ENERGY FROM THORIUM

Energy from Thorium—an Attainable "Solution"!

Real Energy Security and Independence is at Hand, but Requires Action

Energy From Thorium Foundation
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Thorium-Energy Policy

An initiative to balance and ensure U.S. energy security.

Introduction: Pro-Growth Energy Abundance is the Only Way to Ensure America's Economic Future

Generating Economic Growth and Jobs Requires Abundant, Affordable Energy.

America's prosperity, security and economic future activity require a sober and honest recognition of all energy options. Any country's standard of living is dependent upon its access to reliable cost-effective energy. The exceptionally high standard of living in the United States exists in significant part because of its historic development of new energy technologies, the freedom to do so, and the resulting abundant, affordable energy. The higher a country's energy costs are, the higher the hurdles to energy production, the more its standard of living is stifled.

Without energy economies can't produce and grow. To remain vibrant, competitive, and engaged economically, we need lots of energy, really cheap. While we're presently in the midst of a domestic carbon-based energy revolution with great potential (shale oil and gas fracking), entrenched resistance to carbon-energy resources hampers and interferes with that potential at every turn. The resistance won't end. The U.S. economy will always require abundant energy to progress. The more affordable energy it produces, and the more *mixed* its energy sources and technologies, the more it can accelerate progress while balancing environmental concerns and managing the risks and political uncertainties of fossil energy.

> "[Even if California] could obtain 50% of its electricity from wind, solar, geothermal and biomass; grow its fleet of zero-emission vehicles to 17 million from 50,000 today; increase fuel efficiency to 78 miles per gallon, and expand rooftop solar generation by 800%, [i]t would still miss its [2050 emissions] target by a green mile.
>
> … [M]odern environmental policies are less about solving problems than they are about indulging faith-based dreams."
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> — (WSJ, November 12, 2013)

Bold and meaningful energy development—that actually solves problems—is not a choice, but a necessity given the emerging competitive world demand for energy supply and the many hidden costs associated with fossil fuel production, protection, supply disruptions, and market upheavals.

This energy-solutions paper is presented by the Energy from Thorium Foundation to educate, inform, and persuade Americans of the brilliant energy future within the country's grasp.

If the U.S. is to Survive as an Economic Leader, Broad-Based Energy Resources are Essential

Fundamentally reforming regulatory limitations governing the nuclear-energy development cycle, and other changes advocated here, are wise public policy for a very simple reason: they will end dependence on fossil fuels and foreign energy suppliers and permit dramatic and affordable economic growth, which benefits everyone. This is the case for unleashing a powerful, proven, but presently untapped energy source, and bringing jobs back to the U.S.

The U.S. must "Put Growth First" if it is to survive and thrive in today's highly competitive global economy. Business investment in the U.S. is the root of economic growth for this great country. Economic growth is essential to prosperity and, in turn, government revenue streams. To grow economically, we must have an assured, abundant, and affordable energy supply. The U.S. must lead the world in developing energy technologies that deliver such energy, or risk economic dependency, stagnation, and geopolitical irrelevance.

Given our energy history, and our recent struggles to realize a true transition away from fossil fuels, it's nothing short of remarkable that our country isn't *racing* to take full advantage of Thorium, a known, but untapped, energy resource capable of delivering vast amounts of energy at very little cost (comparatively) while simultaneously eliminating the vast majority of energy-related problems.

This is about *actually attaining* energy independence, sustainability, and an end to the risk of man-caused global warming or climate change, and doing so within a very reasonable time frame! We sit atop an alternative energy source that promises to revolutionize nuclear power. America's future can truly be very bright if we have the courage to let American ingenuity run its course. For between $5 to $10 billion thorium energy technology can be commercialized, a small fraction of the many hidden costs we have been paying for decades to "access" oil.

Let's examine a *colossal* energy breakthrough that's cheap, abundant, non-polluting, and non-carbon. Americans need to realize that we actually have an "energy silver bullet" here that is being left for dead.

