Nuclear Reprocessing
Position Paper

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1 Position

When so-called "spent" nuclear fuel is removed from the reactor at the end of a cycle, more than 90% of the energy of fresh fuel remains.[1] The fuel is considered spent partly because of the formation of "hot spots" disrupt the fuel's burn pattern and reduce the maximum allowable power output of the plant, and partly because the fraction of fissile material in the fuel has dropped below the level required for reactivity. In the United States, this spent fuel is then put into storage while it cools and ultimately goes into a geologic repository (a cave)[2] where its radioactivity will be isolated from future humans and the environment for tens or hundreds of thousands of years.[3] It would seem, therefore, that there must be a better way to manage spent nuclear fuel than burying it in a cave.

Nuclear fuel reprocessing should reduce the energy content of the waste, and therefore reduce energy wasted, while reducing the need to mine fresh uranium. However, there are several important reasons not to reprocess fuel. These reasons include: increased waste, increased cost, and limited value.

1.1 Limited Value

By limited value, we mean that reprocessing nuclear fuel does not greatly reduce the overall fuel consumption. Although more than 90% of the energy of fresh fuel remains in spent fuel, that does not mean that reprocessing fuel nine times will extract all the energy.[4] For one, nuclear fuel can only be reprocessed once,[5] and increases the energy generated from a ton of heavy metal by a mere 25-30%. Of the uranium that's reprocessed, only about 1/3 is actually used again in the fuel cycle.[6] Furthermore, much reprocessed fuel ends up in storage rather than being burned in reactors due to its poorer behavior in the reactor[7,8] compared to fresh uranium fuel.

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[1] José Gutierrez, CEO of Westinghouse Corporation at Nuclear Night, University of Pittsburgh 11/15/2016

[2] No full scale geologic repository has yet been opened anywhere in the world.

[3] For a sense of scale, the earliest cave paintings are some 35,000 years old, as stated by the BBC news on October 8, 2014. More details at http://www.bbc.com/news/science-environment-29415716

[4] Or even extract most of the energy.

[5] Using current technology

[6] As discussed further in the Theory section, under "Technical Details" of the supporting document.

[7] As noted in the introduction of reference [1] the content of ^{236}U in reprocessed MOx does not allow it to react as well as fresh fuel

[8] Reference [3] acknowledges that MOx reactors tend to be more "peaky" than uranium reactors.

1.2 Increased Waste

When we think of recycling, we usually think of reducing waste by allowing a natural resource to be used again. However, nuclear reprocessing is different. In nuclear reprocessing, spent fuel is broken into its constituent parts: fission products, uranium, and plutonium. The fission products, which constitute a small percentage[9] of the total waste are disposed of, and all of the plutonium and some of the uranium are mixed again to form "mixed oxide fuel" or "MOx." The MOx is the reprocessed fuel. Once spent, the MOx fuel must also be disposed of, as well as all of the products that are used in the reprocessing procedure, all of which now contain certain levels of radiation. One of the major considerations in disposing of spent nuclear fuel is removing the decay heat, which takes about 50 years for uranium fuel and 150 years for MOx,[10] during which time the fuel must be kept cool to prevent it from melting and causing at best a mess and at worst a criticality accident.

1.3 Increased Cost

Studies vary greatly in the amount by which they calculate the cost increase due to fuel reprocessing, however Reference [1] says that it is not economical to reprocess fuel until the price of uranium reaches $1000 per kilogram heavy metal (kgHM). For comparison, at the time of Reference [1] was published uranium prices were at $40/kgHM. At the time of this writing[11] the uranium price was listed on Cameco.com at $34.97 per kgHM.[12] Even though fuel cost only represents a small fraction of the total cost of nuclear power generation, the studies cited both in Reference [16] and in Reference [1] show that France would have experienced a 5% or 5.5% increase in overall electricity cost if they had chosen to reprocess all of their fuel, compared to none of it.[13]

1.4 Reprocessing Is a Waste

For the three reasons cited above, the increased waste due to disposal of MOx and greater quantities of low and intermediate level radioactive waste, increased cost of energy for the reactor, and limited value gained by reprocessing, the authors opine that nuclear reprocessing should be done only conservatively, if at all, with reprocessing technology available today. These are substantial reasons not to reprocess, and may be joined by others outside the scope of our research, such as security risks.[14,15]The state of reprocessing today, however, does not mean that reprocessing will always be a waste.

