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**Reattori in esercizio e in
costruzione per la produzione di
energia elettronucleare**

Survey internazionale

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N. 4S/2023 - Commissione Ricerca e
Reattori Innovativi
Area Nucleare*

Il Ciclo Chiuso del Combustibile Nucleare: via i rifiuti e energia per secoli

Prof. Agostino Mathis

Prof. Agostino Mathis – Via Bertero, 61 – 00156 ROMA (Italy)
Cell. 338-1901198; E-mail: amathisit@yahoo.com

Pursuing the unlimited energy dream – history of the Integral Fast Reactor

By Guest Author • February 8, 2012



Note:

Len Koch, whose participation in nuclear energy research started in the 1940s, wrote the below open letter to colleagues who are striving to restore interest in the progress that they made in research and development of the Integral Fast Reactor during the period from 1954-1994 the year that President Clinton and Hazel O'Leary, his Secretary of Energy zeroed out all nuclear energy research funding and killed the IFR program.

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I continue to be confused and concerned about the apparent “IFR SRATEGY” to minimize (or ignore) the established history of this concept. **It was CONCEIVED in the 1940s by Enrico Fermi and his colleagues. I learned the details in late 1948 when Dr. Fermi presented a Seminar at which he described his vision of nuclear power for the future, with the potential of providing a new energy source for the foreseeable future.**

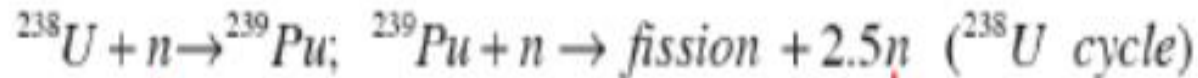
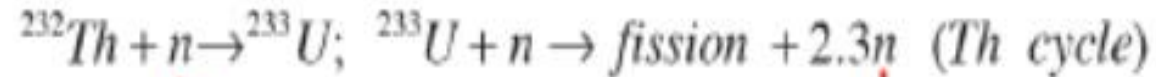
He acknowledged that it had already been demonstrated that the energy contained **in the fissionable rare U-235 isotope could be extracted, but its scarcity essentially eliminated it as a long term energy source.** He then described his vision of nuclear power which involved **extracting the energy from the abundant “non-fissionable” U-238 isotope (the 99.3% of natural uranium).**

He discussed what needed to be done to establish the feasibility of this concept. **He explained that a two step process was required because “non-fissionable U-238” would first be converted to “fissionable Pu-239” and then the Pu would be fissioned.** He had concluded that this could be achieved **in the fast reactor they had conceived, and in fact such a reactor could produce more plutonium than it would consume. IT COULD “BREED” PLUTONIUM!** Fermi cautioned that this concept would also require that it would be necessary to recycle this fuel on a continuing basis to consume the U-238, that it was not a “once thru” option.

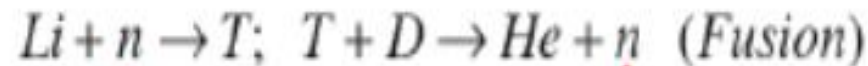
He then described an experiment being developed to demonstrate the feasibility of this breeding concept. Needless to say, I was enthralled to hear his description of the experiment I WAS WORKING ON! It became known as **the Experimental Breeder Reactor (later it became EBR-I to differentiate it from EBR-II).** This reactor, fueled with U-235 as a substitute for Plutonium (because of availability of technology and material), **established the feasibility of the “fast breeder concept”.**

From: Carlo Rubbia «**A future for Thorium Power?**» - Thorium Energy Conference 2013 – ThEC13, in Geneva, October 27 to 31, 2013.

- Particularly interesting and so far largely unexploited are other fission reactions in which a natural element is first bred into a fissionable one:



- These sources of energy available from exploitable ores are comparable to the one for the D-T fusion reaction (ITER)



From: Carlo Rubbia «**A future for Thorium Power?**» - Thorium Energy Conference 2013 – ThEC13, in Geneva, October 27 to 31, 2013.

<i>Resource</i>	<i>Type</i>	<i>Yearly consumption (1999) ZJ</i>	<i>Resources ZJ</i>	<i>Consumed until 1999 (ZJ)</i>
Oil	Conventional	0.13	12.08	4.85
	Unconventional	0.01	20.35	0.29
	Total oil	0.14	32.42	5.14
Natural gas	Conventional	0.08	16.56	2.35
	Unconventional	0.00	33.23	0.03
	Total gas	0.08	49.79	2.38
Coal	Total coal	0.09	199.67	5.99
Total Fossils		0.31	281.88	13.51
Uranium	Thermal reactors	0.04	5.41 (2'000, sw)	
	Breeder	0	324 (120'000, sw)	
Thorium			1'300'000	

sw: including sea water

1 ZJ (Zeta]oule)= 10^3 EJ (Exa]oule)= 10^{21} J ([oule)

I nuovi reattori a neutroni veloci per la fissione nucleare

Detti anche brevemente «reattori veloci», sono in grado di **utilizzare il 100% dell'enorme potenziale energetico, senza ulteriori attività estrattive, già presente nei grandi depositi di uranio impoverito** (uranio naturale privato di parte dell'Uranio 235), **di combustibile irradiato e di plutonio**, oggi disponibili dopo settant'anni di attività nucleare complessiva, **sia militare che civile.**

Potranno poi ovviamente utilizzare il contenuto **delle riserve di Uranio e Torio disponibili sul Pianeta**, e potrebbero così fornire energia per secoli per tutta l'Umanità.