The existence and availability of this dramatic energy source and solution is not widely known, despite plenty of scientific and other literature, and the efforts of a dedicated and diverse group of advocates—and it needs to move front and center. By enabling our nation's leaders and the public to understand the significance of Thorium as an *opportunity*, we can prevent it from slipping through our fingers (again) for all the wrong reasons.

Why Thorium Energy will Change Everything — A Compelling Story

Thorium is an energy resource most people have never heard of. Yet, embracing and developing Thorium means a "new world" of unprecedented progress and prosperity through abundant, affordable energy. This energy source is nothing short of revolutionary. Thorium can ensure a sustainable fuel cycle for millions of years, which gives new meaning to the concept of an inexhaustible energy supply. It's good to know our energy supply could outlast humanity, especially given Earth's population projections (over nine billion anticipated by 2050).

Sadly, we're not producing energy from thorium today, even though we've had the knowledge since the 1960s.

Because this energy source is a genuine and real "giant leap forward" in energy, policy and law makers must learn about it and start advocating its development. With Thorium, the U.S. can jump the energy curve to security, safety, and affordability—without it economic stagnation and energy dependency will worsen. Any energy policy must embrace and address the very real and viable energy source presented here: Thorium.

An Overview of Thorium Science

Thorium
90
Th
232.04

Thorium (atomic number 90) is one of the actinoid[1] elements identified in the Periodic Table. Thorium is approximately three times more abundant in the earth's crust than Uranium, and has long been known as a highly viable energy source. One hundred percent of Natural Thorium is the isotope Th-232, which itself is not fissile; but, it can absorb a neutron and will transform into Uranium-233. Uranium-233 is fissile—i.e., it will fission upon absorption of a neutron, yielding an enormous amount of energy.

Unlike Uranium, Thorium is abundant, cheap, and easy to find (it's as common as lead). Thorium has an extremely high *energy density*. While coal is plentiful, and comparatively cheap, it's not a *dense* energy source. The following shocking Thorium facts illustrate this: it takes just one pound of Thorium to produce the same amount of energy produced by *1,000 tons* of coal—which is a factor of 2 Million, and difficult to fully comprehend. Consider a car that can travel 400 miles on a tank of gas. If its tank is filled with an "inferior gasoline" that has less energy than regular gasoline by a factor of 2 Million, the car couldn't travel 11 inches on that tank of gas. Such "inferior gasoline" would be utterly worthless as an energy source. Similarly, if the same gas tank had only a mere tablespoon of a "superior gasoline," with more energy than regular gasoline by a factor of 2 million, the car could drive for nearly 200,000 miles on that tablespoon. Because of its energy density, Thorium is exceptionally cost effective by comparison to hydrocarbons and so-called "renewables."

As impressive as Thorium is, realizing its full potential as a nuclear fuel requires the right type of reactor to consume the fuel. The liquid fluoride thorium reactor (LFTR) is a type of Molten-Salt reactor (MSR), which is a very different reactor architecture than today's solid-fuel-in-water reactors (Light Water Reactors or LWRs—the vast majority of the world's 434 commercial reactors in operation today are LWR powered by solid uranium fuel). The LFTR uses the cheap and abundant element Thorium as its primary feedstock. These liquid-fueled reactors have many advantages, but perhaps the biggest is this: they almost completely consume their fuel source, and therefore leave very little to no waste behind. When Uranium is consumed in a LWR, only about 3% of it is actually fissioned to create energy. But, when Thorium is consumed in a LFTR, nearly 100% of it is fissioned to create energy. LFTRs produce a mass of waste products approximately 300 times less than what uranium LWR reactors produce.[1]

It takes just one pound of Thorium to produce the same amount of energy produced by *1,000 tons* of coal.

Molten-Salt reactors were first developed in the United States in the 1950s and were proven capable of successful operation for power generation in the 1960s. The underlying science (work at Oak Ridge National Labs—a government-run research laboratory) is sound, and there's every reason to believe its renewed development can successfully continue in the 21st Century.

