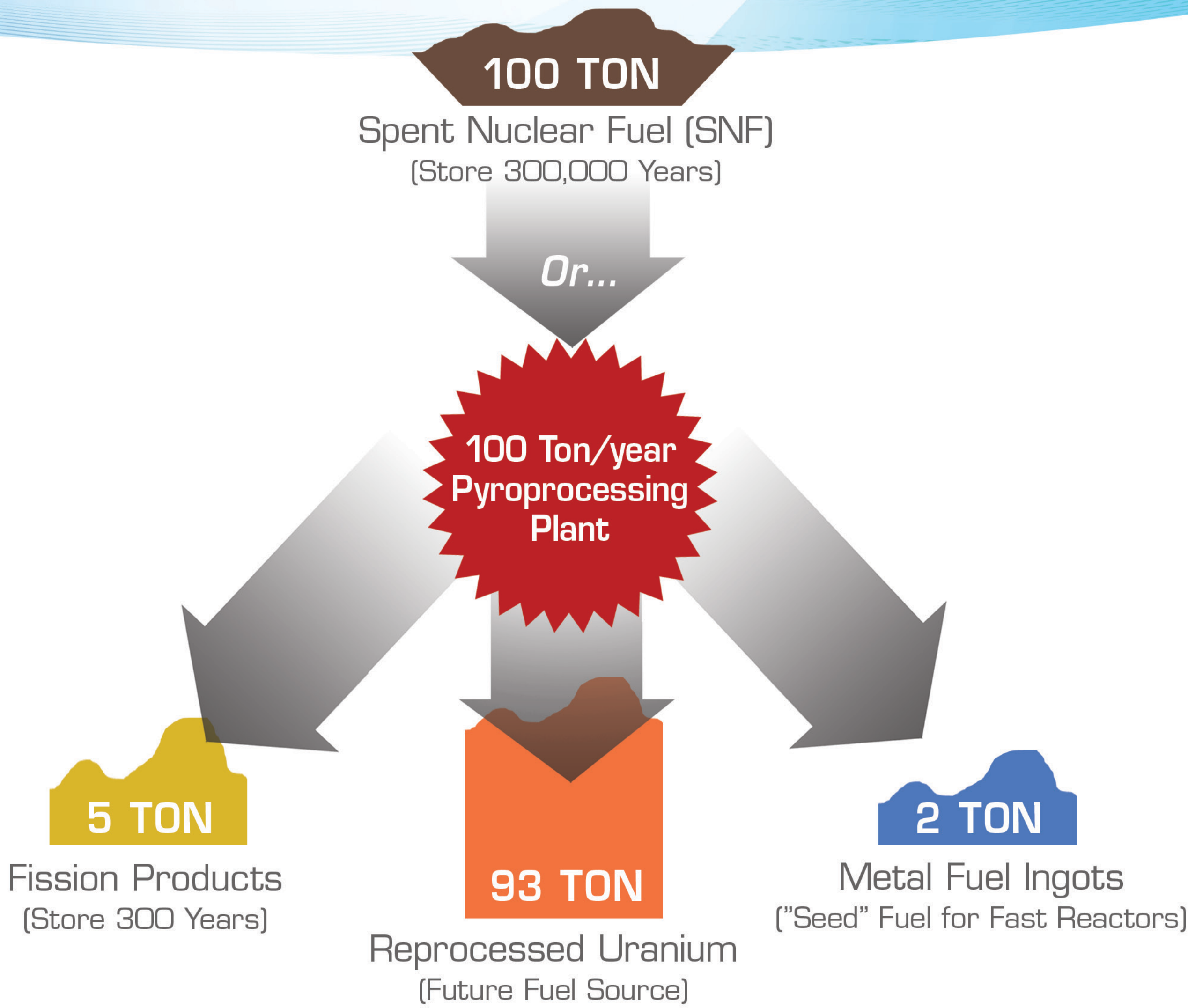
ECONOMIC/BUSINESS CASE for the PYROPROCESSING of SPENT NUCLEAR FUEL (SNF)

100 TON/YR
PYROPROCESSING DEMONSTRATION PLANT



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ABSTRACT

While many still claim that conservation together with wind and solar will solve the world's energy problems, they are dead wrong. Nuclear power is the only proven alternative source of carbon-free energy that can be developed rapidly enough and to sufficient scale to meet the world's growing need for energy. This report outlines the actions which must be taken; both to reduce the amount of troublesome nuclear waste called **Spent Nuclear Fuel (SNF)** and simultaneously create the fuel needed by Fast Reactors. The authors are certain the use of Pyroprocessing to close the nuclear fuel cycle, and Fast Reactors, particularly in the form of Integral Fast Reactor (IFRs), are inevitable in a fossil fuel-free world.

Spent Nuclear Fuel (SNF) reprocessing has long been the subject of debate in the energy policy world. Since a 1977 Presidential Directive which deferred reprocessing SNF, the United States has utilized a "once through" or "open cycle" system which leaves 99% of the energy content in the uranium unused. Advanced technologies such as Pyroprocessing have the potential to close the fuel cycle while increasing proliferation resistance and decreasing the need for geologic repositories.

Because of the many potential benefits, the United States should as soon as possible build a 100 Ton/yr demonstration pilot plant. One of the most important questions asked is, "At what cost"? The answer to that question is the subject of this report.

SUMMARY

There is a great deal of SNF in the world (62,000 Tons in the U.S. alone) that can be disposed of by putting it into long term repositories, but that has been problematical since the beginning of the nuclear age. Another much more practical process to manage SNF is called **Pyroprocessing** (see addendum pages 17-18). The technical aspects of this new solution have been tested and proven in our national laboratories, particularly Argonne National Laboratory (ANL) and Idaho National Laboratory (INL).

If the cost is even close to reasonable, the United States <u>must</u> take advantage of this new technology because of the many non-economic benefits that would accrue to the government, utilities, and the public. However, having said this, it seems certain that the proposed 100 Ton/yr demonstration pilot plant and particularly the subsequent large commercial plants do make very good economic and business sense. This report makes the case and also outlines what must be done immediately to elevate this very optimistic statement to a higher confidence level. Because the demonstration plant is the first large scale attempt to demonstrate this technology, many assumption had to be made. However, even for this proposal, enough of the process is known to provide a reasonably accurate assessment of the economics of this technology.

This paper presents the economics of building a pilot plant to demonstrate both the economical and technical aspects of Pyroproccessing. This technology was developed to separate so-called Spent Nuclear Fuel (SNF) into three streams as shown on the cover. The majority of the 440 reactors worldwide are Light Water Reactors (LWRs), which produce the SNF that has been such a huge problem not only in the U.S. but worldwide. Its toxicity is at unacceptable levels for 300,000 years, and finding suitable repositories in which to store this high level waste for such an incredibly long time has been a problem both politically and technically. WE CAN DO BETTER.

As with many other products, nuclear technology has continued to move forward in both the management of waste products as well as in nuclear plant design. Both of these advanced technologies are ready technically but the question has been whether these new processes make economic and business sense. While many are confident that the economics are favorable, the issues are complex, and a pilot plant is needed to prove not only the expected positive economics, but also to optimize equipment design.

After extensive investigation, consultation with Argonne National Laboratory personnel, and complete financial analysis (P&L and Cash Flow), it appears both the proposed $400 Million 100 Ton/yr Demonstration Pilot Plant and a subsequent large 2000 Ton/yr Commercial Plant should be able to attract private capital. What remains before going ahead with the Demonstration Pilot

Plant is a more detailed analysis to refine and verify the many assumptions that were necessary at this stage. The cost to do such an analysis is $11.5 Million, and the time necessary is 12-18 months. After completing this work (see addendum, Statement of Work, pages 21-27), it is believed that the financials will be at a 95% plus confidence level. Every attempt will be made to manage critical path items to make it possible to get to a "go/no-go" position earlier than 12 months. The nation no longer has the luxury of time.

BACKGROUND

- **Uranium Is An Extremely Rich Energy Source:** Uranium is the densest form of energy on earth. The energy available from one pound of uranium is equivalent to the energy available from 3 Million pounds of coal. It is carbon-free.

- **Nuclear Waste Is Not Waste:** The energy value that can be recovered from the U.S. stockpile of approximately 62,000 tons of spent nuclear fuel rods and 600,000 tons of depleted uranium is the equivalent of 4.5 Trillion Barrels of oil. **That is more than 200 times the Oil reserves of the U.S. and over 4 times the known Global Oil reserves.**

- **This Vast Source of Carbon-Free Energy Must Be Unlocked:** Generation IV Integral Fast Reactors (IFRs) together with Pyroprocessing (Closed Fuel Cycle) make this possible. Pyroprocessing technology was developed in connection with the operation of EBR-II (62.5 MW Experimental Breeder Reactor). Included was the complete recycling of fuel from 1965-1969 and the treatment of spent fuel following the shut down of EBR-II in 1994. This process is ongoing today at Idaho National Laboratory. Pyroprocessing makes it possible to utilize100% of the energy in uranium, while today we are extracting less than1% of the energy available. Continuing with past practice, uranium reserves would last only 100-200 years. With IFRs and Pyroprocessing this same uranium fuel will last thousands of years, or as one scientist put it, "Until the sun engulfs the earth."

- **The U.S. Is Falling Behind In the Global "Nuclear Renaissance."** Nuclear Power is experiencing rapid growth throughout the world. South Korea, China, India, Japan and Russia are all significantly expanding their use of traditional LWR's and, with the help of their governments, are also proceeding with new designs and building their own Fast Reactors. They know fuel supplies for today's LWR plants will last only 100-200 years-- another finite fuel supply issue. These countries all want to lead the way in nuclear technologies which will be important for the world's energy future. Although the U.S. developed the first Fast Reactor design called the Integral Fast Reactor (IFR) and successfully tested it for over 30 years at the Argonne National

Laboratory in Idaho, the U.S. is currently without a Nuclear Regulatory Commission (NRC) approved Fast Reactor design. The timing of commercial Fast Reactors in the U.S. is years away and uncertain at best because of past public blunders. However, this project provides the basis for proceeding with the General Electric (GE) PRISM Fast Reactor--currently acknowledged as the best design in the world. It was100% American developed in our own national labs in cooperation with American industry. You might ask, "So what's the problem?" Simply put, it is national confusion on a grand scale leading to procrastination and insufficient political enablement. For rational present and future energy choices we should be listening to our scientists and engineers who best understand all proposed energy sources including advanced nuclear reactors and SNF management.

- **U.S. Nuclear Renaissance Faces a Major Political Hurdle:** For there to be a true "Nuclear Renaissance" in the U.S. with popular political support, **it must first be established that there is a real solution to the problem of spent nuclear fuel (SNF).** It is believed that the demonstration project discussed herein will convince the public and government that we have an infinitely better solution than just throwing away our very valuable SNF into a repository.

- **Pyroprocessing Addresses the Nuclear Waste Problem By Reducing the <u>Quantity and Storage Time</u> Required for Dangerous Radioactive Material:** Properly reprocessing spent fuel rods via Pyroprocessing can significantly reduce the term and scale of the SNF problem by separating the material into three discrete components (see cover) with distinct handling and storage characteristics:

  Fission Products: 5% of the SNF (the true waste) is converted to a stable vitrified ceramic material that is radioactive and not useful as a future energy source. However, due to the short half-lives of these fission by-products, they become no more lethal than the ore from which they came in about 300 years!

  Reprocessed Uranium: 93% of the SNF is unused uranium which is not fissionable. It is easily stored and will have future energy value when used in Fast Reactors, or it could sit dormant forever.