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[9] About 3%, as discussed in the accompanying documentation

[10] As discussed further in the "Waste Disposition" section under "Technical Details" in the attached document.

[11] November 18, 2016

[12] Please see the section titled "Economic Considerations" for more details.

[13] These are both hypothetical cases. France neither reprocesses all of their nuclear fuel nor reprocesses none of it. They make an easy case study because they are the world's leading reprocessors of nuclear fuel. Their energy portfolio consists of approximately 75% nuclear power as noted in the highlights of [9]. This is discussed further in the attached documentation.

[14] Current reprocessing techniques require the separation of plutonium from the uranium. As plutonium is useful for making atomic weapons, it requires additional security.

[15] The attached documentation includes more details, including a substantial section on safety in reprocessing. The authors included information about nuclear safety in reprocessing because they feel that safety is paramount in the nuclear industry. We do not see these safety considerations as increased risk, but prefer to see them as drivers of increased cost. All processes in the nuclear industry require special attention to safety.

2 Introduction to Reprocessing

Nuclear reprocessing is a process for recycling spent nuclear fuel. When nuclear fuel comes out of a reactor, some 3% of its mass is highly radioactive fission products, 95% is ^{238}U, 1% ^{235}U and the remaining 1% is comprised of several plutonium isotopes.[16] Although the majority of the ^{235}U has been "burned" in the reactor, the remaining ^{238}U, which contains the vast majority of the energy of the fuel may still be used as a fertile material and may be mixed with the fissile ^{239}Pu and ^{241}Pu isotopes to form a new fuel. The fuel so created is called "mixed oxide fuel" or "MOx" for short, and has a net effect of increasing the energy extracted from the uranium by some 25-30%.[17,18] Since the radioactive isotopes are removed in the process, reprocessing does not preclude, or even reduce,[19] the need for a repository for high-level waste. It may also result in a greater need for security as the separated plutonium may be useful in making a weapon.

3 Technical Details

3.1 Theory

Uranium oxide (UO_2) fuel is the most common fuel used in commercial nuclear reactors[20], and is comprised of molecules including two isotopes of Uranium: ^{238}U and ^{235}U, where the superscript refers to the number of protons and neutrons in the atom's nucleus. For the purposes of our discussion, ^{235}U differs from ^{238}U only in its stability. ^{235}U is considered "fissile" meaning that it's very likely to split and release energy when struck by a low-speed, low energy neutron. ^{238}U, on the other hand is "fertile," meaning that it becomes fissile ^{239}Pu when it captures a neutron. The natural uranium of the earth is about 99.3% fertile ^{238}U and 0.7% fissile ^{235}U. In order to maintain a chain reaction in most reactors, the content of the ^{235}U must be increased in a process called "enriching."[21]

Only about two-thirds of the power in a nuclear reactor comes from the enriched fuel, and the rest comes from ^{238}U, that after capturing a neutron and emitting two gamma rays becomes fissile ^{239}Pu. Since only about half of the ^{239}Pu created in the reactor ever fissions, the remaining ^{239}Pu is removed with the spent fuel.[22] When fuel is removed from a reactor, it is not removed because all the fuel has undergone fission; it is removed because of the development of hot spots in the fuel, which occur when certain locations within the reactor core become more reactive than others and therefore generate heat more quickly than others. This uneven distribution of heat results in an uneven distribution of power throughout the core. Since the peak temperature is limited by the melting point of the fuel, a widely spread distribution of temperature necessitates a lower average temperature. A lower average temperature causes a lower power output. In order to produce power at an efficient rate, the reactor must be refueled.[23]

About half the ^{239}Pu remains in the fuel when the reactor when the hot spots require that the fuel be removed from the reactor. If the uranium, plutonium, and fission products are separated from one another, and oxides of uranium and plutonium made, the two oxides can be mixed together to form "MOx," or mixed oxide fuel. There are fairly low concentrations of ^{235}U in MOx, so the fissile behavior of the fuel comes instead from the ^{239}Pu. Rather than enrich the fuel to

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[16] Ref. [11], under "Reprocessing" and "Uranium and Plutonium Recycling"

[17] The use of MOx allows a typical pressurized water reactors to burn plutonium with only the relatively minor design change of the fuel arrangement. This can be useful in burning plutonium from decommissioned nuclear weapons as well as reprocessed nuclear fuel, as discussed in [16], [12], and [10], among others.