While there are several other reactor types suitable for producing energy from Thorium, LFTR is the best choice for a number of reasons and offers compelling advantages. Thorium can be consumed in a solid-fuel reactor, but the shortcomings of solid-fuel reactors remain. To consume Thorium efficiently the fuel must be "reprocessed," and reprocessing the fuel of a solid-fuel reactor requires extracting the fuel (which involves a shutdown), converting it to liquid form (presumably by melting it or some other

[1] Any of a series of radioactive elements with atomic numbers 89 through 103.

chemical process), performing the reprocessing (various chemical processes), fabricating the new solid fuel (e.g., pellets with a cladding), returning the fuel into the reactor, and re-starting the reactor. This is a very time-consuming and expensive process.

A *significant* advantage of the LFTR is that its fuel is already in a form suitable for reprocessing (dissolved in the molten salt). LFTRs permit the extraction of a stream of the liquid core material *while the reactor is operating*, which can then be easily processed, and returned to the core. There are other usable liquid forms as well, but molten salts offer dramatic advantages like high specific heat and high boiling temperature at atmospheric pressure.

Benefits and Advantages of Thorium Energy

Energy from Thorium doesn't just treat symptoms or provide a temporary or fashionable energy fix; it actually *solves* long-term energy-supply, environmental, and economic problems. Nobel Prize winning physicist Carlo Rubbia, a former director of the CERN laboratory, described thorium as having "absolute pre-eminence … as a source of energy" at the Thorium Energy Conference 2013, held on the CERN campus in Geneva.[2]

Thorium is dense enough and reliable enough to provide the energy the world needs—it has a higher energy content than any other fuel. One modest estimate of the amount of energy that can be produced from Earth's thorium supply is 4,600 times the amount of energy we can get from all of the world's oil, natural gas, and coal combined.[3] An individual's lifetime energy supply can be held in the palm of their hand. "Sustainable abundance"™ is the result of widespread implementation of the Thorium energy cycle. Energy abundance—affordably—is what Thorium offers. Electric energy from Thorium can be produced at a fraction of the cost of producing energy from other sources:

Thorium	$.02/KWH	Natural Gas	$.068/KWH
Coal	$.04/KWH	Conventional Nuclear	$.035/KWH

The U.S. has a 1000-year supply of high-grade Thorium—that we know of at just a few mines, much of which is recoverable from Lemhi Pass, Idaho. But, a broad-based effort to locate Thorium deposits hasn't occurred, leaving vast quantities unidentified. Thorium exists in most soils and in Earth's crust at an average concentration of 10 parts per million. While this may seem low, because Thorium's energy density is greater than one million times that of any fossil fuel it is very economical to extract Thorium from soils and the Earth's crust generally. Thus, we have an essentially inexhaustible supply of this element and potentially billions of years of Thorium energy available. This means lots of energy for everybody.

LFTR Provides Very High Safety Levels — LFTRs are "walk-away safe." Their safety attributes come from the fundamental properties of molten salts and the structure of the reactor itself, not from emergency-activated "engineered" systems that can themselves fail. The properties of molten salt give LFTRs a remarkable safety feature: during an emergency the molten salt (with the fuel dissolve in it) can be drained into a passively cooled and passively safe configuration where fission stops and decay heat is passively absorbed into the surrounding medium, something that can't be done with a solid-fueled reactor.

LFTR uses a passive "walk-away safe" core that requires no human intervention. If, for some reason, the fuel salt within a LFTR core begins to overheat, its thermal expansion reduces reactivity, and thus the temperature begins to drop—a property called a "negative temperature coefficient." The molten salt in a LFTR core has a *very strong* negative temperature coefficient. Also, if the fuel salt overheats significantly for any reason, freeze plugs thaw and open, allowing the core salt to drain into tanks where fission stops and decay heat is passively dissipated. These features render the system walk-away safe because they are passive, and rely on basic physics, not machines (active powered systems) or humans, to keep the reaction under control. The system is completely self-regulating, and doesn't require computer systems or dozens of attentive operators to carefully watch every aspect of its operation. This drastically improves LFTR safety and dramatically reduces the cost of ensuring operational safety.