  Metallic Fuel Ingots (Actinides): The remaining **2%** of the SNF is extremely valuable as it is converted to metallic fuel ingots (long radioactive half-life) that will be used as "seed" fuel for Fast Reactors. These ingots can be stored at the plant site until a decision is made regarding the future of Fast Reactors. They can then be used as commercial Fast Reactor "seed" fuel. **The physical size of**

this 2% is approximately 3.6 cubic feet or about 25 gallons (1/2 of an oil barrel) for every 100 Tons of SNF processed.

As a result, the amount of difficult long half-life material is reduced by 98% and the 300,000 years waste storage problem is reduced to about 300 years---a period that is clearly feasible with today's technology.

Pyroprocessing cannot extract from SNF, plutonium with the chemical purity needed for bombs. Further processing would be required, even if the isotopic purity were acceptable, which it is not.

- **The United States is the Technology Leader in Nuclear Pyroprocessing:** It took over 30 years of experimentation at a cost of over $3 Billion to develop this technology and the U.S. is the only country to have successfully done so.

- **Pilot Demonstration to Establish Economic Feasibility Is Necessary:** The U.S. should ASAP demonstrate the feasibility and economics of Pyroprocessing by building the 100 Ton/yr Demonstration Pilot Plant proposed. Once this is accomplished, valid comparisons can be made between Pyroprocessing and other storage and reprocessing alternatives. This cannot be accomplished without first developing detailed engineering drawings and specifications for the Pilot Plant in order to confirm the cost assumptions for the plant and any subsequent commercial plants. The cost profile and general layout for a commercial 2000 Ton/yr plant is also to be included.

BUSINESS CONSIDERATIONS

- **DOE Is the Customer for the Proposed 100 Ton/yr Pyroprocessing Demonstration Pilot Plant:** The customer for the processing and storage services at the Demonstration Pilot Plant is the DOE which is under a legal obligation to provide a method of processing and storing the spent fuel in the U.S. The DOE can look to the utility industry's $24 Billion Nuclear Waste Trust Fund (growing at approximately $1.8 Billion per year) as a source for funding this expenditure. DOE will also be the customer for any subsequent Pyroprocessing plants.

- **Ultimate Customers are Utilities who own Nuclear Plants:** In the long term the Nuclear Waste Policy Act will likely need to be amended to incorporate Pyroprocessing as part of the waste management strategy with the utility industry becoming responsible for this part of the fuel processing.

- **Potential Future Customers**: Several U.S. companies including General Electric are currently developing Fast Reactor designs that would benefit from access to metallic fuel. There is significant international interest in Pyroprocessing and in metallic fuel; however, international sales cannot be pursued without approval of the U.S. State Department which has historically opposed sharing this technology due to policies regarding nuclear non-proliferation.

OTHER OPPORTUNITES

There are several opportunities for cooperation in designing and building the proposed 100 Ton/yr pilot plant. Some have already offered help.

- **Develop Pilot Plant and Interim Storage Facility on University of Texas Land:** A commercially successful pilot project can be established in conjunction with the University of Texas on their property along the Texas-New Mexico border in Andrews County, Texas. At full deployment, this is an ideal site for interim storage and reprocessing of the entire U.S. nuclear waste stock pile. The reprocessed uranium fission products, and metallic fuel ingots can be safely stored there until a further determination is made by the U.S. government. The University of Texas owns over 2.2 Million acres of vacant land in a remote region that could work well for the proposed storage.

- **Argonne/Idaho National Lab Participation:** A large portion of the design work must be done at these national laboratories to take advantage of their vast knowledge in Pyroprocessing and other similar processes. An ideal location could be at the central or a regional spent fuel interim storage facility. Of course, any DOE site with legacy waste could qualify as a suitable site.

DOES PYROPROCESSING MAKE ECONOMIC SENSE?

The question for some time has been whether Pyroprocessing is both an economically and technically sound process to treat Spent Nuclear Fuel (SNF). This report and analysis will show that this process is a very good way to reduce by 98% the amount of SNF the world has to manage-- a dramatic benefit. Further, scientists who know the most about SNF and Pyroprocessing tell us that Pyroprocessing is absolutely necessary if we are to deploy Fast Reactors which the authors believe are an inevitable part of the world's future energy mix. There is literally no other energy source that is constant 24/7 or reliable enough, except the continued use of fossil fuels which are the very problem--- they are rapidly depleting and represent a heavy health, and environmental (global warming) penalty.

A Word about Conservation: Yes, we can conserve in the U.S, but we cannot conserve our way out of our energy problems. The U.S. can maybe conserve

30% after we have plug-in and all electric automobiles, but since on a per capita basis the rest of the world consumes only about 20% of the energy Americans use, there is little room for them to conserve. Further, China uses about 7% and India uses only 2% of the energy we use on a per capita basis. No chance for conservation in those two countries as their per capita use of energy in the short and long term will increase. We must remember that all nations are in the "same boat" with respect to energy, and we will all "sink or swim" together.

A Word about Renewables (Primarily Wind and Solar): Both wind and solar are intermittent, and operate at name plate capacity only about 25-30% of the time. These renewables will play a major role in solving the world's energy problem, but they have some serious limitations since they don't produce when the wind is not blowing or when the sun is not shining. They also require enormous amounts of land, offer serious maintenance issues, especially in severe weather, cleaning challenges, and finally their useful life expectancy is relatively short (25-30 years). The costly so-called "smart" grid is a must if more than 20% renewables are to be used supplying energy to the grid. Even if there were no problems with renewables, it is practically impossible for these energy sources to save us in time.

Based on the analysis here, there is NO question that a large Commercial Plant 2000 Ton/yr presents a very strong business proposition. The Demonstration Pilot Plant discussed can also be operated as a sound business. However, this analysis shows the return on investment for the 100 Ton/yr is considerably less owing to the fact that it is a "first-of-a-kind" pilot project.

FINANCIALS: ECONOMIC/BUSINESS CASE FOR THE PYROPROCESSING OF SPENT NUCLEAR FUEL (SNF):

(See Addendum for detailed financials for the 100 Ton/yr Demonstration Pilot Plant, pages 28-30 and 2000 Ton/yr Commercial Plant, pages 31-33.)

1) $500 Million Investment Required for a 100 Ton/yr Pyroprocessing Demonstration Pilot Plant

Basic Assumptions:

- Total Investment- $500 Million
- Plant cost - $400 Million
- Borrow 60% of plant cost ($240 Million @ 6% - 15 year pay back)
- Capital Investment - $260 Million
- Depreciation - straight line 25 years
- Process Fee - $1,200/Kg
- Storage Fee - $8/Kg per year

Plant Capital Cost:
It is estimated that $400 Million will be required to build a 100 Ton/yr Pyroprocessing Pilot Plant. This estimate was calculated by scientists who were at Argonne National Laboratory and who worked on the development of both Pyroprocessing and the Integral Fast Reactor (IFR). While there is reasonable confidence in this number, the capital cost could be 30% higher, or more likely, up to 30% lower.

Operating and Maintenance Costs:
These costs were developed by people who have had experience operating similar plants such as nuclear plant operations, and other plants of this size and magnitude. O & M costs are as follows:

Administrative Personnel	
▪ CEO, COO, CFO, CTO, GC, and 40 compliance, regulatory, & other	$4,500,000
Operating Personnel	
▪ 44 operating professionals at various pay rates	$5,500,000
Security Personnel	
▪ 75 security professional at various pay rates	$6,000,000
Total Cost Management and Staff Personnel	**$16,000,000**

Other Operating Costs, Power, Utilities, supplies, Parts, Maintenance, Property taxes and Insurance, etc	$16,000,000
Total Operating and Maintenance Costs	**$32,000,000**
20% Contingency	$6,000,000
Total O & M Costs	**$38,000,000**

Other Assumptions and Comments:

The Pilot Plant will be built in three years will be at approximately 25% capacity in the fourth year, and at full capacity in the fifth year.

Although much investigation and discipline has gone into the 100 Ton/yr plant projections, there are a number of assumptions that must be verified: confirmation of the cost of the all important regulatory issues, equipment, ancillary needs and timetables. It is highly unlikely that there will be any technical show stoppers.

The economics of a larger production plant (2000 Ton/yr) is assured if this small production pilot plant operates as expected. We truly see **no** serious stumbling blocks, unless there are oppressive regulatory issues-- which would be extremely unfortunate, if not tragic.

$11.5 Million and 12-18 months are needed to do sufficient research to essentially eliminate any major risk in building the Demonstration Pilot Plant. If after one year it is deemed that the investment in the commercial pilot plant still makes sense, as expected, we see no reason to delay. We are confident that both the pilot plant and subsequent commercial plant can attract private capital, particularly if the capital is guaranteed by the U.S. government.

Based on the above, the 100 Ton/yr Demonstration Pilot Plant compound return on investment over the first five years of operation would be 18% with an enterprise value in 5 years (8 x EBITDA minus debt) of $590 Million.

Note 1: It is possible that the Pilot Plant project can get by with $450 Million Total Investment. In such a case, return on investment over the first 5 years would be 21% and the enterprise value in five years would be $535 Million.

Note 2: If the processing fee were to be increased to $1,500/Kg, the return on investment over 5 years would be 26% with an enterprise value in five years of $825 Million.

2) $7 Billion Investment Required for a 2000 Ton/yr Pyroprocessing Commercial Plant

Basic Assumptions:

- Total Investment - $7 Billion
- Plant Cost - $6 Billion
- Borrow 60% of plant cost($3.6 Billion @ 6% - 15 year pay back)
- Capital Investment - $3.4 Billion
- Depreciation - straight line 25 years
- Process fee - $1,000/Kg
- Storage Fee - $8/Kg per year

Based on the above and scaled-up assumptions based on the 100 Ton/yr Demonstration Pilot Plant, the compound return on investment over the first 5 years of operation would be 30% with an enterprise value in 5 years (8 x EBITDA minus debt) of $13.1 Billion.

- The business case for both projects appear quite sound, particularly the 2000 Ton/yr Commercial Plant even after lowering the processing fee. This is no surprise since the 100 Ton/yr Demonstration Plant carries cost burdens that are typical for a "first-of-a-kind" effort.

- The above numbers were derived by modeling both efforts on paper quarter by quarter. (See Addendum pages 28-33) Further, an effort was made to break each variable down to its most fundamental form in order to make the most reasonable assumptions. For greater insight, many models were studied.

- Export opportunities could be huge. However, no value was assigned to this opportunity since at present the US government does not allow it.

The government's total processing cost for each plant is as follows:

100 Ton/yr. Pilot Plant- $120 Million/yr.

2000 Ton/yr. Commercial Plant- $2 Billion/yr.

Government Benefits

Pyroprocessing causes the dangerous portion of the Spent Nuclear Fuel (SNF) to be reduced by 98%. Therefore, the government does not have to build a large new 300,000 year repository saving an estimated **$15-20 Billion.** The long half life of the 2% "seed" fuel will be consumed in Fast Reactors, and therefore will not need a repository.

1) 5% of the SNF (Fission Products) must be stored for about 300 years instead of 300,000. This could be stored in Yucca Mountain if the government so desires. A number of scientists agree that Yucca Mountain with a few minor changes would be an ideal repository for this 'true waste'.

2) The 2% 'seed' fuel for Fast Reactors, and the 93% reprocessed uranium resulting from Pyroprocessing of SNF is owned by the government and becomes a **very** significant asset.