Così anche **i rifiuti radioattivi, con i reattori a neutroni veloci, potranno essere limitati ai soli prodotti di fissione** con basso tempo di dimezzamento, e comunque **meno radioattivi rispetto all'Uranio e al Torio originari estratti: l'intero sforzo, quindi, potrebbe ridurre alla fine anche la radioattività del Pianeta!**

*Sono passati ottant'anni dalle affermazioni di **Fermi** sugli **Integral Fast Reactor**, ed ora, dopo **migliaia di anni di funzionamento di reattori civili e militari**, abbiamo anche **immensi depositi di combustibile irraggiato** disponibili per alimentarli.*



From: https://www.weplanet.org/_files/ugd/dccfdc_cd3102ec02be4b35b810c531c4d472d5.pdf

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ABOUT US

RePlanet is a network of grassroots charitable organisations driven by science-based solutions to climate change, biodiversity collapse and the need to eliminate poverty.

As a young global environmental organization, the start-up of our activities has been made possible by membership fees and donations, as well as very welcome contributions from the Rodel Foundation, Quadrature Climate Foundation, The Dreamery Foundation and the Anthropocene Institute. Our funding has come exclusively from charitable sources. As part of our commitment to transparency all donors of over €5,000 are listed here. We have not received any funding from industry or party political sources.

EU Transparency Register 179551845769-58

www.replanet.ngo

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All current **nuclear power reactors used in Europe** – with the exception of the gascooled reactors in the UK and the heavy water reactors in Romania – are **light-water reactors using enriched uranium as their fuel**.

While these have a long history of safe use, and have provided prodigious quantities of clean electricity for decades, **they utilise less than 1% of the actual energy potential in the natural uranium used to make their fuel**. Irradiated fuel assemblies removed from reactors are thus considered ‘nuclear waste’, as are depleted uranium ‘tails’ left over from the enrichment process (see below).

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While **this nuclear ‘waste’ is not a serious environmental or health threat** – it occupies trivial volumes compared to waste produced by other industries, and does not harm anyone if properly shielded and safeguarded – it does provide **a political challenge**, and is among **the most oft-cited reasons for continued opposition** to carbon-free nuclear power.

Deep geological disposal strategies – while entirely feasible technically and economically – add to the sense that nuclear power is somehow inherently unsafe and **will leave a toxic legacy for unborn generations** many millennia into the future.

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It does not have to be this way. **Repurposing and reducing this legacy using a waste-to-energy approach would have wide political appeal and be environmentally beneficial as a fully efficient way to use uranium, without the need for additional uranium mining, to support the ongoing increase of nuclear needed to tackle the climate emergency. While nuclear energy needs less material extraction than fossil fuels or solar energy, mining of any kind has a local environmental impact.**

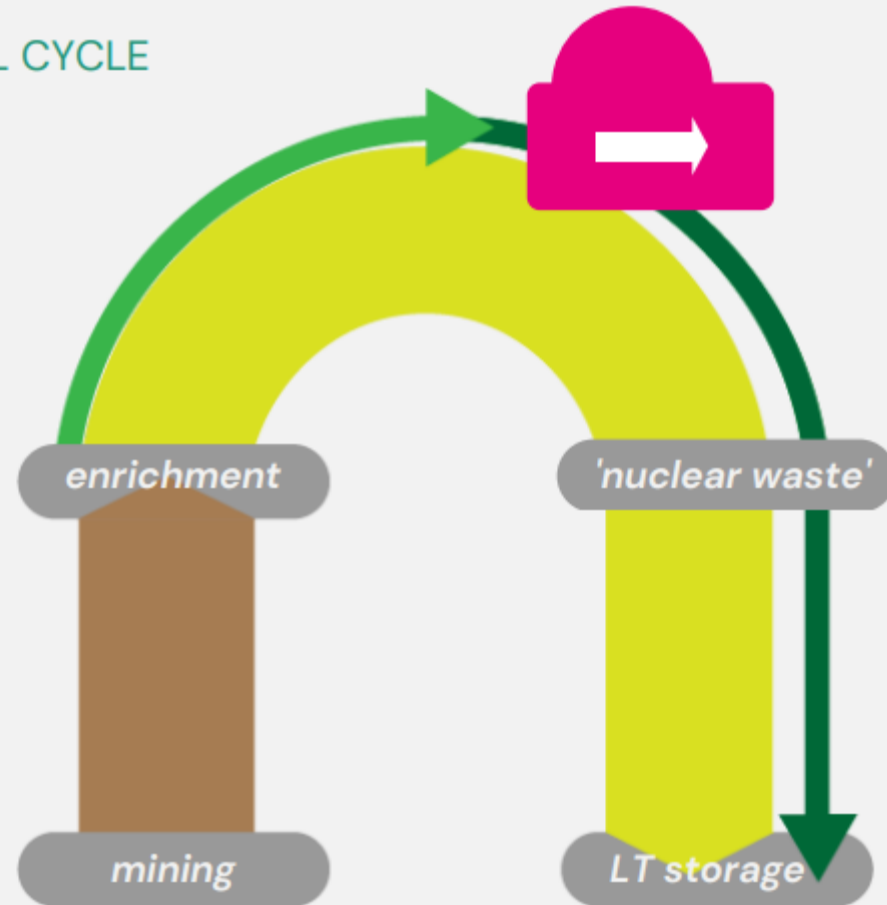
Increasing the energy use of nuclear fuels would reduce or even eliminate the need for mining of fresh uranium. Climate and environmental groups should therefore support fast reactors with the design potential not just to produce carbon-free power, but to eliminate existing stockpiles of long-lived nuclear waste by employing modular, passively safe and meltdown-proof designs.