LFTRs don't use water as a coolant and so don't hold fluid under pressure that can rapidly change state from liquid to gas (fluoride salts remain liquid at temperatures up to 1400° C or 2500° F. This means a LFTR operates at atmospheric pressure, doesn't require a large containment building—and the higher temperatures mean LFTR plants don't *need* to be located near water (though it remains advantageous). Its design can be much smaller than today's light-water nuclear reactors, and there is no chance of a gas or vapor radioactive cloud forming if an accident occurs. Essentially, LFTRs are incapable of meltdowns, and can't blow up. An added benefit of these reactor design features is that they need almost no maintenance or maintenance-related reactor shutdowns.

This is nuclear power, but *without the waste and without the risk*. The traditional objections to, controversy over, fears about, and related costs of nuclear power from traditional LWR reactors revolve primarily around risks associated with release of radioactive elements into the environment (meltdowns) and nuclear waste. But, with Thorium and the LFTR, waste is drastically reduced and the risk of a meltdown and associated need for containment are eliminated. Thorium, when consumed in a LFTR, is simply a superior way to generate energy.

Vastly More Clean Energy — With more energy we can have more of everything we produce with energy (potable water, for example). When consumed in a LFTR, Thorium is very *clean* energy. The environmental and safety advantages of producing energy from Thorium in LFTRs include:

- LFTRs efficiently extract nearly 100 percent of the energy from thorium—which means there is very little waste (only about three percent of the nuclear waste by mass compared to current uranium LWRs). Most of the nuclear waste that is produced (almost entirely fission products, i.e., elements created as atoms split) decays to a harmless state within a *decade*. The remainder (equivalent to less than one percent of LWR waste) requires about 300 years to be safe. By comparison, LWR waste is not considered safe for hundreds of thousands of years. The "long-lived waste" issue is eliminated with Thorium LFTRs.
- The fuel salts are inherently chemically stable and impervious to radiation damage, enabling unlimited fuel burn-up and continuous solvent recycling. This is how LFTRs consume all of their thorium-derived fuel.

- LFTRs need no water.
- LFTRs produce no CO_2 (no carbon footprint).
- The Liquid Fluoride Salts LFTRs use as a fuel medium have the very favorable property of operating at both high temperature (permitting high thermodynamic efficiencies) *and* low pressure.
- Extremely low fuel-preparation costs, and no fuel-fabrication costs.
- The Thorium fuel cycle is highly unsuitable for weapons diversion.
- LFTRs are "proliferation resistant." In a traditional light-water reactor uranium-235/238 nuclear reactions generate a byproduct—plutonium-239, a radioactive isotope used to make weapons. When thorium is consumed in a LFTR much less plutonium waste is produced, and the vast majority of this is Pu-238. Pu-238 is highly valuable for use in RTG "nuclear batteries," but completely unsuitable for weapons use.

Small footprint, easy to manufacture, affordable — Because they don't require the construction costs associated with the safety features of uranium reactors, thorium reactors are much cheaper to build, and can be scaled down for use in small communities. Small, modular design enables placement anywhere, and requires a fraction of the land area of conventional reactors. Lawrence Livermore, Los Alamos, and Argonne national laboratories are designing a next-generation, self-contained, tamper-resistant nuclear reactor called SSTAR (small, sealed, transportable, autonomous reactor) capable of producing 10 to 100 megawatts of electric power. A 500-ton, 100MW SSTAR-sized thorium reactor could fit in a large industrial room, requires no retaining walls and little maintenance, and only costs $25 million.[4]

- Thorium reactors are well suited for assembly-line manufacturing, and can be produced on a small modular scale capable of being safely transported on ship or by a heavy-haul transport truck for delivery to power generation sites. They can be located closer to electric users, which will improve delivery efficiency and reduce transmission costs. A 5-ton, truck-sized 1MW thorium reactor may cost as little as $250,000, but would generate enough electricity for 1,000 people, use only 20 kg of thorium fuel per year, run almost automatically, and require only annual safety checks.[5]

High-Temperature Reactors Yield Process Heat — Thorium-fueled high-temperature reactors run at significantly higher temperatures than conventional reactors and not only produce low-carbon electricity, but also yield clean heat for industrial processes, making them suitable as industrial heat sources for producers of cement, steel, and oil and chemicals.[6]

Economic Consequences of Energy from Thorium—Freedom

With thorium we can have far more energy, far more affordably, than we can now, while hedging against the uncertainties of fossil fuels, and avoiding the profound economic costs associated with environmental regulations aimed at curbing carbon-based greenhouse-gas emissions. This enables the economy to do things that require energy *much* more affordably (actually, at levels of affordability previously unimaginable). Thorium as an energy source literally fuels previously impossible technological innovation by making the energy needed for that innovation available affordably.