   To determine the value of this asset produced by the 100 Ton/yr and the 2000 Ton/yr plants, is was assumed that the fuel costs for the Fast Reactors would be the same as the fuel costs for today's Light Water Reactors (LWRs) (5.5 mils per kwh). The value of this asset that results from operating the 100 Ton/yr Demonstration Pilot Plant for 25 years is approximately **$9 Billion**. This is based on the fact that the 100 Ton/yr plant will produce enough IFR fuel to fuel five 1000 MWe plants over their entire operating life (40-60 yrs). (See addendum page 20.)

   On the same basis, the value of this asset that results from operating the 2000 Ton/yr Commercial Plant for 25 years is approximately **$150 Billion.**

3) Another very important benefit would be the re-establishment of the U.S. as a worldwide leader in nuclear matters.

Public Benefits

1) The very serious long term (300,000 Years) storage problem of SNF essentially goes away when SNF is burned in Fast Reactors. Any reasonable study of future energy mixes must include nuclear, and the nuclear reactors must be Fast Reactors, preferably the American Integral Fast Reactors (IFRs).

2) Pyroprocessing and IFRs together would put the U.S. and the world well on the way to a pollution free environment. Future generations would have clean air to breath, clean water to drink and recovering oceans to enjoy. Fossil fuel-related medical costs would also be reduced. This

expense today is approximately **$150 Billion**. There is absolutely no way the world can fix their environmental problems, and still maintain a reasonable standard of living, without this technology.

3) Pyroprocessing is an enabling technology. It will encourage the building of Fast Reactors. This in turn will lessen the need and the cost of large numbers of Light Water Reactors as a stop-gap. This will also provide assurance that future generations will have abundant energy to grow and prosper.

4) Having this technology functional could assure an adequate supply of US produced medical isotopes – another security issue.

<u>World Benefits:</u>

1) The world would have available (with the U.S. government's permission) to an elegant process to reduce the volume of their SNF by 98%. Pyroprocessing could totally replace other systems having inferior performance and higher cost.

2) Many countries are already aggressively pursuing nuclear energy, including the development of their own Fast Reactors. They realize nuclear energy <u>must</u> be a significant part of their future energy mix. Pyroprocessing would accelerate the world's use of much needed Fast Reactors.

3) The world could benefit from the availability of American "seed" fuel for Fast Reactors. Reinstatement of the Global Nuclear Energy Partnership (GNEP) or a similar organization could facilitate such sharing.

   IMPORTANT NOTE: An international treaty should be put in place to manage nuclear energy technology. It should be mandatory that all nations share their intellectual property (patents) with other nations for, of course, fair compensation. As far as energy is concerned, the world will sink or swim together. Nations that solve their energy problems will mean nothing if the rest of the world does not. Sharing vital technology in all energy areas would therefore benefit every person on earth.

COMPETITION

While Pyroprocessing is a dry process, there is also a wet process called 'PUREX' that purports to do the same as Pyroprocessing (see addendum page 19). Studies at Argonne National Laboratory and elsewhere have shown this process to be considerably more costly. With Pyroprocessing being available, it is doubtful that it could be shown that PUREX makes any business sense whatsoever.

Attempts have been made to sell PUREX technology to the U.S. government. It is quite certain, however, that Pyroprocessing will be shown to be less expensive by a factor of 4 or 5. The PUREX process is much more complex, requiring a building 4 times larger and processing cells about 10 times bigger. In this sense, Pyroprocessing offers a very interesting export opportunity.

The authors believe that there is no process any place in the world that can successfully compete with U.S. developed Pyroprocessing. This will be undisputedly proved after the 100 Ton/yr Demonstration Pilot Plant is operational.

CONCLUSION

The only energy sources that can fill the gap after renewables have been deployed to their inherent limitations are nuclear or fossil fuels. Of course, fossil fuel reserves are dangerously low, and their continued use could according to some credible people cause the end of life on this planet (global warming out-of-control). That leaves only nuclear.

The U.S. was once the world leader in nuclear technology and was most influential in determining international nuclear policy. Today, however, the U.S. is falling behind in deployment of nuclear energy in spite of the fact the U.S. was the world leader in this technology for decades and in spite of the fact that we still have the best Generation IV Fast Reactor technology (IFR) in the world. We are literally sitting on our nation's backside while other advanced, and some not so advanced, nations are intent on leaving us in the dust in yet another technology.

Imagine a future without adequate energy: total chaos. No matter how rich or educated one might be, all will slide into poverty and despair. Many of our political leaders and many NGO's who are not elected by anyone just don't get it. You don't have to be a PhD in mathematics when simple arithmetic leads one to the conclusion that Pyroprocessing (Closed Fuel Cycle) together with Generation IV Fast Reactors are inevitable if our children and grandchildren are to have any kind of a future.

The problem of handling and managing SNF has been a formidable barrier to further development of nuclear energy. Pyroprocessing essentially fixes the SNF problem and is an enabler for the inevitable deployment of Fast Reactors. MOST IMPORTANTLY, THIS REPORT SHOWS THAT PYROPROCESSING ALSO MAKES GOOD ECONOMIC AND BUSINESS SENSE. Pyroprocessing, in a sense is therefore, a critical path step in the world's march to energy security.

There is growing realization of the need for this technology…

The Nuclear Division of the America Institute of Chemical Engineers (July 2010 Chemical Engineering Progress) recommends, "Expanding the role of nuclear power and closing the nuclear fuel cycle." Pyroprocessing is the very best way to 'close the nuclear fuel cycle'.

Popular Mechanics (August 2010) states, "We need nuclear energy and a closed nuclear fuel cycle."

Fortune (April 2010) says, "The number one myth about energy is that nuclear power isn't a safe solution."

Green Labor Journal (September 2010) reports, "Broad independent studies looking at future energy and climate scenarios clearly point to nuclear energy as an important component of our energy portfolio."

Russia clearly understands the economic opportunity…

The Moscow Times (August 2010) said, "Russia is aiming to capitalize on Fast Reactors."

For the U.S. to get started, $11.5 Million are needed to verify the projected economics before building the 100 Ton/yr Demonstration Pilot Plant. This must be done immediately as time is running out.

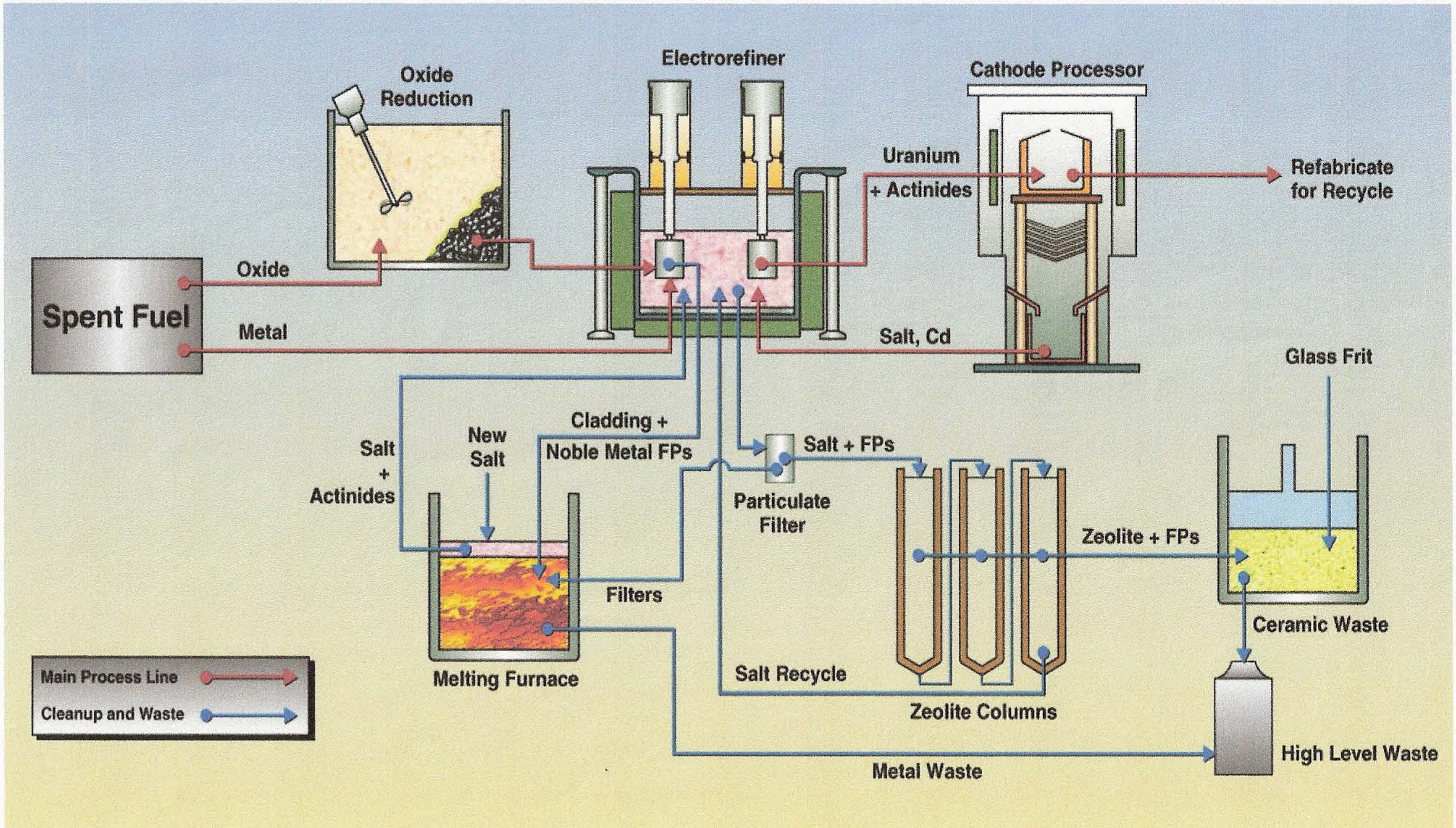
Nations can have neither prosperity nor security without adequate, relatively inexpensive energy. The turmoil in global and national economies and recent wars cannot be decoupled from the world's energy problems.