[18] [8], "Fuel Cycle – Back-End"

[19] According to [16] pp. 3-4; more on this in the Theory section.

[20] According to [3]

[21] The remarkable [3]

[22] [10], Introduction, 3rd paragraph

[23] The thought-provoking [3]

increase the content of fissile ^{235}U, fissile ^{239}Pu is mixed with the spent ^{235}U. Since only 1% of a spent fuel load is a plutonium isotope and the quantity of mixed oxide fuel that's fissile material is 3-4%, there's should only be a 25-33% increase in the total burn per ton of heavy metal. This agrees well with Japan's experience whose fuel burn only increases by 25-30% per tHM.[24]

3.2 Current Reprocessing Technique

The primary technique for reprocessing spent nuclear fuel is a process known as PUREX, which stands for **P**lutonium and **U**ranium **R**ecovery by **Ex**traction. Although there are other processes, most follow the same basic steps: 1. Fuel cooling, 2. fuel dissolution, 3. solvent extraction, 4. product preparation, and 5. waste handling.[25] The first of these steps, fuel cooling, is required to allow the fission products to decay to more stable forms. Immediately after the neutron flux in a core has been stopped, the core still generates some 7% of its initial full power. This power output decays exponentially with time, during which time the fuel is said to cool. Once the fuel has cooled, it must be dissolved in an acid solution. The acid depends on what type of cladding the fuel has, but zirconium-clad fuels are usually dissolved in nitric acid or hydrofluoric acid. Occasionally, an electric current helps speed this process, and then the uranium is dissolved in nitric acid, which forms nitrates of uranium, plutonium and fission products.The third step is the solvent extraction. This step is where the uranium is separated from the fission products. The extraction happens in a tall vessel known as an extraction column. Heavy, aqueous uranium is poured in the top while a light solvent, such as tributyl phosphate is inserted in the bottom. The lighter solvent rises to the top of the extraction column as the aqueous solution falls to the bottom. The solvent has an affinity for the uranium and as the solvent and aqueous solutions mix, the solvent lifts the uranium as it rises to the top. The solvent does not have an affinity for the fission products, allowing them to sink to the bottom. Through a similar process, the solvent and uranium are separated, leaving a deep, yellow liquid of pure uranium. The product is then dried into a powder in an oxygen reducing atmosphere.[26] Wastes are dealt with appropriately.

3.3 Criticality Control

Throughout this process, steps must be taken to ensure a substantial margin of safety to prevent an accidental criticality. Since there are a wide range of fissile products in nuclear reprocessing, including fuel assemblies, fuel rods, sheared fuel, uranium and plutonium oxides, uranium and plutonium metals, among others, it's possible that multiple control parameters are necessary. Since many fissile materials are put into liquid form, a variety of measures must be taken to ensure the safe handling of liquids. One element of criticality control is ensuring that misdirection of liquid fissile material does not occur. Misdirections can occur through operator error or through unexpected pressure differentials between fluids. There also have to be appropriate systems for managing leaks in the fluid systems in order to prevent an accumulation of fissile material in the sump or on the floor. Such accumulations, not accounted for in the design process, can result in an unexpected criticality. Another problem arises when dissolution of the fissile material is incomplete. A criticality may occur as the fissile material accumulates in an unexpected location. There are many drivers of complete dissolution including the acidity and temperature of the solvent, the dissolution time, low acid volume and overloading the fuel. As a result, devices that measure these parameters must be reliable and must regularly be checked for accuracy. [27]

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[24] [8], "Fuel Cycle – Back-End"

[25] [12], pp.13-17

[26] [12], p. 18

[27] [6], sections 5.44-5.57

3.4 Waste Disposition

Reprocessing nuclear fuel does not eliminate or even reduce the need for a storage facility for high level waste, nor does it reduce the need for a permanent geologic repository.[28] Reprocessing creates large quantities low and intermediate level radioactive wastes as well as small quantities of high level radioactive waste. The problem is further complicated by the fact that once the MOx fuel has been spent, it too must be placed in a geologic repository after an extended period of storage to allow its heat generation to subside. MOx fuel generates appreciable levels of heat for some 150 years after removal from the reactor and must be kept cool for that time. Similar cooling of pure uranium fuel is only approximately 50 years.[29]