A growing, healthy economy runs on energy, and truly abundant energy solves a lot of significant economic problems. It enables America to dramatically increase productivity and improve its competitiveness in the global marketplace. With abundant, low-cost energy, our economy produces more with less. Manufacturing costs will go down; wages will increase. With reduced energy costs everyone can produce more. This increases demand and triggers employment increases. Employers will both need to hire more workers to keep up with demand, and will be able to *afford* to hire those workers.

With plenty of energy from Thorium to power America, and continued improvements in U.S. production of oil and natural gas, the nation can be, for the first time in a very long time, in a position to sell its oil and gas to other countries**—increasing international commerce and exports on a scale potentially sufficient to generate tax revenues capable of retiring all U.S. debt.**

Industries in the U.S. and the world are chasing low-cost energy rather than low-cost labor. When energy is abundant and inexpensive capital flows to invest in industries that have access to it. Why? Abundant, low-cost energy reduces production costs and affords industries significant competitive advantages over those without access to such energy sources. For the U.S., abundant energy from Thorium would attract a rush of foreign investment. Economic growth would be persistent. As capital flows, so too do jobs. Abundant, affordable energy will transform the U.S. economy into a high-employment destination. Developing Thorium is an energy plan that also acts as a campaign to "Stop Shipping Jobs Overseas."

Virtually all industries will benefit from policy changes permitting and supporting the development of energy from Thorium. As the economy *actually* thrives and grows revenues to the treasury will grow too, reducing debt and tax burdens that now stifle economic activity. Through economic strength the U.S. will be liberated to pursue a robust free-trade strategy.

Enhanced Utility for Fossil Fuels through Affordable Conversion — Thorium can provide us with safer, cheaper energy at a fraction of what conventional energy costs us today. Because LFTRs can produce electricity at such a low cost they will naturally, in a free market, displace more expensive coal, natural gas, and traditional nuclear as primary sources of electricity. The displaced energy resources can then be diverted from electricity generation to equally important uses — like transportation fuels.

Far from making abundant energy sources like coal and natural gas obsolete, the abundant electricity and heat produced by LFTRs can be efficiently and affordably used to power the *conversion* of coal, waste coal (unusable by current energy producers), shale (Kerogen), and natural gas to liquid fuels. Other countries, including China, India, and South Africa, have developed significant capabilities in coal-to-liquid-fuel production. LFTR technology will significantly aid this complicated energy conversion process, which requires heat, pressure, and a catalyst. How? LFTR generates enough low-cost process heat to drive the chemical processes that transform coal into gasoline and diesel fuel equivalents—affordably and efficiently. (Some estimates indicate that the retail cost of a gallon of converted coal fuel would be approximately $2.25 and a gallon converted natural gas would be $1.10.

Why is this important? Because Thorium, in addition to being a source of energy itself, is so abundant, and so efficient when used in the LFTR, that it renders the conversion of other energy sources to liquid transportation fuels both feasible and economical. Converting our 500-year supply of coal and natural gas is significant to our ability to attain and maintain energy independence (i.e., complete energy selfsufficiency). Eliminating our dependence on foreign sources of energy solves many economic and national security problems.

Medical Solutions — Beyond producing energy, developing LFTR yields significant and dramatic side benefits—in cancer treatment. LFTR facilities will produce Actinium-225, which has shown great promise in cancer treatment. LFTR facilities will also yield scarce nuclear isotopes used in diagnostic processes, reducing the cost of both diagnoses and nuclear pharmaceuticals.