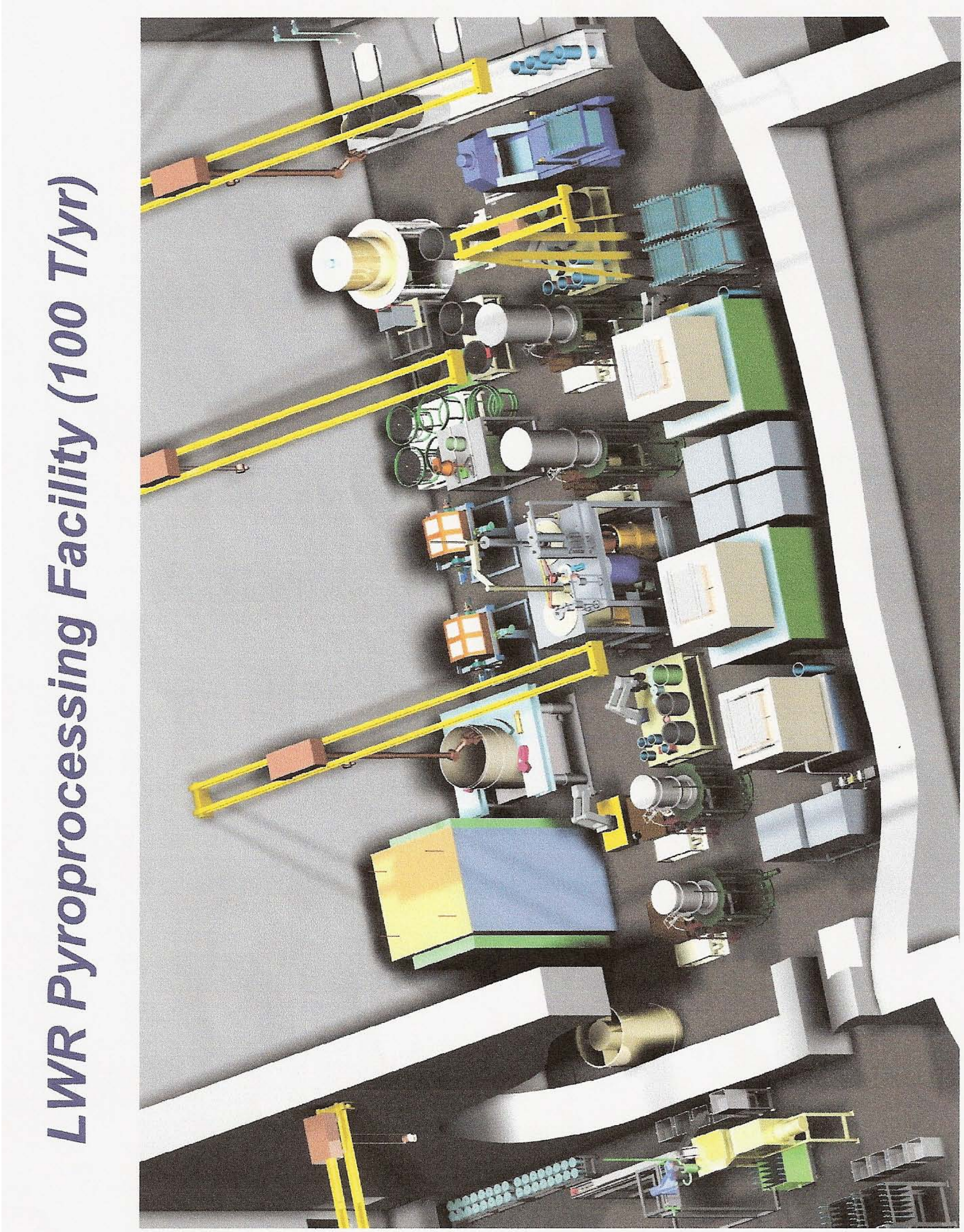
Finally, it is safe to say that most of our U.S. scientists and scientists around the world believe that both a closed fuel cycle and Integral Fast Reactors (IFRs) will be an important and indispensable part of the world's future energy mix. Make no mistake: **There is a race to get there first with great benefits accruing to the winner.**

As a nation, we can and have done great things. While we can point to our participation in the two great World Wars, the Manhattan Project and the man to the moon, we should not overlook the dramatic U.S. led advances in electronics, aviation, genetics and the many advancements in just about every other scientific endeavor. We are now being called to action once again to put forth an extraordinary effort. What are we waiting for?

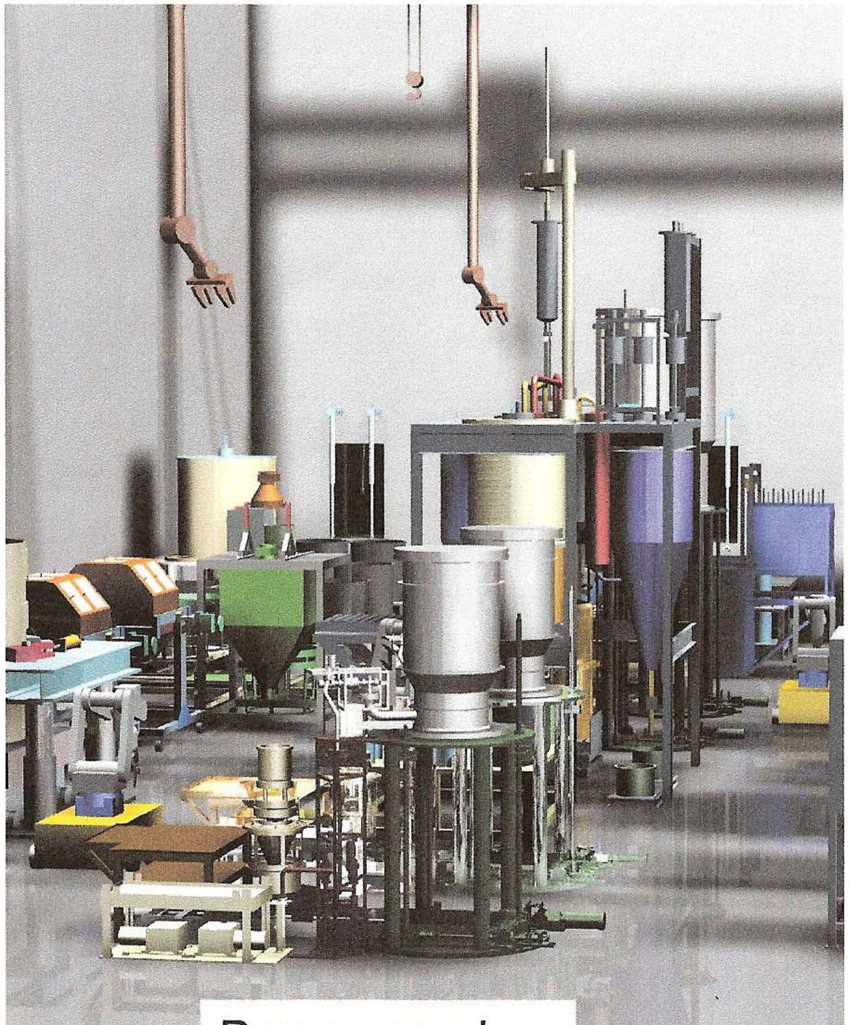
ADDENDUM

Pyroprocessing Flowsheet

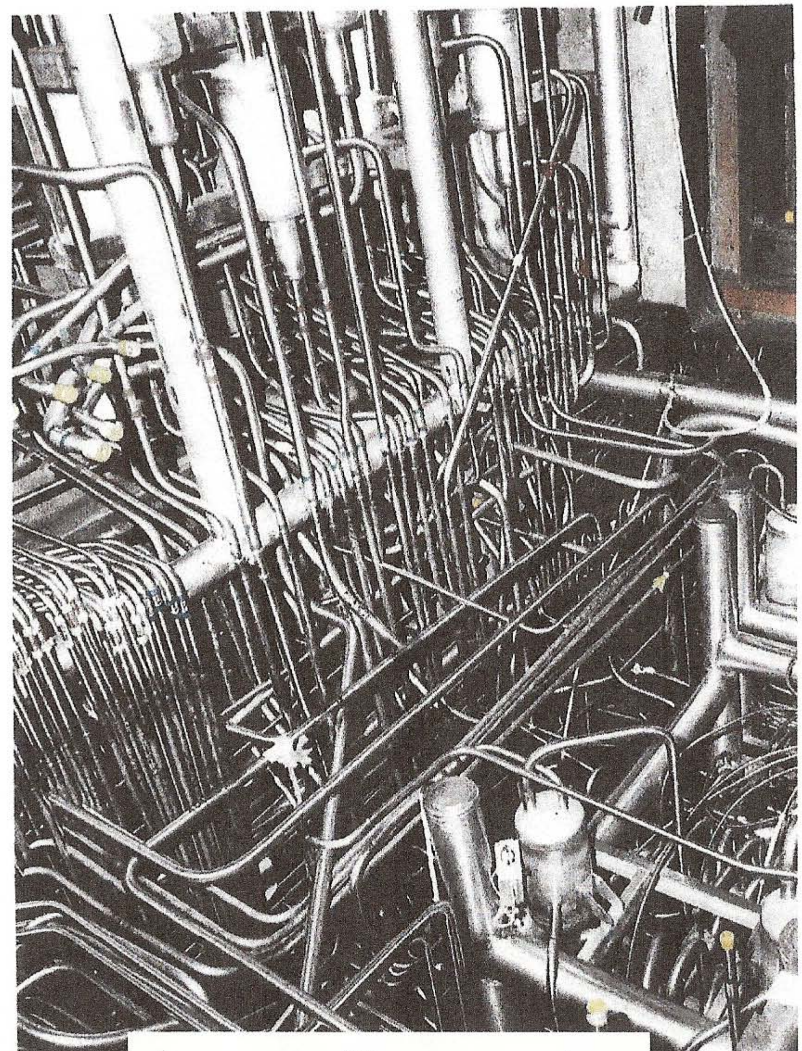



LWR Pyroprocessing Facility (100 T/yr)

Pyroprocessing provides economic fuel cycle closure and intrinsic proliferation resistance

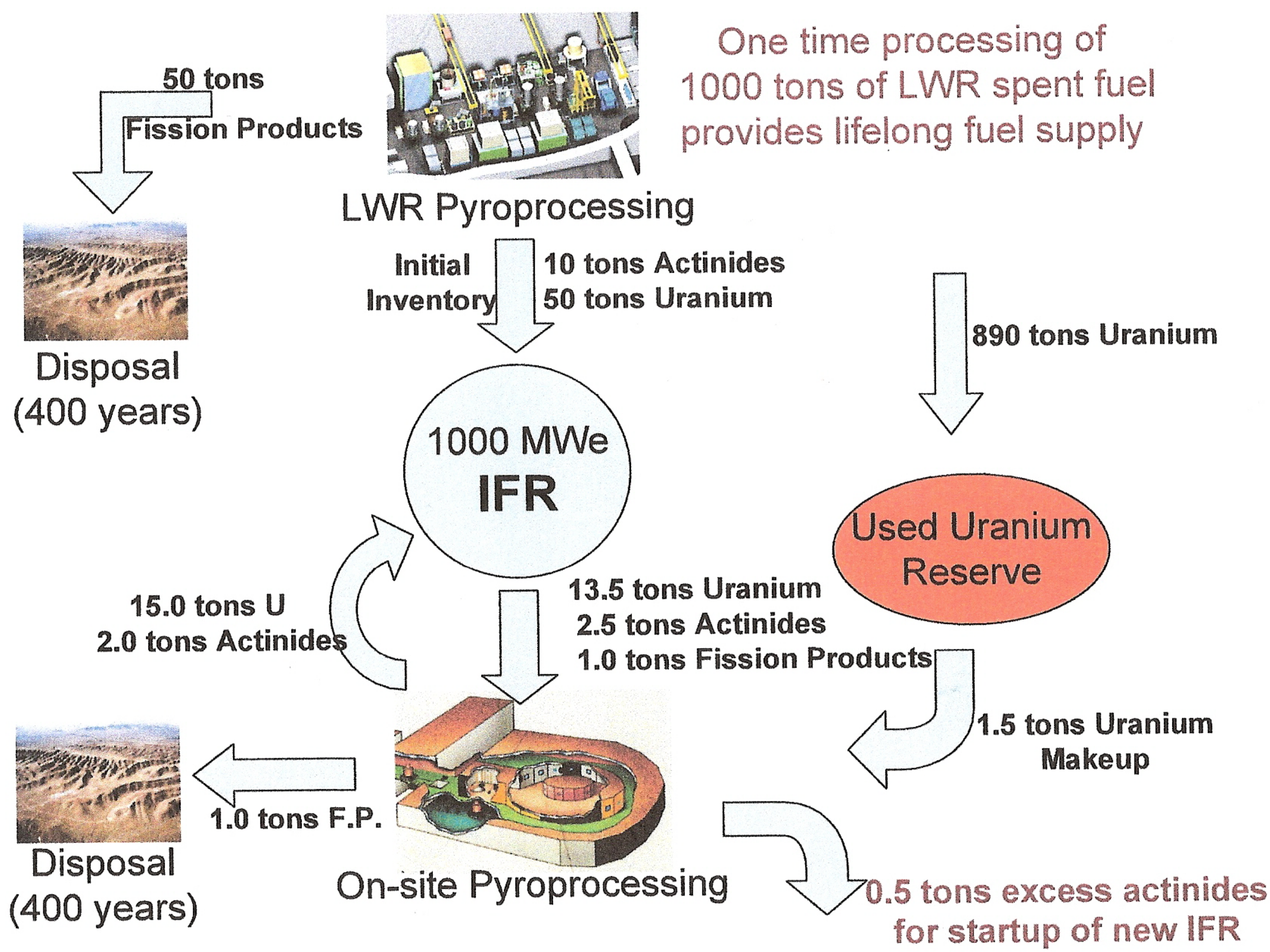


Pyroprocessing



Aqueous Reprocessing

Annual Mass Flow for IFR



Statement of Work

100 T/yr Pyroprocessing Demonstration Pilot Plant

1. Purpose

The purpose of this proposal is to develop a conceptual design of a pilot-scale (100 T/yr) pyroprocessing facility for LWR spent fuel and the capital and operating cost estimates in order to facilitate a decision to proceed with the construction project as a follow-on phase. Another purpose is to develop a preliminary cost profile and the general layout of a commercial 2000 T/y pyroprocessing plant.