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STANDARD REACTOR "ONCE THROUGH" FUEL CYCLE

The open nuclear fuel cycle as it is today: uranium is mined, 1% of it is split in a reactor to generate electricity, and the other 99% becomes various forms of "nuclear waste" to be disposed of. (Arrow width indicates relative mass flow size)



- **less than 1%** of mined uranium is fissioned
- fissile material is consumed and not replenished
- spent fuel is not reprocessed and needs long duration storage
- **16 tons of natural uranium** needed for every **1 TWh of electricity** generated

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Uranium enriched to lower levels, **around 5%**, is sufficient to run **light-water reactors** to generate electricity. However, this means that **most of the remaining uranium in their fuel, primarily U-238 plus un-fissioned U-235, is left over at the end in highly radioactive fuel assemblies and in the ‘depleted uranium’** from which most of the U-235 has been separated [4].

The used fuel assemblies contain a mix of mostly **short-lived ‘fission products’** such as **caesium-137** and **strontium-90**, along with **long-lived ‘actinides’** such as **plutonium, curium, americium and neptunium**, as well as the leftover uranium, and remain **significantly radioactive for millennia** (though at increasingly weak levels) unless the long-lived materials can be removed and refashioned into fuel.

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Unlike thermal reactors, which exploit the fact that U-235 is far more likely to fission when hit with slowed down ‘thermal’ neutrons, **fast reactors do not use a ‘moderator’** to slow down neutrons in the fission chain reaction. **Fast reactors are designed to run using fresh, fast neutrons directly, as soon as they are released by a fission event.**

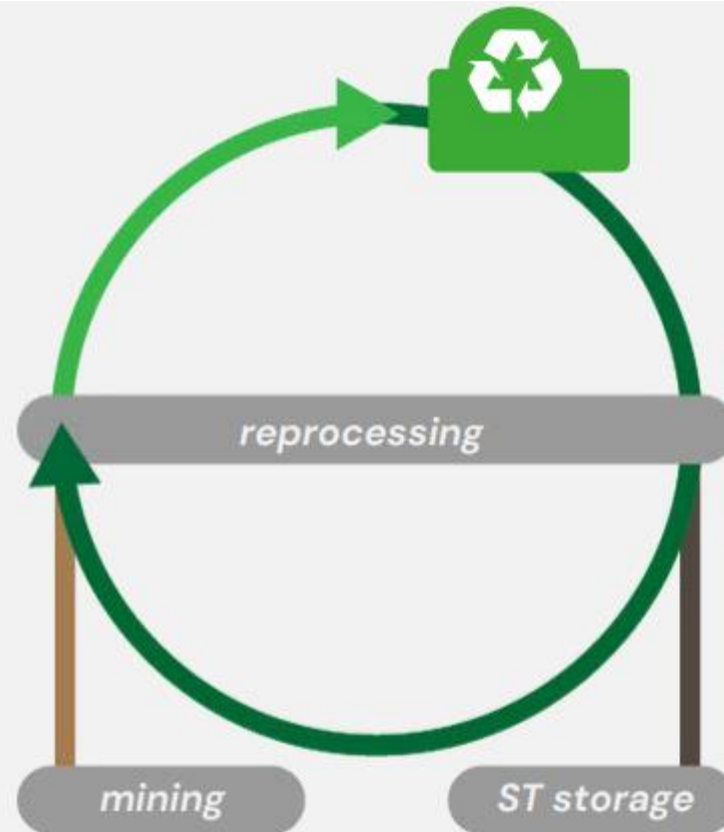
Fast neutrons are far less likely to cause fission – making it harder to achieve a chain reaction – but **they are more likely to cause fission events that yield greater numbers of neutrons, which are then available to transmute ‘fertile’ materials like U-238 into fissionable fuels like plutonium.** This is known as ‘breeding’ fissile fuels from fertile materials.

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FAST BREEDER REACTOR CIRCULAR FUEL CYCLE

The closed nuclear fuel cycle as it was envisioned by the inventors of nuclear power nearly a century ago: all the mined uranium (or thorium) is used up to generate electricity in a closed cycle of irradiation, splitting, breeding, and reprocessing of nuclear materials, leaving nothing to waste. (Arrow width indicates relative mass flow size)



- more than **99% of mined uranium is fissioned**
- fissile material is created as much as is consumed
- only useless fission products are sent to disposal
- **0.1 tons of natural uranium** needed for every **1 TWh of electricity** generated

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Plutonium is a key fuel for fast reactors because **it tends to yield more neutrons** when fissioning than uranium.

Plutonium-239 is a fissile isotope that does not occur naturally on Earth, and which was originally generated by transmutation of U-238 in military nuclear reactors optimised for plutonium production, and isolated in order to be used in nuclear bombs.

Light-water reactors also get about a third of their heat from the generating and fissioning of Pu-239, but fast reactors – albeit through multiple recycling and refabrication cycles of fuel – are much more efficient fuel ‘breeders’ and are thus able to utilize essentially all their uranium this way.

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Fast reactors will also be able to use all the actinides left over in spent nuclear fuel. These actinides are what make spent fuel radioactive for very long periods of time because **they have long half-lives**, even though they are **primarily alpha emitters** and are thus not a significant concern in terms of any likely effects on future people.