NASA Research – LFTRs actually produce a valuable reaction product—Plutonium-238—which cannot be used for weapons, but does alpha decay to Uranium-234 with an 87-year half-life. This makes it ideal for use in radioisotope thermoelectric generators (RTGs), which provide a great power source for NASA's deep-space probes like Voyager I and II and the latest Mars rover Curiosity.

U.S. Taxpayers and History have Already Proven that Thorium Works

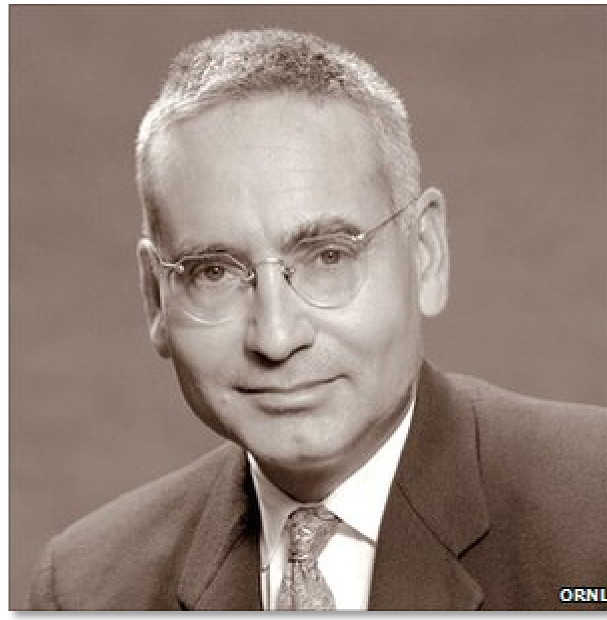
The Thorium fuel cycle and LFTR are technologies that America's taxpayers shelled out about $1 Billion for in the 1950s and 1960s. The proof-of-concept research and development work is done. Research was conducted for some two decades at Oak Ridge National Labs (ORNL), which culminated in the Molten Salt Reactor Experiment (MSRE) that verified (proved) a number of key, basic LFTR principles and features. The MSRE was a proof-of-concept reactor that ran with the fuel dissolved in molten salt. In fact, it ran for 4 years on three different fuels (U-233, U235, and Pu-239) and at the relatively high temperature of 650^{o} C (1200^{o} F). Significantly, it proved that the fuel salt could be processed to remove the fuel, which was required when switching fuels.

This provokes some common questions: What went wrong? Why didn't the U.S. pursue this incredible energy technology and advance beyond the constraints of traditional energy? Why didn't this happen? Why are we instead arguing over oil imports, terrorists, and wind farms?

In the early days of the Atomic Age, thorium and uranium were both considered potential fuel sources and were pursued in tandem. But, with wars raging the primary application and technological focus was their use in weapons. Because Thorium was somewhat problematic as a fuel source for weapons Thorium research was shelved, and development focused instead on Enriching Uranium (separating U-235 from Natural uranium, which is 0.7% U-235 and 99.3% U-238) to produce explosive material for atomic weapons, and breeding Plutonium-239, which comes from Uranium-238. Uranium reactors provided Plutonium-239 (the weapons-grade waste that released the explosive power of the bomb) and so were favored by the military to ensure U.S. strength in the emerging Cold War. The military wanted to see the development of a large number of uranium reactors because the byproducts enabled a path to weapons.

Despite successfully testing a thorium-fueled facility, government, politics, political history, and their respective inertias, have, unfortunately, left this profoundly important energy technology to be forgotten. At the height of the Cold War, through a historical quirk, this unbelievably promising LFTR technology and thorium were sidelined and left on the shelf of a government operation's back room with no one to manage it forward. The pacifists in the nuclear-science community were also sidelined, and Thorium, a victim of historical timing and geopolitical priorities, was not looked at again until today's renewed focus on nuclear (carbon-free) energy for power generation. This set the stage for the emergence of the world's uranium-based nuclear industry.

In the early '70s a number of politicos, including Nixon, jumped on and pushed for the development of fast breeder reactors because they saw great economic benefits for their regions of the country in doing so. Also, many feared that others (like France) were going to beat the U.S. on water-reactor technology. The Atomic Energy Commission (AEC) in September 1972 issued a report critical of some aspects of the promising though less-widely-supported LFTR technology, while ignoring LFTR's clear safety and economic advantages.