2. Partnership

It is envisioned that this work will be done in cooperation with Argonne National Laboratory (ANL). While a private group of experienced business leaders and other project related experts should manage and carry out this project, Argonne's participation would be indispensable to the project.

3. Task Description

Task 1. Establish Process Flowsheet: A baseline process flowsheet for treating spent oxide fuel based on established electrochemical technologies. Flowsheet and unit operations design requirements including processing assumptions will be developed. Material and energy balances developed for each unit operation. Each operation and technology will be designed against these key criteria- producing high quality products, the scale-up to commercial-scale, limited waste production, and a complete understanding of the economics.

Subtask 1.1 Flowsheet Design Requirements: A baseline flowsheet will be developed to establish the principle unit operations, energy and mass balance streams, overall facility throughput, equipment batch size, product/waste stream purity requirements, and processing assumptions. Emphasis will be given to waste minimization by identifying and exploring all waste forms.

Subtask 1.2 Unit Operation Process Requirements: Each unit operation will establish guidelines to meet the throughput goals set by the mass balance flowsheet. Requirements for temperature, electrical power, processing time, product purities, consumable and non-consumable resources, and material transfers for each unit operation.

Subtask 1.3 Baseline Process Descriptions: The process descriptions will be developed that detail the technology, design basis, performance specifications, assumptions, material flows and handling equipment requirements. If the baseline process is determined to fail to meet overall flowsheet requirements, alternative processes will be evaluated and the best will be selected.

Task 2. Develop Equipment Conceptual Designs: If necessary, the equipment will be designed to meet the unit operation process requirements along with the material handling systems required for the processing operations. Replaceable components or equipment that may require maintenance will be designed for simplicity of replacement. Every effort will be made to utilize “off the shelf” processing equipment.

Subtask 2.1 Chopper: Chopping equipment will be designed to prepare spent oxide fuel for pyroprocessing. The equipment’s core function is to mechanically segment the fuel elements into exposed fuel particles and then load the product into the processing baskets.

Subtask 2.2 Off-gas Capture and Handling System: Equipment will manage the fission gases released during the chopping of the spent fuel.

Subtask 2.3 Electrolytic Reducer: This equipment will convert the processing basket loaded with chopped oxide fuel segments into metal form before being transferred to the electrorefiner.

Subtask 2.4 Electrorefiner: This equipment will recover the uranium and a co-deposited uranium-transuranic product from metal feed provided by the electrolytic reducer.

Subtask 2.5 Cathode Processor for Uranium: This equipment will separate the uranium product from any adhering salt electrolyte and consolidate the uranium metal into a storable ingot. The separated salt is transferred to U/TRU Drawdown.

Subtask 2.6 Cathode Processor for TRU: This equipment will separate the uranium-transuranic product from any adhering salt electrolyte and consolidate the metal into storable ingot. The separated salt is transferred to U/TRU Drawdown.

Subtask 2.7 Salt Distillation: This equipment will separate the noble metals and cladding in the electrorefiner baskets from any adhering salt electrolyte and transfer the salt to U/TRU Drawdown.

Subtask 2.8 U/TRU Drawdown: This equipment will electrolytically recover the remaining uranium and transuranics elements from the process chloride salt collected in the cathode processors and the salt distillation equipment. The U/TRU product is sent to oxidant production and the salt is transferred to lanthanide drawdown.

Subtask 2.9 Lanthanide Drawdown: Equipment will electrolytically recover the lanthanide fission products from the U/TRU drawdown salt and send the products to lanthanide waste fabrication. The remaining salt with residual fission products are transferred to oxidant production.

Subtask 2.10 Oxidant Production: Equipment will synthesize the oxidant used in the electrorefiner molten salt electrolyte by utilizing the U/TRU product from U/TRU Drawdown.

Subtask 2.11 Cs/Sr Recovery: Equipment will capture the Cs/Sr from the electrolytic reducer processing salt and send the purified salt back to the reducer. The Cs/Sr products are sent to Cs/Sr waste production. Several options including precipitation and ion exchange will be evaluated to select the best option.

Subtask 2.12 Cs/Sr Waste Form: Equipment will capture the Cs/Sr waste into a stabilized waste form. Several operations including encapsulating the recovered Cs and Sr fission products in glass shall be evaluated to select the best option.

Subtask 2.13 Lanthanide Waste Form: Equipment will capture the lanthanide fission products recovered electrolytically in the lanthanide drawdown operation into a stabilized waste form.

Subtask 2.14 Metal Waste Form: Equipment will produce a metal waste form to stabilize the noble metal fission products and the fuel elements cladding. Several metal compositions will be evaluated to select the best option.

Subtask 2.15 In-cell Materials Handling System: Equipment for the material transfers between each distinct unit operation will be developed to maximize use of resources and eliminate processing bottlenecks. Materials handling system will include overhead cranes, hoists, robotics, transfer locks, carts, bridges, manipulators, etc. Equipment will be designed to perform the specialized material transfers required to accept the spent fuel from the DOT shipping cask and transfer it to storage and the chopper equipment.

Task 3. Develop Process Monitoring and Control System

Subtask 3.1 Process Monitoring and Control System: Advanced remote technologies will be identified to improve process control and efficiency by using electrochemical in-situ monitoring techniques. Design requirements for control system will be established to run the facility and reduce operating risks. Techniques being utilized will include sampling, efficiency data, physical measurements, modeling, etc.

Subtask 3.2 Materials Control and Accountancy (MC&A): Design requirements will be established for a materials tracking system including monitoring measures to detect loss of accountable materials along with the use of statistical and accounting measures to maintain knowledge of the nuclear material quantities within each area of a facility.

Task 4. Develop Facility Layout

Subtask 4.1 Design Requirements: Personnel working on Tasks 1 and 2 will develop the design requirements and infrastructure needed for all of the processing and auxiliary equipment identified in Tasks 1 and 2. These individual requirements will then be compiled into an overall Facility Design requirement document for the entire facility complex.

Subtask 4.2 Spent Nuclear Fuel Receipt and Storage: The scope for this subtask will be to create a layout for the facility that is used for accepting the spent nuclear fuel from the DOT shipping cask and referring it to storage.

Subtask 4.3 Air Cell: The scope of this subtask will be to create a layout for the facility used for the mechanical disassembly and conditioning of the spent core assemblies prior to transferring into the main process cell.

Subtask 4.4 Process Cell Design and Layout: The scope of this subtask will be to create a layout for the main argon atmosphere hot cell based upon the square footage needs and placement needs of the processing equipment identified and designed in Task 2. This process cell is expected to be an inerted shielded hot cell facility that will contain the major pyroprocessing equipment.

Subtask 4.5 Product and Waste Storage: The scope of this subtask will be to develop a design of the facility used for the storage of the Uranium and Transuranic products and the waste products generated from the processing of LWR spent nuclear fuel (SNF). A major portion of the LWR spent fuel will be a product that can be re-used in future fast reactors. Another part of the recycling process will be the generation of wastes that will need to be stored pending shipment to an appropriate offsite storage or disposal location. This layout will be based upon the work accomplished in Tasks 1 and 2 above and the design requirements for this facility.

Subtask 4.6 Hot Repair Area: The scope of this subtask will be to develop a design layout for a hot repair area as needed for the process equipment repairs and other support equipment systems.

Subtask 4.7 Analytical Laboratory: The scope of this subtask will be to develop a design layout for the facility used for analyzing the products generated from the pyroprocessing activities. This facility will include gloveboxes and a small hot cell facility with the infrastructure to measure the radioactive and chemical constituents of the process streams during different stages of the pyroprocessing treatment. This facility layout will be based upon the work accomplished in Tasks 1 and 2 above and the design requirements for this facility.

Subtask 4.8 Control Room: The scope of this subtask will be to develop the functions and requirements needed for the control room/building used for the control and monitoring of they systems and equipment used for he treatment of spent nuclear fuel.

Task 5. Architect/Engineering Services: This task will be subcontract to an Architect/Engineering firm to perform the scope of work described below. The selection of the Architect/Engineering firm will be made by the project team based on the prior work experience in the hot cell facilities and other related activities with Argonne.

Develop an integrated facility layout for the facilities and infrastructure identified in Task 4 above, along with a cost and schedule estimate for these facilities and infrastructure.

This will include the location of all major equipment (technical process equipment and supporting equipment). Prepare the conceptual design report for the facilities and infrastructures complete with cost and schedule.

The Architect/Engineering Services Company will furnish personnel, facilities equipment, materials and supplies necessary to complete a conceptual design report, consisting of:

1. conventional facilities and building designs for facilities identified in Task 4 including other facilities such as an office building, equipment maintenance, shop facilities, etc as defined during the Task 2 design process.
2. the Balance of plant Facilities/Building including the other auxiliary buildings and structures that are not accounted for by the above Task 4, but are needed for a fully functioning pyroprocessing facility complex. The balance for plant facilities could include a security building, an emergency diesel generator building, a mockup facility for testing and checking out equipment, a maintenance shop, etc.
3. the necessary site infrastructure and improvements to support the Task 4 facilities such as roads, parking, cooling towers, and other site infrastructure needs.
4. a site plan.
5. a preliminary cost estimate for the design and construction, of said facilities.
6. a preliminary design and construction schedule for the entire facility complex.

The nature, purpose and technical requirements of this facility complex if designed in Subtask 4.1 above. A design requirements document will be prepared in cooperation with Argonne National Laboratory.

The conceptual design will be defined to a sufficient design detail to enable proper sizing of all facilities and process equipment. This will include facility floor plans and equipment layout, facility elevation views, and lists of necessary conventional facility and site infrastructure equipment.

Task 6. Develop Operation and Maintenance Systems: In-cell material handling systems required for the processing operations are included in Task 2. This task deals with the required systems for installing process equipment into the process cells, supporting maintenance operations on process equipment, and the transfer systems between the process and the hot repair area, etc.

Task 7. Develop Safety Assessment Strategy: Develop the facility and process safety design approach/criteria based on applicable NRC regulations, develop a criticality safety design approach and criticality control approach, and a licensing strategy.

Task 8. Develop Business Model for Construction Phase: In order to transition from a conceptual design phase to the next follow-on phase of the actual construction and a complete business plan, including feedback from the Department of Energy, the nuclear utility industry, and others as required.

Task 9. Develop Cost and Schedule Estimates: The cost and schedule estimates will be developed using a combination of the Argonne National Laboratory personnel who understand the cost and schedule for developing the technical process equipment and an outside architect engineering firm specializing in the design and construction of buildings and structures for nuclear applications.