However, if they are removed from fuel and burned in fast reactors, **the radioactivity of the remaining waste – which will then be composed mostly of fission products with short half-lives – will decline to the original uranium ore levels within as little as 200–300 years, making surface storage feasible** and reducing and simplifying, if not removing altogether, the need for deep geological disposal with complex design considerations taking into account million-year timescales.

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HOW MUCH FUEL IS THERE?

Answering this question involves a quantification of all the stockpiles of nuclear material currently held in Europe. These statistics are not easy to access and have been compiled here from a number of sources, some more up to date than others. There are also assumptions in this calculation, which are described below. Ideally, the outputs should be considered as answering an order-of-magnitude question rather than viewed as exact numbers. We see them as most useful as a strategic guide to energy system decisions currently being taken to achieve climate goals.

Country	Fuel type	Amount (tonnes/tHM ⁶)
France ⁶	Mined natural uranium Uranium in spent fuel (incl. MOX) Depleted uranium (DU)	29,900 tHM 46,700 tHM 310,000 tHM
United Kingdom ⁷	Plutonium Uranium (DU/low enriched/natural) Spent fuel	112 tHM 99,000 tHM 6,100 tHM
Netherlands ⁸	Depleted uranium	48,000 tonnes
Germany ⁹	Depleted uranium	13,000 tonnes
Finland	Spent fuel	2,500 tonnes
Spain ¹⁰	Spent fuel	5,710 tonnes
Sweden ¹¹	Spent fuel	6,756 tonnes
	Total nuclear heavy metals in Europe	567,778 tonnes or tHM

tHM: tonnes of Heavy Metals

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In the table above we present the approximate inventory data, considering **heavy metals which are either fertile or fissile as interchangeable.**

Thus, **depleted uranium (DU), uranium in spent fuel and plutonium can all be considered in a single tonnage total, since all can be used as fuel in fast reactors.** (In reality, fissile plutonium-239 and U-235 will be needed separately to start up fast reactors and begin the breeding process of creating more fissile materials from U-238.)

We find that Europe (meaning the UK and the EU combined) has a total inventory of nearly 580,000 tonnes of potential nuclear fuel for fast reactors.

This compares with **about 470,000 [11] tonnes of uranium in depleted uranium** (mostly stored as 700,000 metric tonnes of UF₆, or uranium hexafluoride) in the **United States**, and **a worldwide stock of about 1.6 million [12] tonnes of DU only** (not including spent fuel), according to the World Nuclear Association. This global stock of DU increases by about 50,000 tonnes per year due to new uranium enrichment and fuel fabrication.

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Calculating how much energy could be released by using the entire stock of fissionable and fertile materials consists of summing the fission energy yields of all the components of that stock. Fortunately, this procedure can be simplified by recognising that **the specific fission energy yield of all nuclear fuels**, including thorium, uranium, plutonium and other actinides, is around **22 terawatt-hours (TWh) of heat energy per tonne** [15].

Thus, the **580,000-tonne stock of heavy metals in Europe** could yield **around $580,000 \times 22 =$ over 12 million TWh of heat energy**. This heat can be converted to electricity with **an efficiency of at least 33%**, resulting in a total potential of **at least 4 million TWh of electricity yield locked inside the stock**.

The EU and the UK currently consume about 3,000 TWh of electricity annually, so Europe's stock of nuclear heavy metal 'waste' could therefore be used **to power all of Europe at current rates of consumption for over 1,000 years** under a high-end estimate of perfectly effective fuel recycling. At the low end, assuming more realistic partially effective recycling, the stock would last over 600 years.

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We are not, however, proposing 100% of generation from fast reactors. If we instead assume, for illustrative purposes, **that renewables (plus whatever is the size of the light-water reactor fleet at the time) make up 80% of generation on an annualised basis [16], this means fast reactors need only to generate 20% of power, allowing us to multiply the available energy in current fuel stockpiles by a factor of five.**

Fast reactors could therefore make up the difference for a fully carbon-free electricity grid for over a thousand years, even at tripled rates of electricity use in our high estimate, if they work in support of renewables.

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From a **global perspective**, current inventories of **1.6 million tonnes of fertile and fissile heavy metal** would, using the above calculation and the lower estimate, add up to **over 11 million terawatt-hours (TWh) of electrical energy**.

Current world electricity consumption is about 23,000 TWh annually, so we already have enough fuel for **500 years of global clean electricity** at current rates of use **with 100% nuclear power**, and much more with a more realistic energy generation mix.

If we include **uranium still in the ground in economically proven reserves**, this gives another **6.2 million tonnes**, enough for **about 2,000 years of clean power globally** at our lower estimate.

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There are **even larger amounts of uranium in unconventional resources, such as dissolved in seawater or as trace amounts in common rock [17].**

And uranium is not the only potential nuclear fuel. We can also use **the thorium fuel cycle**, as pioneered in India and proposed for a new generation of thorium reactors.

Thorium-232 breeds into fissile uranium-233 by neutron capture, making this another fuel source. **Thorium is three to four times more abundant than uranium on Earth [18], making it a source of power which could support human civilisation for tens of thousands of years, merely using conventional reserves.**

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The up to 100-fold greater fuel efficiency of breeder reactors means that even very poor sources of nuclear fuel, such as seawater or common rock, are rendered economically viable. **Remarkably, even the discarded ashes from coal power plants contain uranium and thorium traces, with an energy content ten times that of the original coal before it was burned.** This illustrates **the power of fast breeder reactor technology: we could even utilise coal ash for future clean nuclear power.** Unconventional sources of uranium and thorium contain not millions, but **billions of tonnes of uranium and thorium**, multiplying by a further factor of one thousand the already long time periods above. **In other words, if uranium or thorium are used in breeder reactors with a closed fuel cycle, the supply of nuclear fuel for fission is essentially limitless on any timescale meaningful to human civilisation.**

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Note that the calculations above concern **physics not economics**. This is a back-of-the-envelope exercise simply to understand the energy resource implied by known nuclear fuels.