During reprocessing, the radioactive fission products are removed from the plutonium and uranium. This process concentrates much of the radioactivity of the spent fuel into some 3% of the mass, meaning that this portion of the waste is highly radioactive. In order to contain the radioactive material, the waste is melted with a borosilicate glass powder at some 1100°C, forming large cylinders of glass and fission products. At the La Hague reprocessing plant in France, the cylinders are 1.3 m long and .43 m in diameter, and each canister holds the high level waste for approximately 1.3 tHM (tons heavy metal) of reprocessed spent fuel.[30]

Just as with the disposal of fuel in the direct disposal method, the high level waste must be kept cool to remove the continued heat generated by the radioactive material. This is usually accomplished by either forced or natural air convection, but this air must then be filtered to ensure that no radioactive material enters the environment.[31] The cooling continues for 40-50 years, until the heat generation rate is approximately 0.1% of what it was at the time of fuel removal from the reactor.[32]

It takes about 300,000 years for the radioactivity generated by spent to reach the same level as the radioactivity of uranium ore. However, the high level waste generated by reprocessing will reach natural uranium ore radioactivity levels in only about 9000 years, or about 33 times faster.[33]

As discussed in the Technique section above, the hydrofluoric acid or the nitric acid will become low-level radioactive waste[34] as the neutron sources dissolved in the acids irradiate the water. Likewise, the solvent may also become irradiated and therefore must be dealt with as a low-level or very-low-level waste. The disposal of these wastes from La Hauge do not cause significant damage to the environment and are calculated to cause perhaps 3000 cancer deaths in 100,000 years.[35]

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[28] [16] notes on pp. 3 and 4 that there are five common miscalculations common in analyzing the waste generated by reprocessing. They are as follows: 1. exclusion of decommissioning and clean-up wastes stemming from the post-operational period of reprocessing plants; 2. exclusion of radioactive discharges to the environment from reprocessing–their retention and conditioning would greatly increase solid waste volumes; 3. A focus on high-level waste and long-lived intermediate-level waste, leaving aside the large volumes of low level waste and very low level wastes generated by reprocessing; 4.comparison of the volumes of spent fuel assemblies packaged for direct disposal with those of unpackaged wastes from reprocessing, which overlooks for instance the fact that packaging reprocessing waste is expected to increase its volume by a factor of 3 to 7; and 5. failure to include the significantly larger final disposal volumes required for spent MOx fuel, because of its high heat generation, unless it is stored on the surface for some 150 years instead of the 50 years for low-enriched uranium spent fuel.

[29] [16], p. 4 as cited in the previous footnote as well.

[30] [7], pp. 4-5

[31] [7], p. 5

[32] [14], "Managing High Level Waste"

[33] [14], "Recycled Used Fuel"

[34] [12], pp. 13-17

[35] [16], p. 4

4 Economic Considerations

4.1 The Initial Investment

Early nuclear reprocessing techniques were developed for the manufacture of fissile isotopes of plutonium, which are not naturally occurring and are useful in the manufacture of a fission atomic weapons. Fissile ^{235}U irradiates ^{238}U making fissile ^{239}Pu in a reactor and then the isotopes of uranium and plutonium are separated so that the plutonium can make a bomb.[36] When nuclear power generation began in 1957 with the Shippingport reactor in Shippingport, PA, cheap access to uranium became a commercial necessity. Throughout the late 1960s and 1970s, public opinion of nuclear power generation was favorable and the price of natural uranium was expected to rise dramatically.[37] In order to combat the expected high price of uranium, two methods were developed to increase the power output per ton of uranium mined. The first was breeder reactors, which are reactors that create more fissile material than they consume, and the second was nuclear reprocessing. This led to the development of MOx fuel, which could take the plutonium produced in a nuclear reactor and use it as the fissile material to burn more ^{238}U.

After the accidents at Chernobyl and Three Mile Island, public opinion turned against nuclear as a source of energy generation, and the number of reactors being built fell far short of the projections. As a result, the price of Uranium never rose as expected, and countries such as the United States abandoned their nuclear reprocessing plants.[38] In countries such as France and Japan, where energy independence is of paramount importance and natural resources are scarce, reprocessing took hold in order to generate the maximum power per ton of imported Uranium.