> **Subtask 9.1 Equipment Costs:** This will be based on the experience of similar equipment design and fabrication with appropriate scale-up factors and vendor quotes on specific components or commercially available equipment.
>
> **Subtask 9.2 Facility Construction Cost:** This will based on the Architect/Engineering estimate.
>
> **Subtask 9.3 Operating Cost:** This will be estimated using best available data from similar operations at national laboratories, and/or at other facilities.
>
> **Subtask 9.4 Construction Schedule Estimate:** Both licensing and construction schedules will be estimated.

4. Project Costs

Tasks	**Effort (man-months)**	**Cost ($ in thousands)**
Task 1. Establish Process Flowsheet		600
Task 2. Develop Equipment Designs		4,400
Task 3. Develop Process Monitoring and Control		800
Task 4. Develop Facility Layout	21	700
Task 5. Architect/Engineering Services		2,000
Task 6. Develop Operation and Maintenance Systems		600
Task 7. Develop Safety Strategy1	12	500
Task 8. Develop Business Model	3	100
Task 9. Develop Cost and Schedule Estimates	9	300
Total		10,000
15 % Contingency		**1,500**
Total		**11,500**

5. Project Schedule

Recognizing that time is running out to solve the nation's energy problems, project target completion should be in 18 months, with 24 months being the maximum. The project will be completed in 24 months starting on a mutually agreed date.

6. Project Review Meetings

Project review meetings will be held on mutually agreed intervals (months or quarterly depending on the progress status) in order to review the status of progress of the project in general, in particular on Task 8 dealing with the working with stakeholders and developing the business model for the project.

7. Project Deliverables

The project deliverables include a final Conceptual Design Report with cost and schedule estimates for a pilot-scale (100 T/yr) pyroprocessing facility for LWR spent fuel. Also, included will be a cost profile and rough preliminary layout for a 2000 T/yr plant.

Also included will be the presentation of a business plan complete with the financials that will show clearly the business feasibility of both the pilot plant and a 2000 T/yr commercial plant. We are already confident of the economics feasibility of both projects. However, this analysis will bring more surety to this statement. The expectation is that based on what is learned during this project, will we find the economics or be considerably better than those presented herein-particularly as to capital costs.

The deliverables will also include 10 hard copies and 10 electronic (DVD discs) copies of the report. The intellectual property rights created through this project will be separately negotiated.

Economic/Business Case for Pyroprocessing Spent Nuclear Fuel (SNF)
100 ton per year demonstartion plant

Demonstration Pilot Plant: 100 Ton/yr; $500M Capital; $400M plant cost; $1,200/kg processing fee

Assumptions

Total Capital	$	500,000,000	
Plant			
Capital Requirement	$	400,000,000	
Percent Financed		60%	
Amount Financed	$	240,000,000	
Interest		6%	
Bond payment (amortization)	$	24,711,063	per year
Total payment for bond	$	370,665,950	
Interest expense yr 4, 5, & 6	$	14,400,000	per year
Length of re-payment schedule		15	Years
Depreciation		25	Years
Process			
Process Fee	$	1,200	per kg
Process Cost (direct labor)	$	30	per kg
Manufacturing, security and misc.	$	24,000,000	per year
Storage			
Storage Fee	$	8.00	per kg per yr
Storage Cost	$	2.00	per kg per yr
Percent Processed stored		100%	
Processing capacity		100,000	kgs per year
SG&A at capacity	$	5,000,000	per year
Misc		1%	of SG&A

Proforma Profit/Loss & Cash Flow

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
kgs processed	-	-	-	41,250	100,000	100,000
Total kgs processed	-	-	-	65,000	415,000	815,000
Total Revenue	-	-	-	49,630,000	120,830,000	121,630,000
Cost of Sales	-	-	-	11,320,000	27,207,500	27,407,500
Gross Profit	**-**	**-**	**-**	**38,310,000**	**93,622,500**	**94,222,500**
Operating Expense	227,250	616,100	3,333,000	5,050,000	5,050,000	5,050,000
Operating Income/Loss (EBITDA)	**(227,250)**	**(616,100)**	**(3,333,000)**	**33,260,000**	**88,572,500**	**89,172,500**
Depreciation	-	-	-	16,000,000	16,000,000	16,000,000
Interest Expense	14,173,249	13,547,068	12,882,462	12,177,074	11,428,401	10,633,787
Income Tax Expense	-	-	-	-	7,506,764	21,888,550
Net Income	**(14,400,499)**	**(14,163,168)**	**(16,215,462)**	**5,082,926**	**53,637,335**	**40,650,164**
Plant Construction Cost	10,150,633	142,590,363	247,259,004	-	-	-
Opening Cash Balance	500,000,000	465,244,427	297,660,273	22,690,579	1,490,389	57,978,435
Ending Cash Balance	**465,244,427**	**297,660,273**	**22,690,579**	**1,490,389**	**57,978,435**	**100,684,695**

Economic/Business Case for Pyroprocessing Spent Nuclear Fuel (SNF)
100 ton per year demonstartion plant

Demonstration Pilot Plant: 100 Ton/yr; $500M Capital; $400M plant cost; $1,200/kg processing fee

REVENUE		Q1_yr1	Q2_y1	Q3_yr1	Q4_yr1	YEAR 1	Q1_yr2	Q2_y2	Q3_yr2	Q4_yr2	YEAR 2	Q1_yr3	Q2_y3	Q3_yr3	Q4_yr3	YEAR 3
kgs processed		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
kgs processed (total)	100,000 kgs max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Process Fees	1,200 per kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Storage Fees	8 per kg per yr	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Revenue		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Process Cost (direct labor)	30 per kg															
Storage Cost	2.00 per kg per yr															
Plant Personnel Cost																
TOTAL Cost of Sales		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gross Profit		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Expense																
SGA		50,000	50,000	50,000	75,000	225,000	125,000	125,000	180,000	180,000	610,000	300,000	750,000	1,000,000	1,250,000	3,300,000
Misc	1% of SGA	500	500	500	750	2,250	1,250	1,250	1,800	1,800	6,100	3,000	7,500	10,000	12,500	33,000
Total Operating Expense		**50,500**	**50,500**	**50,500**	**75,750**	**227,250**	**126,250**	**126,250**	**181,800**	**181,800**	**616,100**	**303,000**	**757,500**	**1,010,000**	**1,262,500**	**3,333,000**
Operating Income/Loss (EBITDA)		**(50,500)**	**(50,500)**	**(50,500)**	**(75,750)**	**(227,250)**	**(126,250)**	**(126,250)**	**(181,800)**	**(181,800)**	**(616,100)**	**(303,000)**	**(757,500)**	**(1,010,000)**	**(1,262,500)**	**(3,333,000)**
Depreciation																
Interest Expense		**3,600,000**	**3,562,584**	**3,524,606**	**3,486,059**	**14,173,249**	**3,446,933**	**3,407,221**	**3,366,913**	**3,326,000**	**13,547,068**	**3,284,474**	**3,242,325**	**3,199,543**	**3,156,120**	**12,882,462**
Income Tax Expense																
Net Income		**(3,650,500)**	**(3,613,084)**	**(3,575,106)**	**(3,561,809)**	**(14,400,499)**	**(3,573,183)**	**(3,533,471)**	**(3,548,713)**	**(3,507,800)**	**(14,163,168)**	**(3,587,474)**	**(3,999,825)**	**(4,209,543)**	**(4,418,620)**	**(16,215,462)**
Opening cash		**500,000,000**	**493,724,941**	**487,319,746**	**477,921,415**	**500,000,000**	**465,244,427**	**440,804,670**	**415,063,550**	**369,746,432**	**465,244,427**	**297,660,273**	**161,126,533**	**76,192,820**	**36,554,317**	**297,660,273**
Receivables/collection		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		500,000,000	493,724,941	487,319,746	477,921,415	500,000,000	465,244,427	440,804,670	415,063,550	369,746,432	465,244,427	297,660,273	161,126,533	76,192,820	36,554,317	297,660,273
Dispersments																
Cost of sales		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating expense (including SGA)		50,500	50,500	50,500	75,750	227,250	126,250	126,250	181,800	181,800	616,100	303,000	757,500	1,010,000	1,262,500	3,333,000
Plant Construction Cost	400,000,000	130,136	260,273	3,253,408	6,506,816	10,150,633	18,219,084	19,520,448	39,040,895	65,809,936	142,590,363	130,136,318	78,081,791	32,534,079	6,506,816	247,259,004
Bond amoritization		6,094,423	6,094,423	6,094,423	6,094,423	24,377,690	6,094,423	6,094,423	6,094,423	6,094,423	24,377,690	6,094,423	6,094,423	6,094,423	6,094,423	24,377,690
Income tax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		6,275,059	6,405,195	9,398,331	12,676,988	34,755,573	24,439,757	25,741,120	45,317,118	72,086,158	167,584,154	136,533,740	84,933,713	39,638,502	13,863,738	274,969,694
Ending cash balance		**493,724,941**	**487,319,746**	**477,921,415**	**465,244,427**	**465,244,427**	**440,804,670**	**415,063,550**	**369,746,432**	**297,660,273**	**297,660,273**	**161,126,533**	**76,192,820**	**36,554,317**	**22,690,579**	**22,690,579**
Financed Amount (Bond)	240,000,000															
Payment		6,094,423	6,094,423	6,094,423	6,094,423		6,094,423	6,094,423	6,094,423	6,094,423		6,094,423	6,094,423	6,094,423	6,094,423	
Interest		3,600,000	3,562,584	3,524,606	3,486,059		3,446,933	3,407,221	3,366,913	3,326,000		3,284,474	3,242,325	3,199,543	3,156,120	
Principal		2,494,423	2,531,839	2,569,817	2,608,364		2,647,489	2,687,202	2,727,510	2,768,422		2,809,949	2,852,098	2,894,879	2,938,302	
Balance		237,505,577	234,973,738	232,403,922	229,795,558		227,148,069	224,460,867	221,733,358	218,964,936		216,154,987	213,302,889	210,408,010	207,469,708	

Economic/Business Case for Pyroprocessing Spent Nuclear Fuel (SNF)
100 ton per year demonstartion plant

Demonstration Pilot Plant: 100 Ton/yr; $500M Capital; $400M plant cost; $1,200/kg processing fee