We do not yet know what forms of reactor design will perform best economically, or to what extent nuclear will be able to out-compete alternative sources of clean energy.

However, **nuclear does have inherent physical advantages**. In the fast reactor system described above, there will be no need for uranium mining for centuries to come.

The existing stockpile of 'waste' will be repurposed as fuel, and the remnant will be so short-lived that deep geological disposal will be very much simplified, if not unnecessary altogether.

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Nuclear is also very power dense, so uses land much more efficiently than any competing power source. For RePlanet, as an environmental group concerned about land use, this is a major consideration. **Nuclear is at least 50 times more land-efficient than solar PV and uses 800 times less land than onshore wind [19].** If we wish to see a large-scale restoration of natural ecosystems over more than 50% of the Earth's surface, alongside a flourishing high-energy human civilisation, nuclear will therefore be an essential component. Nuclear also has a similar or better materials use intensity compared to current renewables – another important environmental consideration – and **materials use intensity decreases further with a closed fuel cycle [20].** Furthermore, **nuclear power has one of the lowest environmental impacts of any energy source, in terms of other life-cycle indicators such as eutrophication, ecotoxicity and human health [21, 22].**

Ed anche i “prodotti di fissione” si possono neutralizzare

Come abbiamo visto, nei reattori veloci si possono consumare, producendo energia, tutti gli “elementi pesanti”. **Restano i “prodotti di fissione”, con brevi vite medie, che in qualche centinaio di anni ridurranno la loro attività a meno di quella del corrispondente minerale di uranio estratto dalle miniere** (riducendo così anche la radioattività del Pianeta...), **ed eviteranno così anche la necessità di depositi geologici.**

Tuttavia, **per annullare praticamente del tutto il problema dei “prodotti di fissione”, si può oggi anche fare assegnamento sulle tecniche della fusion nucleare**, le quali, anche se non sono ancora in grado di produrre energia con un bilancio positivo, **producono potenti neutroni in grande quantità.**

Guardate nelle seguenti tavole che fa la **SHINE Technologies.**

New value from fusion neutrons

7 June 2023

Despite major breakthroughs, cost-effective energy from fusion reactors remains elusive. Nonetheless, commercial fusion is already here to stay. Greg Piefer, founder and CEO of SHINE Technologies, tells NEI about the business case.



Above: Neutron radiography is used in the inspection of gas turbine blade cooling channels

Is fusion commercial? When it comes to the production of electrons, right now the answer is an emphatic 'no', but for neutrons it is a different story. "Fusion is commercial," says Greg Piefer, founder and CEO of SHINE Technologies who was inspired by the realisation that while cost-effective fusion power was a perhaps a step too far, fusion nonetheless offered considerable commercial opportunities. "Fusion is going to generate some of the hottest densest states of matter ever created by humans in one of



Isotope separation capabilities are expected to yield value in nuclear waste management



Once commissioned, SHINE's US facility in Janesville, Wisconsin, will be the biggest isotope production plant in the world, capable of generating about 20 million doses of molybdenum 99 per year



Greg Piefer, founder and CEO of SHINE Technologies, has a vision to develop value from fusion right away

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<**“Fusion is going to generate some of the hottest densest states of matter ever created by humans** in one of the worst radiation environments created by humans and then we are going to put some of the most fragile, exotic and expensive to manufacture materials in proximity to all that.

I didn’t see a way of making fusion energy cost effectively. For me the lesson learned was that maybe **there are things that can be done with fusion that can add value to the world** and they may allow you to learn how to do fusion more cost effectively going forward.>

<Instead of energy, Piefer settled on **an application which focuses on using the neutrons from fusion reactions**. And, it turns out those neutrons on a per reaction basis can be far more valuable than the energy produced. “There was a market that I knew we had enough output to be able to address right away. That market is **neutron radiography**,” he says.

In contrast to X rays, **neutrons** tend to scatter more off less dense materials but can penetrate materials like steel or lead fairly easily and so **they provide a complimentary imaging process known as neutron radiography.**>

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<Their current fusion device is an ion beam type in which a particle beam of deuterium ions is accelerated to about 320 KeV and fired into a gaseous target to generate a scatter of neutrons.

Piefer explains: “Our first-generation technology I would characterise as a particle beam-solid target. The current generation is particle beam-gas target fusion device. **Our DT fusion devices don’t generate a lot of power, maybe 150 W, but that’s not nothing and it’s a pretty bright neutron source at that.** At full capacity we should be able to generate **tens of millions of dollars of revenue.** That gives you an idea of just how much more valuable the neutrons are versus the electricity.”>

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<We needed to increase the fusion output enough to get from phase one to phase two so that **we could start to alter small amounts of matter – transmutation**. In particular, we're looking at **turning elements that aren't very valuable into elements that are extremely valuable**," says Piefer.>

<For example, we can take **uranium that we buy for \$6 a gramme** and turn it into **Molybdenum-99 which is worth about \$150 million per gramme**. The value of that material is that it ultimately decays into **Technetium-99m**, which can be injected into the human body to illuminate disease. There are actually **about 30 different diagnostic tests performed with that single isotope**."