4.2 The Price of Reprocessed Fuel

Nearly all analyses performed on the question show that reprocessing significantly increases the cost of nuclear fuel, however it has no effect on the capital costs of power generation. Since fuel cost in nuclear represents a much smaller fraction of the total cost of generation than it does in conventional power generation, an increase in fuel cost does not affect the price of electrical power as much as in convention power generation. Since France has the largest reprocessing operations in the world and derives a large fraction[39] of their power generation from nuclear sources, their experience reflect the difference in cost between using reprocessed fuel and direct disposal. Research shows that if France were to reprocess all of their fuel, they would have had a 5% or 5.5% increase in electricity price compared to direct disposal.[40] Measurements of the back end costs vary dramatically, due partly to differences in accounting[41] and the fact that no geologic repository has been established for spent nuclear fuel. Since no geologic repository has been established, the actual cost of such a facility has only theoretical estimates, and no empirical data.[42] Reference [1] notes that the break-even price for nuclear fuel would need to reach $1000 per kgHM in order for reprocessing fuel to be economically viable and notes that the price of nuclear fuel was $40 per kgHM at the time of their writing. Today, the price of uranium has reached $34.97 per kgHM.[43] Although prices of commodities are historically volatile, the authors do not expect a

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[36] Many sources including [12], [16], and [1].

[37] Many sources, especially [16], pp. 6.

[38] [12], p.5 and [16], p. 6

[39] About 75%, as stated earlier.

[40] This was found in two separate studies. As noted in [1], footnote 2, and again in [16], p. 8.

[41] For instance the French power company EDF assigns a 0 value to their plutonium holdings, and some countries may even assign a negative value to their plutonium, as mentioned in [16], pp.8-10.

[42] As discussed in [1]

[43] The price applies to November 4, 2016 and is listed $18.75 per pound U_3O_8. Assuming average atomic mass of Uranium is 238 AMU and the average mass of Oxygen is 16 AMU, the U_3O_8 is 84.8% heavy metal by mass. Assuming 2.2 lbs/kg, the calculated price is $34.97. To get an updated price at the time of your reading, please visit https://www.cameco.com/invest/markets/uranium-price and multiply the listed price by 1.887 to convert from

sudden rise in the price of Uranium[44] without a sudden increase in the demand for nuclear power, which they do not anticipate.

5 Case Study: France

France is the world's largest and most experienced reprocessor of spent nuclear fuel and has been reprocessing fuel since 1958.[45] One of the main reasons France started fuel reprocessing, aside from attempting not to waste uranium, was to provide high grade plutonium for nuclear weapons and for use as a neutron source in certain designs of fast breeder reactors.[46] When the French government passed legislation requiring fuel reprocessing, fast breeder reactors were expected to come on-line in the next few years, however fast breeders requiring plutonium were never built.[47]. As other types of fast breeder reactors proved unreliable, the the French government redoubled their reprocessing efforts and built two new reprocessing lines at La Hague, along with LWRs that used MOx as fuel with plutonium from reprocessing.[48] This solution was insufficient, and the stockpiles of plutonium continued to increase. [49] As explained above in "Economic Considerations," fuel reprocessing is incredibly costly and therefore places a financial burden on the reprocessing plant's owner. France was no exception to this, even in an environment that decreased the financial burden. Unlike the in United States, the French government is centrally planned, and therefore could put a value of zero in the accounts of stocks of reprocessed uranium and separated plutonium.[50] In an attempt to overcome the financial burden that Frances centrally planned government could not offset, France began to sell their their reprocessing technologies to other countries including China,[51] but this strategy failed to completely offset the excess cost.

Another significant issue France is encountering stems from the fact that vitrified high level waste is created in large amounts by spent fuel reprocessing as described in the section titled "Waste Disposition," above. Radioactivity from two dump sites used exclusively to store reprocessing waste in France is leaking into the groundwater and contaminating it. The first case of this was at the CSM dumpsite near La Hauge, which is one of the largest dumpsites in the world.[52] Originally, the dumpsite was deigned to contain only low level waste, but it has been found that it now contains high level waste, and the radioactivity leakage is getting consistently worse because the contaminated water is found to have seven times the radioactivity safety limit of 100 Bq/L.[53] A newer dumpsite was built in the Champagne region of France with state of the art technology to prevent radioactivity leakage: however, this dumpsite also began to leak tritium and small amounts of radioactivity to the environment when the dumpsite was not licensed for any leakage.[54] The leakage is believed to be a result of fractures in the concrete cells by water migration, and France has not yet found a way to prevent the problem.[55]

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dollars/pound to dollars per kgHM.