REVENUE			Q1_yr4	Q2_y4	Q3_yr4	Q4_yr4	YEAR 4	Q1_yr5	Q2_y5	Q3_yr5	Q4_yr5	YEAR 5	Q1_yr6	Q2_y6	Q3_yr6	Q4_yr6	YEAR 6
kgs processed			1,250	5,000	10,000	25,000	41,250	25,000	25,000	25,000	25,000	100,000	25,000	25,000	25,000	25,000	100,000
kgs processed (total)	100,000	kgs max	1,250	6,250	16,250	41,250	65,000	66,250	91,250	116,250	141,250	415,000	166,250	191,250	216,250	241,250	815,000
Process Fees	1,200	per kg	1,500,000	6,000,000	12,000,000	30,000,000	49,500,000	30,000,000	30,000,000	30,000,000	30,000,000	120,000,000	30,000,000	30,000,000	30,000,000	30,000,000	120,000,000
Storage Fees	8	per kg per yr	2,500	12,500	32,500	82,500	130,000	132,500	182,500	232,500	282,500	830,000	332,500	382,500	432,500	482,500	1,630,000
Total Revenue			**1,502,500**	**6,012,500**	**12,032,500**	**30,082,500**	**49,630,000**	**30,132,500**	**30,182,500**	**30,232,500**	**30,282,500**	**120,830,000**	**30,332,500**	**30,382,500**	**30,432,500**	**30,482,500**	**121,630,000**
Process Cost (direct labor)	30	per kg	37,500	150,000	300,000	750,000	1,237,500	750,000	750,000	750,000	750,000	3,000,000	750,000	750,000	750,000	750,000	3,000,000
Storage Cost	2.00	per kg per yr	625	3,125	8,125	20,625	32,500	33,125	45,625	58,125	70,625	207,500	83,125	95,625	108,125	120,625	407,500
Manufacturing, security and misc.	24,000,000	per year	450,000	1,200,000	2,400,000	6,000,000	10,050,000	6,000,000	6,000,000	6,000,000	6,000,000	24,000,000	6,000,000	6,000,000	6,000,000	6,000,000	24,000,000
TOTAL Cost of Sales			488,125	1,353,125	2,708,125	6,770,625	11,320,000	6,783,125	6,795,625	6,808,125	6,820,625	27,207,500	6,833,125	6,845,625	6,858,125	6,870,625	27,407,500
Gross Profit			1,014,375	4,659,375	9,324,375	23,311,875	38,310,000	23,349,375	23,386,875	23,424,375	23,461,875	93,622,500	23,499,375	23,536,875	23,574,375	23,611,875	94,222,500
Operating Expense																	
SGA			1,250,000	1,250,000	1,250,000	1,250,000	5,000,000	1,250,000	1,250,000	1,250,000	1,250,000	5,000,000	1,250,000	1,250,000	1,250,000	1,250,000	5,000,000
Misc	1%	of SGA	12,500	12,500	12,500	12,500	50,000	12,500	12,500	12,500	12,500	50,000	12,500	12,500	12,500	12,500	50,000
Total Operating Expense			**1,262,500**	**1,262,500**	**1,262,500**	**1,262,500**	**5,050,000**	**1,262,500**	**1,262,500**	**1,262,500**	**1,262,500**	**5,050,000**	**1,262,500**	**1,262,500**	**1,262,500**	**1,262,500**	**5,050,000**
Operating Income/Loss (EBITDA)			**(248,125)**	**3,396,875**	**8,061,875**	**22,049,375**	**33,260,000**	**22,086,875**	**22,124,375**	**22,161,875**	**22,199,375**	**88,572,500**	**22,236,875**	**22,274,375**	**22,311,875**	**22,349,375**	**89,172,500**
Depreciation	16,000,000	per year	4,000,000	4,000,000	4,000,000	4,000,000	16,000,000	4,000,000	4,000,000	4,000,000	4,000,000	16,000,000	4,000,000	4,000,000	4,000,000	4,000,000	16,000,000
Interest expense			3,112,046	3,067,310	3,021,903	2,975,815	12,177,074	2,929,036	2,881,556	2,833,363	2,784,447	11,428,401	2,734,797	2,684,403	2,633,252	2,581,335	10,633,787
Income Tax Expense	35%									**2,111,539**	**5,395,225**	**7,506,764**	**5,425,727**	**5,456,490**	**5,487,518**	**5,518,814**	**21,888,550**
Net Income			**(7,360,171)**	**(3,670,435)**	**1,039,972**	**15,073,560**	**5,082,926**	**15,157,839**	**15,242,819**	**13,216,974**	**10,019,703**	**53,637,335**	**10,076,351**	**10,133,482**	**10,191,105**	**10,249,226**	**40,650,164**
Opening cash			**22,690,579**	**14,845,531**	**7,637,984**	**3,585,436**	**22,690,579**	**1,490,389**	**17,432,841**	**33,412,794**	**47,318,707**	**1,490,389**	**57,978,435**	**68,645,160**	**79,318,622**	**89,998,557**	**57,978,435**
Receivables/collection			-	1,502,500	6,012,500	12,032,500	19,547,500	30,082,500	30,132,500	30,182,500	30,232,500	120,630,000	30,282,500	30,332,500	30,382,500	30,432,500	121,430,000
Total			22,690,579	16,348,031	13,650,484	15,617,936	42,238,079	31,572,889	47,565,341	63,595,294	77,551,207	122,120,389	88,260,935	98,977,660	109,701,122	120,431,057	179,408,435
Dispersements																	
Cost of sales			488,125	1,353,125	2,708,125	6,770,625	11,320,000	6,783,125	6,795,625	6,808,125	6,820,625	27,207,500	6,833,125	6,845,625	6,858,125	6,870,625	27,407,500
Operating expense (including SGA)			1,262,500	1,262,500	1,262,500	1,262,500	5,050,000	1,262,500	1,262,500	1,262,500	1,262,500	5,050,000	1,262,500	1,262,500	1,262,500	1,262,500	5,050,000
Plant Construction Cost	400,000,000		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bond amortization			6,094,423	6,094,423	6,094,423	6,094,423	24,377,690	6,094,423	6,094,423	6,094,423	6,094,423	24,377,690	6,094,423	6,094,423	6,094,423	6,094,423	24,377,690
Income tax			-	-	-	-	-	-	-	2,111,539	5,395,225	7,506,764	5,425,727	5,456,490	5,487,518	5,518,814	21,888,550
Total Dispersments			7,845,048	8,710,048	10,065,048	14,127,548	40,747,690	14,140,048	14,152,548	16,276,586	19,572,772	64,141,954	19,615,775	19,659,038	19,702,566	19,746,362	78,723,740
Ending cash balance			**14,845,531**	**7,637,984**	**3,585,436**	**1,490,389**	**1,490,389**	**17,432,841**	**33,412,794**	**47,318,707**	**57,978,435**	**57,978,435**	**68,645,160**	**79,318,622**	**89,998,557**	**100,684,695**	**100,684,695**
Financed Amount (Bond)	240,000,000																
Payment			6,094,423	6,094,423	6,094,423	6,094,423		6,094,423	6,094,423	6,094,423	6,094,423		6,094,423	6,094,423	6,094,423	6,094,423	
Interest			3,112,046	3,067,310	3,021,903	2,975,815		2,929,036	2,881,556	2,833,363	2,784,447		2,734,797	2,684,403	2,633,252	2,581,335	
Principal			2,982,377	3,027,113	3,072,519	3,118,607		3,165,386	3,212,867	3,261,060	3,309,976		3,359,626	3,410,020	3,461,170	3,513,088	
Balance			204,487,331	201,460,218	198,387,699	195,269,092		192,103,705	188,890,838	185,629,778	182,319,803		178,960,177	175,550,157	172,088,987	168,575,899	

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Economic/Business Case for Pyroprocessing of Spent Nuclear Fuel (SNF)
2,000 ton per year commercial plant

Commercial Plant: 2000 ton per year; $7B capital; $6B plant cost; $1,000 per kg processing fee

Assumptions

Total Capital	$	**7,000,000,000**	
Plant			
Capital Requirement	$	**6,000,000,000**	
Percent Financed		**60%**	
Amount Financed	$	3,600,000,000	
Interest		**6%**	
Bond payment (amortization)	$	370,665,950	per year
Total payment for bond	$	5,559,989,254	
Interest expense yr 4, 5, & 6	$	216,000,000	per year
Length of re-payment schedule		**15**	Years
Depreciation		**25**	Years
Process			
Process Fee	$	**1,000**	per kg
Process Cost (direct labor)	$	**30**	per kg
Manufacturing, security and misc.	$	**50,000,000**	per year
Storage			
Storage Fee	$	**8.00**	per kg per yr
Storage Cost	$	**1.50**	per kg per yr
Percent Processed stored		**100%**	
Processing capacity		**2,000,000**	kgs per year
SG&A at capacity	$	**10,000,000**	per year
Misc		**1%**	of SG&A

Proforma Profit/Loss & Cash Flow

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
kgs processed	-	-	-	516,250	2,000,000	2,000,000
Total kgs processed	-	-	-	540,000	7,065,000	15,065,000
Total Revenue	-	-	-	517,330,000	2,014,130,000	2,030,130,000
Cost of Sales	-	-	-	32,240,000	112,649,375	115,649,375
Gross Profit	**-**	**-**	**-**	**485,090,000**	**1,901,480,625**	**1,914,480,625**
Operating Expense	227,250	616,100	3,333,000	8,837,500	10,100,000	10,100,000
Operating Income/Loss (EBITDA)	**(227,250)**	**(616,100)**	**(3,333,000)**	**476,252,500**	**1,891,380,625**	**1,904,380,625**
Depreciation	-	-	-	240,000,000	240,000,000	240,000,000
Interest Expense	212,598,729	203,206,017	193,236,935	182,656,115	171,426,018	159,506,803
Income Tax Expense	-	-	-	-	357,007,562	526,705,838
Net Income	**(212,825,979)**	**(203,822,117)**	**(196,569,935)**	**53,596,385**	**1,122,947,044**	**978,167,984**
Plant Construction Cost	152,259,492	2,138,855,451	3,708,885,057	-	-	-
Opening Cash Balance	7,000,000,000	6,481,847,903	3,976,710,997	(101,172,415)	(491,617,770)	673,089,938
Ending Cash Balance	6,481,847,903	3,976,710,997	(101,172,415)	(491,617,770)	673,089,938	1,681,099,370

Economic/Business Case for Pyroprocessing of Spent Nuclear Fuel (SNF)
2,000 ton per year commercial plant

Commercial Plant: 2000 ton per year; $7B capital; $6B plant cost; $1,000 per kg processing fee