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“It is the next scale in our fusion journey, but what we want to do first and foremost is **recycle nuclear waste**” he says, adding: “To recycle nuclear waste, you take the uranium oxide, dissolve it and **separate out the highly valuable materials including plutonium, but also precious metals and other isotopes that you could sell**. All these things look exactly like what we’re doing in the isotope plant, just at a larger scale.”

Piefer suggests that **such a process can remove about 96% of the waste stream that can be recycled and used as new fuel**. However, it also ties in with a fusion-derived neutron flux to generate commercial value.

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“Fusion comes in on the very back end of this. **About 96% of the uranium waste stream is recyclable or valuable** but there’s a very small amount, **about 0.1%**, of the waste stream that consists **of really long-lived isotopes** that have no value and currently have no disposal path,” Peifer explains. “Just like we use transmutation in phase two to turn low value materials into high value materials, **we believe we can use fusion to take those long-lived isotopes and make them short-lived isotopes** and thus solve the problem of long-lived nuclear waste as well.

I find that to be **incredibly valuable from a sociological perspective**, because one of the biggest challenges nuclear energy faces is the waste problem.”>

SHINE Technologies has announced a long-term supply agreement with radiopharmaceutical company **Nucleus RadioPharma** to provide **Lutetium-177** to **Nucleus RadioPharma's radioligand therapy** offerings for targeted radiopharmaceutical treatments for neuroendocrine tumours and prostate cancer.

SHINE describes its **Cassiopeia facility**, which opened earlier this year, as **the largest Lutetium-177 production facility in North America**. Radioisotope production is part of SHINE's four-phase plan to develop fusion technology competencies and eventually develop commercially viable nuclear fusion. Both companies are based in Wisconsin.

From WNA-wnn_20 Nov. 2023

<https://www.ans.org/news/article-5500/shine-looks-to-license-used-fuel-recycling-facility/>

Orano and SHINE Technologies to co-operate on used fuel recycling

The Orano group and US-based SHINE Technologies have signed a Memorandum of Understanding (MOU) with a view to developing a pilot plant in the USA for recycling used nuclear fuel from light water reactors. The material recovered from the used fuel will be able to be re-used to fabricate new nuclear fuel for advanced and existing reactor designs. Certain radioactive isotopes extracted during the process could also be used for other industrial and medical applications.

Staff Writer March 6, 2024

E così, la tecnologia della Fusione Nucleare, comunque vada, potrà intanto moltiplicare di ordini di grandezza lo sfruttamento dei materiali utili per la Fissione Nucleare (Uranio e Torio), annullandone anche il problema dei rifiuti radioattivi !!!

Si tenga presente che su questa linea **l'Italia non è assente**, perché **presso il Centro del Brasimone dell'ENEA** da qualche anno è in corso lo sviluppo di un apparato denominato **SORGENTINA**, che comincia ad operare come quelli della SHINE Technologies:

<https://www.media.enea.it/comunicati-e-news/archivio-anni/anno-2022/salute-radiofarmaci-su-nature-approccioinnovativo-enea-per-sviluppare-produzione-nazionale.html>

The case of Russian Federation (1/3)

Electricity production was **1121 TWh in 2019**, of which 514 TWh (46%) was from natural gas, **209 TWh (19%) from nuclear**, 197 TWh (18%) from hydro, 188 TWh (17%) from coal, 8.6 TWh (<1%) from oil, 2.9 TWh from bio-fuels & waste, and 1.3 TWh from solar.

Rosatom's current long-term strategy up to 2050 involves moving to **inherently safe nuclear plants using fast reactors with a closed fuel cycle**, especially under the ***Proryv* (Breakthrough)** project.

It envisages **nuclear providing 45-50% of electricity** at that time, with the share rising to **70-80% by the end of the century**. **The ultimate aim of the closed fuel cycle is to eliminate the production of radioactive waste from power generation.**

The case of Russian Federation (2/3)

Transition to Fast Reactors

Innovative nuclear power for Russia is based on **full recycling of fuel**, balancing **thermal and fast reactors**, so that **100 GWe of total capacity requires only about 100 tonnes of input per year**, from **enrichment tails, natural uranium and thorium**, with **minor actinides being burned**.

About only **100 t/yr of fission product wastes** go to a geological repository.

At **Beloyarsk** the **BN-600 reactor** has operated successfully **since 1980**.

The **BN-800** reactor at Beloyarsk has operated **since 2014**, as a demonstration unit for the **BN-1200**.