[44] At least, that's what our crystal ball says. Do you doubt that?

[45] [16], p. 2

[46] [2], p.2

[47] [16], p. 8

[48] [16], p. 41

[49] [2], pp. 11-12

[50] [16], pp. 26 includes historical levels of plutonium stockpiles in France.

[51] [2], p. 12.

[52] [2], p. 5 under the heading "The French Nuclear Waste Crisis"

[53] [2], p. 6. The 100 Bq/L is a European standard radiation level. More worrying still, radiation levels approaching 9000 Bq/L had been found in the aquifer below the CSM site.

[54] [2], p. 6

[55] [2], p. 6

6 The Future of Reprocessing

As briefly discussed, the future of reprocessing of nuclear materials has much to do with the current amount of minable Uranium deposits left on our planet. Although many estimates were made in the earlier years of the nuclear industry on availability and quantity of material, we now know much more precisely the amount of Uranium still to be had. Not only were the quantities of mineral sources considerably greater than previously conceived, but the world's known uranium resources increased by at least one-quarter in the last decade due to increased mineral exploration.[56] With this in mind, and noting that there are vast amounts of uranium stored in areas that we have not yet exposed,[57,58] many countries are comparing current economic trends in concordance with relative supply of materials available to make their decision on how to invest in reprocessing in the coming decades. One such country entertaining nuclear expansion opportunities of the future is China. As it expands its fleet of nuclear power plants, China faces an important decision: whether to make large capital investments in facilities to reprocess spent nuclear fuel, or to continue to store nuclear fuel. The Belfer Center for Science and International Affairs notes that even the lowest bound estimates on the capital and operating costs of reprocessing the spent fuel over a 40-year period would exceed dry storage in the same time frame by approximately $9 billion.[59] In Russia, although futuristic reprocessing techniques are being entertained, a massive gains in uranium mine production are expected. In June 2015 Rosgeologia signed several agreements to expedite mineral exploration in Russia, including one with Rosatom.[60] Having found giant reserves of uranium throughout their country, Russia may be moving away from nuclear reprocessing. Currently, in the USA, the same trend seems to be unfolding. Along with increasing political and government involvement through forms of Congress and the NRC, the current price of minable uranium fuel makes it just too economically unfeasible to consider large scale reprocessing in this country. Although countries including the US have signed agreements to begin reducing the plutonium in storage in upcoming years,[61] it seems that it would take a huge, and costly, transition to meet these goals at this point in time, and much of it will be dealt with in later generations as the industry matures.

Although some nuclear reprocessing proponents argue that today, with uranium enrichment technology more easily available, reprocessing no longer represents an efficient route toward nuclear weapons,[62] many disagree, and believe that if there is a future in reprocessing. One of the main concerns in the future is that reprocessing continues to increase the global stockpiling of plutonium,[63] as plutonium itself is extracted to be reused as nuclear reactor fuel and this also in turn becomes stockpiled as more fuel is mined. These growing stockpiles could make it easier for terrorism and provide material for countries to continue to increase their nuclear weapon stockpiles.[64] All in all, when considering the future of the nuclear reprocessing industry, one must consider the price and availability of new fuel materials, the present and future storage situation inferred, and the political and geographical implications behind the reprocessing in order to make an educated decision on its feasibility.

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[56] [17], in the highlights

[57] There are large quantities of uranium stored in different layers of the Earths crust or even in solution throughout the worlds seawater

[58] [17], under heading "Geological Knowledge"

[59] [4], p. 1

[60] [15], introductory section

[61] [5], under "The Future of Reprocessing"

[62] [13], in the document's Abstract.

[63] [18], 2nd paragraph

[64] [18], paragraphs 4 and 5.

7 Conclusion

Nuclear reprocessing is an exceptionally well-understood and mature practice. It allows nations like France and Japan an increased level of energy independence and is broadly a safe process. It does not have a substantial economic foundation, but has been safely and effectively performed since the early days of nuclear power. One of the technologies necessary for reprocessing fuel, MOx, has had the added advantage of allowing reactors to burn nuclear weapons, improving lives instead of destroying them. However, nuclear reprocessing in its current form is not very effective at doing what it purports to do, and therefore must be considered carefully before being used.

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