REVENUE			Q1_yr1	Q2_y1	Q3_yr1	Q4_yr1	YEAR 1	Q1_yr2	Q2_y2	Q3_yr2	Q4_yr2	YEAR 2	Q1_yr3	Q2_y3	Q3_yr3	Q4_yr3	YEAR 3
kgs processed			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
kgs processed (total)	2,000,000	kgs max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Process Fees	1,000	per kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Storage Fees	8	per kg per yr	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Revenue			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Process Cost (direct labor)	30	per kg															
Storage Cost	1.50	per kg per yr															
Plant Personnel Cost																	
TOTAL Cost of Sales			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gross Profit			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Expense																	
SGA			50,000	50,000	50,000	75,000	225,000	125,000	125,000	180,000	180,000	610,000	300,000	750,000	1,000,000	1,250,000	3,300,000
Misc	1%	of SGA	500	500	500	750	2,250	1,250	1,250	1,800	1,800	6,100	3,000	7,500	10,000	12,500	33,000
Total Operating Expense			**50,500**	**50,500**	**50,500**	**75,750**	**227,250**	**126,250**	**126,250**	**181,800**	**181,800**	**616,100**	**303,000**	**757,500**	**1,010,000**	**1,262,500**	**3,333,000**
Operating Income/Loss (EBITDA)			**(50,500)**	**(50,500)**	**(50,500)**	**(75,750)**	**(227,250)**	**(126,250)**	**(126,250)**	**(181,800)**	**(181,800)**	**(616,100)**	**(303,000)**	**(757,500)**	**(1,010,000)**	**(1,262,500)**	**(3,333,000)**
Depreciation																	
Interest Expense			**54,000,000**	**53,438,755**	**52,869,091**	**52,290,882**	**212,598,729**	**51,704,001**	**51,108,316**	**50,503,695**	**49,890,006**	**203,206,017**	**49,267,111**	**48,634,872**	**47,993,150**	**47,341,802**	**193,236,935**
Income Tax Expense																	
Net Income			**(54,050,500)**	**(53,489,255)**	**(52,919,591)**	**(52,366,632)**	**(212,825,979)**	**(51,830,251)**	**(51,234,566)**	**(50,685,495)**	**(50,071,806)**	**(203,822,117)**	**(49,570,111)**	**(49,392,372)**	**(49,003,150)**	**(48,604,302)**	**(196,569,935)**
Opening cash			**7,000,000,000**	**6,906,581,116**	**6,811,210,188**	**6,670,942,230**	**7,000,000,000**	**6,481,847,903**	**6,117,019,047**	**5,732,669,743**	**5,055,458,175**	**6,481,847,903**	**3,976,710,997**	**1,932,946,892**	**669,546,193**	**89,108,662**	**3,976,710,997**
Receivables/collection			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			7,000,000,000	6,906,581,116	6,811,210,188	6,670,942,230	7,000,000,000	6,481,847,903	6,117,019,047	5,732,669,743	5,055,458,175	6,481,847,903	3,976,710,997	1,932,946,892	669,546,193	89,108,662	3,976,710,997
Dispersments																	
Cost of sales			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating expense (including SGA)			50,500	50,500	50,500	75,750	227,250	126,250	126,250	181,800	181,800	616,100	303,000	757,500	1,010,000	1,262,500	3,333,000
Plant Construction Cost	6,000,000,000		1,952,045	3,904,090	48,801,119	97,602,238	152,259,492	273,286,267	292,806,715	585,613,430	987,149,039	2,138,855,451	1,952,044,767	1,171,226,860	488,011,192	97,602,238	3,708,885,057
Bond amoritization			91,416,339	91,416,339	91,416,339	91,416,339	365,665,355	91,416,339	91,416,339	91,416,339	91,416,339	365,665,355	91,416,339	91,416,339	91,416,339	91,416,339	365,665,355
Income tax			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			93,418,884	95,370,928	140,267,958	189,094,327	518,152,097	364,828,856	384,349,304	677,211,569	1,078,747,177	2,505,136,906	2,043,764,106	1,263,400,699	580,437,530	190,281,077	4,077,883,412
Ending cash balance			**6,906,581,116**	**6,811,210,188**	**6,670,942,230**	**6,481,847,903**	**6,481,847,903**	**6,117,019,047**	**5,732,669,743**	**5,055,458,175**	**3,976,710,997**	**3,976,710,997**	**1,932,946,892**	**669,546,193**	**89,108,662**	**(101,172,415)**	**(101,172,415)**
Financed Amount (Bond)	**3,600,000,000**																
Payment			91,416,339	91,416,339	91,416,339	91,416,339		91,416,339	91,416,339	91,416,339	91,416,339		91,416,339	91,416,339	91,416,339	91,416,339	
Interest			54,000,000	53,438,755	52,869,091	52,290,882		51,704,001	51,108,316	50,503,695	49,890,006		49,267,111	48,634,872	47,993,150	47,341,802	
Principal			37,416,339	37,977,584	38,547,248	39,125,456		39,712,338	40,308,023	40,912,644	41,526,333		42,149,228	42,781,467	43,423,189	44,074,536	
Balance			3,562,583,661	3,524,606,077	3,486,058,830	3,446,933,374		3,407,221,035	3,366,913,012	3,326,000,369	3,284,474,035		3,242,324,807	3,199,543,341	3,156,120,152	3,112,045,616	

Economic/Business Case for Pyroprocessing of Spent Nuclear Fuel (SNF)
2,000 ton per year commercial plant

Commercial Plant: 2000 ton per year; $7B capital; $6B plant cost; $1,000 per kg processing fee

REVENUE		Q1_yr4	Q2_y4	Q3_yr4	Q4_yr4	YEAR 4	Q1_yr5	Q2_y5	Q3_yr5	Q4_yr5	YEAR 5	Q1_yr6	Q2_y6	Q3_yr6	Q4_yr6	YEAR 6
kgs processed		1,250	5,000	10,000	500,000	516,250	500,000	500,000	500,000	500,000	2,000,000	500,000	500,000	500,000	500,000	2,000,000
kgs processed (total)	2,000,000 kgs max	1,250	6,250	16,250	516,250	540,000	1,016,250	1,516,250	2,016,250	2,516,250	7,065,000	3,016,250	3,516,250	4,016,250	4,516,250	15,065,000
Process Fees	1,000 per kg	1,250,000	5,000,000	10,000,000	500,000,000	516,250,000	500,000,000	500,000,000	500,000,000	500,000,000	2,000,000,000	500,000,000	500,000,000	500,000,000	500,000,000	2,000,000,000
Storage Fees	8 per kg per yr	2,500	12,500	32,500	1,032,500	1,080,000	2,032,500	3,032,500	4,032,500	5,032,500	14,130,000	6,032,500	7,032,500	8,032,500	9,032,500	30,130,000
Total Revenue		**1,252,500**	**5,012,500**	**10,032,500**	**501,032,500**	**517,330,000**	**502,032,500**	**503,032,500**	**504,032,500**	**505,032,500**	**2,014,130,000**	**506,032,500**	**507,032,500**	**508,032,500**	**509,032,500**	**2,030,130,000**
Process Cost (direct labor)	30 per kg	37,500	150,000	300,000	15,000,000	15,487,500	15,000,000	15,000,000	15,000,000	15,000,000	60,000,000	15,000,000	15,000,000	15,000,000	15,000,000	60,000,000
Storage Cost	1.50 per kg per yr	469	2,344	6,094	193,594	202,500	381,094	568,594	756,094	943,594	2,649,375	1,131,094	1,318,594	1,506,094	1,693,594	5,649,375
Manufacturing, security and misc.	50,000,000 per year	450,000	1,200,000	2,400,000	12,500,000	16,550,000	12,500,000	12,500,000	12,500,000	12,500,000	50,000,000	12,500,000	12,500,000	12,500,000	12,500,000	50,000,000
TOTAL Cost of Sales		487,969	1,352,344	2,706,094	27,693,594	32,240,000	27,881,094	28,068,594	28,256,094	28,443,594	112,649,375	28,631,094	28,818,594	29,006,094	29,193,594	115,649,375
Gross Profit		764,531	3,660,156	7,326,406	473,338,906	485,090,000	474,151,406	474,963,906	475,776,406	476,588,906	1,901,480,625	477,401,406	478,213,906	479,026,406	479,838,906	1,914,480,625
Operating Expense																
SGA		1,250,000	2,500,000	2,500,000	2,500,000	8,750,000	2,500,000	2,500,000	2,500,000	2,500,000	10,000,000	2,500,000	2,500,000	2,500,000	2,500,000	10,000,000
Misc	1% of SGA	12,500	25,000	25,000	25,000	87,500	25,000	25,000	25,000	25,000	100,000	25,000	25,000	25,000	25,000	100,000
Total Operating Expense		**1,262,500**	**2,525,000**	**2,525,000**	**2,525,000**	**8,837,500**	**2,525,000**	**2,525,000**	**2,525,000**	**2,525,000**	**10,100,000**	**2,525,000**	**2,525,000**	**2,525,000**	**2,525,000**	**10,100,000**
Operating Income/Loss (EBITDA)		**(497,969)**	**1,135,156**	**4,801,406**	**470,813,906**	**476,252,500**	**471,626,406**	**472,438,906**	**473,251,406**	**474,063,906**	**1,891,380,625**	**474,876,406**	**475,688,906**	**476,501,406**	**477,313,906**	**1,904,380,625**
Depreciation	240,000,000 per year	60,000,000	60,000,000	60,000,000	60,000,000	240,000,000	60,000,000	60,000,000	60,000,000	60,000,000	240,000,000	60,000,000	60,000,000	60,000,000	60,000,000	240,000,000
Interest expense		46,680,684	46,009,649	45,328,549	44,637,232	182,656,115	43,935,546	43,223,334	42,500,439	41,766,700	171,426,018	41,021,956	40,266,040	39,498,785	38,720,022	159,506,803
Income Tax Expense	35%							**96,940,702**	**129,762,839**	**130,304,022**	**357,007,562**	**130,849,058**	**131,398,003**	**131,950,917**	**132,507,859**	**526,705,838**
Net Income		**(107,178,653)**	**(104,874,493)**	**(100,527,143)**	**366,176,674**	**53,596,385**	**367,690,861**	**272,274,871**	**240,988,129**	**241,993,184**	**1,122,947,044**	**243,005,393**	**244,024,863**	**245,051,704**	**246,086,025**	**978,167,984**
Opening cash		**(101,172,415)**	**(194,339,222)**	**(288,380,405)**	**(380,015,337)**	**(101,172,415)**	**(491,617,770)**	**(112,407,702)**	**170,674,164**	**421,746,393**	**(491,617,770)**	**673,089,938**	**924,700,948**	**1,176,575,512**	**1,428,709,662**	**673,089,938**
Receivables/collection		-	1,252,500	5,012,500	10,032,500	16,297,500	501,032,500	502,032,500	503,032,500	504,032,500	2,010,130,000	505,032,500	506,032,500	507,032,500	508,032,500	2,026,130,000
Total		(101,172,415)	(193,086,722)	(283,367,905)	(369,982,837)	(84,874,915)	9,414,730	389,624,798	673,706,664	925,778,893	1,518,512,230	1,178,122,438	1,430,733,448	1,683,608,012	1,936,742,162	2,699,219,938
Dispersments																
Cost of sales		487,969	1,352,344	2,706,094	27,693,594	32,240,000	27,881,094	28,068,594	28,256,094	28,443,594	112,649,375	28,631,094	28,818,594	29,006,094	29,193,594	115,649,375
Operating expense (including SGA)		1,262,500	2,525,000	2,525,000	2,525,000	8,837,500	2,525,000	2,525,000	2,525,000	2,525,000	10,100,000	2,525,000	2,525,000	2,525,000	2,525,000	10,100,000
Plant Construction Cost	6,000,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bond amoritization		91,416,339	91,416,339	91,416,339	91,416,339	365,665,355	91,416,339	91,416,339	91,416,339	91,416,339	365,665,355	91,416,339	91,416,339	91,416,339	91,416,339	365,665,355
Income tax		-	-	-	-	-	-	96,940,702	129,762,839	130,304,022	357,007,562	130,849,058	131,398,003	131,950,917	132,507,859	526,705,838
Total Dispersments		93,166,807	95,293,682	96,647,432	121,634,932	406,742,855	121,822,432	218,950,634	251,960,271	252,688,955	845,422,292	253,421,490	254,157,936	254,898,350	255,642,792	1,018,120,568
Ending cash balance		**(194,339,222)**	**(288,380,405)**	**(380,015,337)**	**(491,617,770)**	**(491,617,770)**	**(112,407,702)**	**170,674,164**	**421,746,393**	**673,089,938**	**673,089,938**	**924,700,948**	**1,176,575,512**	**1,428,709,662**	**1,681,099,370**	**1,681,099,370**
Financed Amount (Bond)	3,600,000,000															
Payment		91,416,339	91,416,339	91,416,339	91,416,339		91,416,339	91,416,339	91,416,339	91,416,339		91,416,339	91,416,339	91,416,339	91,416,339	
Interest		46,680,684	46,009,649	45,328,549	44,637,232		43,935,546	43,223,334	42,500,439	41,766,700		41,021,956	40,266,040	39,498,785	38,720,022	
Principal		44,735,655	45,406,689	46,087,790	46,779,107		47,480,793	48,193,005	48,915,900	49,649,639		50,394,383	51,150,299	51,917,553	52,696,317	
Balance		3,067,309,961	3,021,903,272	2,975,815,482	2,929,036,376		2,881,555,582	2,833,362,577	2,784,446,677	2,734,797,039		2,684,402,656	2,633,252,357	2,581,334,803	2,528,638,487	