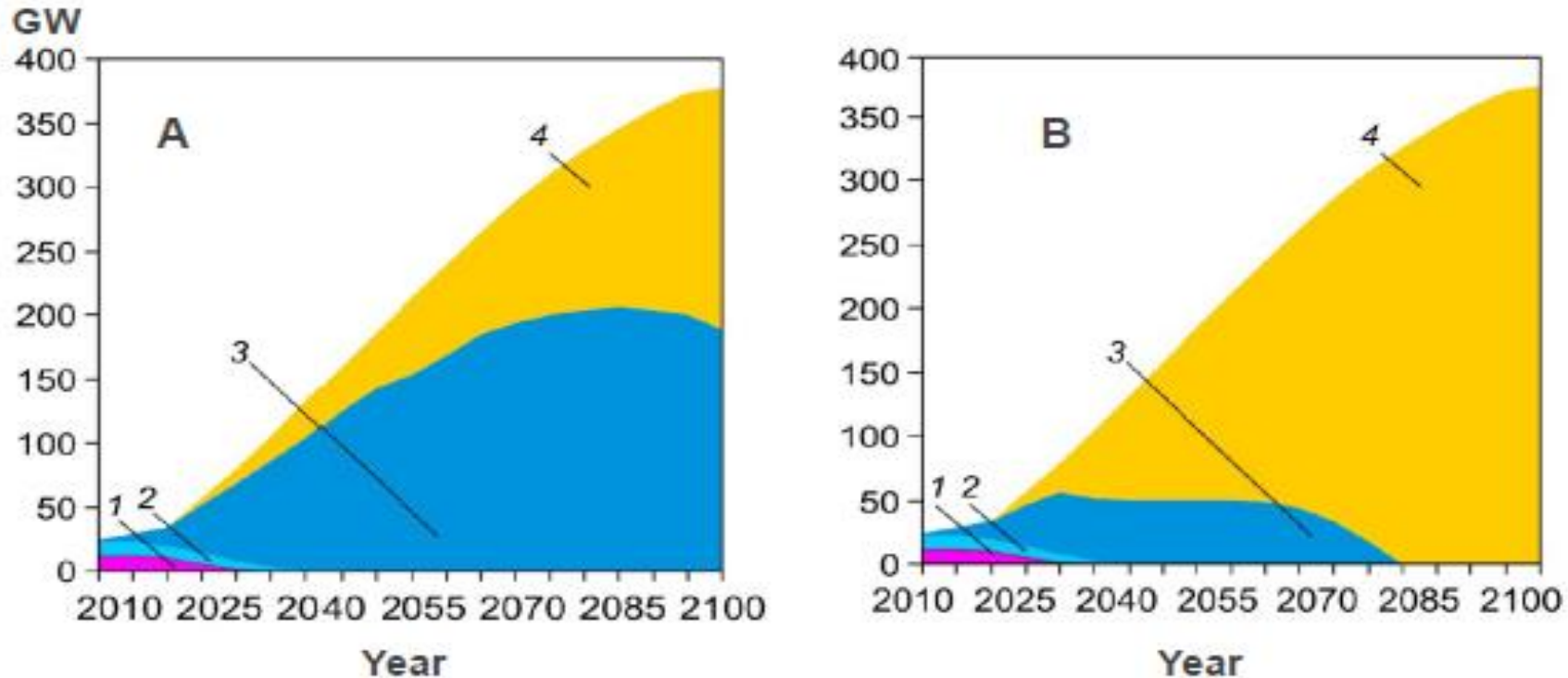
From: <http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx>

The case of Russian Federation (3/3)

Development of nuclear energy



Fast reactors: driver for Russian nuclear industry development



NPP capacity subject to Fast Reactors being commissioned using Pu (A) and using Pu+U (B):
1 – RBMK; 2 – VVER (Gen II); 3 – VVER (Gen III+); 4 – FR

Russia's BN-800 unit enters commercial operation

01 November 2016

Unit 4 of the Beloyarsk nuclear power plant in Russia has started commercial operation, state nuclear corporation Rosatom announced today. The BN-800 fast neutron reactor started operating at 100% power for the first time on 17 August.



Beloyarsk 4 (Image: Rosatom)

A view of the BN-800 fast neutron reactor plant



From: <http://euanmearns.com/the-bn-800-fast-reactor-a-milestone-on-a-long-road/>

Russia awards contract to build BREST reactor

05 December 2019

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Siberian Chemical Combine (SCC) has awarded a RUB26.3 billion (USD412 million) contract to Titan-2 for the construction and installation works for the BREST-OD-300 lead-cooled fast neutron reactor facility at its site in Seversk, Russia. Siberian Chemical Plant is a subsidiary of TVEL, the nuclear fuel manufacturing subsidiary of Russian state nuclear corporation Rosatom.



How the PDEC complex will look (Image: TVEL)

BREST-OD-300 is part of Russian state nuclear corporation Rosatom's *Proryv*, or Breakthrough, project to enable a closed nuclear fuel cycle. The 300 MWe unit will be the main facility of the Pilot Demonstration Energy Complex (PDEC), which is in the process of construction at the Siberian Chemical Plant site. In addition, the PDEC demonstrate an on-site closed nuclear fuel cycle with a facility for the fabrication/re-fabrication of mixed uranium-plutonium nitride nuclear fuel, as well as a used fuel reprocessing facility.

...continua...

From: <https://www.euronuclear.org/news/rosatom-starts-brest-300-construction/>

...continua...

The **Brest-OD-300** is a **Generation IV lead-cooled fast reactor** (LFR) and it is part of a **pilot demonstration energy complex** in the framework of the [“Proryv” project](#).

This project is aimed at achieving a **new quality of nuclear energy, development, creation and industrial implementation of closed nuclear fuel cycle** (CNFC) based on fast reactors that will lead to the development of **a large-scale nuclear power industry**.

According to the planned timeline, **the BREST-OD-300 reactor should start operating in 2026**.

A **fuel production facility will be built by 2023** and the construction of an **irradiated fuel reprocessing module** is scheduled **to start by 2024**.

Read the [TVEL Press Release](#).

Second tier of containment installed for BREST-OD-300

19 April 2024



The 184-tonnes tier - the second of three - has been lifted into place for the lead-cooled fast neutron reactor under construction at the Siberian Chemical Combine site in Russia.



(Image: SCC)

The steel reactor base plate and lower tier of the containment were installed at the turn of the year, the third enlarged unit is planned to be installed in the reactor shaft in December 2024. The final height of the structure will be 17 metres.

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...continua...

The BREST-OD-300 fast reactor is part of Rosatom's *Proryv*, or *Breakthrough*, project to enable a closed nuclear fuel cycle.

The 300 MWe unit will be the main facility of the Pilot Demonstration Energy Complex at the Siberian Chemical Combine site. The complex will demonstrate an on-site closed nuclear fuel cycle with a facility for the fabrication/re-fabrication of mixed uranium-plutonium nitride nuclear fuel, as well as a used fuel reprocessing facility.

The target for the BREST-OD-300 reactor is to start operation in 2026.

...continua... 45

...continua...

According to the World Nuclear Association information paper on fast neutron reactors, **"the BREST fast neutron reactor, of 700 MWt, 300 MWe has lead as the primary coolant, at 540°C, and supercritical steam generators.**

It is **inherently safe** and uses a mixed uranium and plutonium nitride fuel ... **no weapons-grade plutonium can be produced, since there is no uranium blanket - all the breeding occurs in the core** ... fuel cycle is quoted at 5-6 years with partial refuelling at about 10 months. The initial cores can comprise plutonium and used fuel - hence loaded with fission products, and radiologically 'hot'. Subsequently, any surplus plutonium, which is not in pure form, can be used as the cores of new reactors. **Used fuel can be recycled indefinitely, with onsite facilities. The nitride fuel has been successfully tested in the BN-600 reactor to a burn-up of 7.4%".**

Initial operation of the demonstration unit will be focused on performance and after 10 years or so it will be commercially oriented. **The plan has been that if it is successful as a 300 MWe unit, a 1200 MWe (2800 MWt) version will follow - the BR-1200.**

L'industria nucleare dell'Occidente «ha perso il passo»... (1/3)

Come si vede, **la Russia è di gran lunga all'avanguardia nello sviluppo e nella gestione del "ciclo chiuso" del nucleare basato sui reattori a neutroni veloci**, ma **la Cina segue a ruota con l'aiuto della Russia**, ed in proprio **col reattore a sali fusi in grado di usare come combustibile anche il Torio** (quattro volte più abbondante dell'Uranio sul Pianeta).

Questi nuovi reattori cinesi a sali fusi potranno svolgere un ruolo fondamentale per fornire energia elettronucleare, ed anche termica, nelle aree interne della Cina, ed anche lungo tutta la Via della Seta nell'Asia Centrale (Belt and Road Initiative).

L'industria nucleare dell'Occidente «ha perso il passo»... (2/3)

Occorre tener presente che, a seguito dell'evento di Fukushima, la Cina sospese per prudenza la costruzione di molti reattori refrigerati ad acqua previsti lungo i grandi fiumi della Cina centrale: **i nuovi reattori a sali fusi, invece, con temperature molto più alte, possono essere raffreddati ad aria**, senza perdere molto nel rendimento.

E' sintomatico il fatto che **questo "crash program" della Cina è partito ai tempi di Fukushima, basandosi su tutto il know-how del Molten-Salt Reactor Experiment realizzato negli anni '60 all'Oak Ridge National Laboratory**, e ceduto gratuitamente dagli Americani (eravamo ai tempi del Presidente Obama... Trump se ne pentì, ma era troppo tardi).

L'industria nucleare dell'Occidente «ha perso il passo»... (3/3)

Negli **Stati Uniti**, sessant'anni fa all'avanguardia anche nei reattori veloci con **gli EBR-I e EBR-II**, il filone venne a più riprese abbandonato al passaggio di **Presidenti antinucleari** (Carter, Clinton), anche se il know-how è rimasto presso la General Electric, e dovrebbe ora essere rivalorizzato dalla **TerraPower di Bill Gates per il suo Natrium**.

In **Europa**, oltre ai reattori veloci inglesi abbandonati, avevamo **la lunga e impegnativa filiera veloce francese di Phénix e Superphénix** (a cui aveva largamente contribuito **anche l'industria nucleare italiana**), ma, sotto la pressione degli ambientalisti antinucleari, alcuni Presidenti francesi **affossarono anche questa**. **Solo recentemente il Presidente Macron ha rilanciato «alla grande» il nucleare francese, in tutte le sue alternative.**

Ma ora nuovi spunti positivi vi sono anche in Europa

Come visto, **l'Unione Europea non ha più la capacità di avviare e gestire la filiera dei reattori veloci per chiudere il ciclo nucleare, ma nuove iniziative stanno sorgendo sia presso aziende private che a cura della Commissione.**

Questa capacità, che deve essere operativa a tutti i livelli (**istituzionali, politici, scientifici e industriali**) sarà la condizione indispensabile per **aumentare di due ordini di grandezza lo sfruttamento di Uranio e Torio, e per ridurre drasticamente la quantità e la durata dei residui radioattivi.**

Come noto, anche in Italia abbiamo nuove importanti iniziative, **in particolare nel settore dei reattori veloci in grado di chiudere il ciclo nucleare, come la seguente.**



Stefano Buono, ceo di Newcleo

⚡ CORPORATE ITALIA

Leggi dopo

Nucleare pulito, la startup italiana Newcleo chiude la prima fase di autorizzazione per costruire i suoi reattori in Francia

di Marco Capponi

🕒 tempo di lettura 1 min

Passo importante verso la costruzione dei reattori di ultima generazione in territorio transalpino, dove la startup fondata da Stefano Buono ha pianificato investimenti per 3 miliardi di euro

From: <https://www.milanofinanza.it/news/nucleare-pulito-la-startup-italiana-newcleo-chiude-la-prima-fase-di-autorizzazione-per-costruire-i-suoi-202407021634022037>