Dr. Alvin M. Weinberg, Nuclear Physicist,
Director Oak Ridge National Labs 1955-1973

A significantly higher level of safety is possible with the thorium-based LFTR (because of low pressures and no meltdown risk), but the politicos of the day were singularly focused on fast breeder reactors, and in their drive to advance their own cause and parochial interests, those who advocated/espoused the molten-salt breeder reactor (especially its creator Alvin Weinberg), were pushed aside. The AEC director had Congress' confidence and support—and what he advocated was what received support, funding, and attention.

An entire direction of development was ended because of government power, political influence and the desire of politicos to keep safety issues out of the spotlight (the development wasn't ended because scientists or engineers declared the efforts complete or pointless). This was a critical moment. Powerful forces in industry, government, the military, and finance were lining up behind the fast breeder reactors, and their political maneuvering squeezed out the Thorium and LFTR advocates like Weinberg who were touting safety. Safety advocates like Weinberg were driven out and shuttered. In January 1973 the AEC directed Oak Ridge to terminate all development activity on LFTRs, and defunded it. Eventually, the group that had developed and advocated thorium liquid fluoride reactors disbanded, and what they knew was forgotten over the intervening decades. Regrettably, and inexplicably, the AEC's decision to shut down the Thorium / molten salt development was never re-examined or revisited, and the U.S. free market and American ingenuity were never permitted to commercialize this promising energy technology.

When LFTR research was halted, uranium-fueled reactors emerged as the standard. So the electric power industry, in combination with politicos of the day, made a tragic misjudgment and selected uranium instead of thorium to produce electricity from reactors, leaving the world a legacy of high environmental, economic, and regulatory costs—and America's nuclear energy, unlike all other commercial energy sources (coal, oil, wind, and solar) was never privatized to a point that permitted significant research and free-flow development efforts without government approval or interference.

Despite this history, Thorium is now re-emerging as an overlooked energy-source gem. The scientific community has realized that Thorium and the Liquid Fluoride Thorium Reactor (LFTR) can wean humanity off fossil fuels and leave the risk of a nuclear meltdown in science history's dustbin forever, and can achieve this much more effectively and economically than *any* of today's other energy sources (e.g., wind, solar).

Much has been and is being written about Thorium and LFTRs and the history of Thorium energy, including many books. *Despite* this abundance of compelling information about Thorium, nothing is being done to unleash this remarkable life-changing energy source. Our political leaders turn their heads — worried that supporting anything "nuclear" may affect their next election.

The State of Thorium Energy Technology Today

How far away is the U.S. from having abundant energy from Thorium, and what has to be done for this to become a reality? Were it just a technical matter (i.e., just a matter of science and engineering) LFTRs could be up and running in perhaps as little as two years, and perfected to remove bugs and establish a robust power-production model within another few years. We know this because in the early days, reactors could go from concept to working model in less than two years. ORNL even developed "portable" reactors as demos, including a working "swimming pool" reactor that stole the show at 1955's Geneva conference. By the conference's end, thousands of Swiss citizens had seen the reactor and luminous Cerenkov glow.

The U.S. could be producing energy from Thorium commercially within 10 years, even accounting for inevitable regulatory compliance, negotiation, and revision. There is a learning curve, and implementing electricity generation from the Thorium fuel cycle includes a number of significant steps. Because 40 years have passed since Thorium development was terminated, re-establishing the status of work previously completed through another MSRE is a starting point. Following that, a breeding MSRE would be necessary to optimize chemistry, production materials, and designs. A viable LFTR program would require a relatively modest investment of roughly 1 billion dollars over 5–10 years to conduct research, address technical gaps, construct a reactor prototype, and then a full-scale reactor. Fortunately, many of the engineering and technological issues identified through the ORNL program have since been solved through non-nuclear research, including liquid fluorides, resistant metal cladding, and high-temperature turbines.[7]

Assuming a variety of firms vie for market share and are free to partake in the development process, a number of paths will be tested simultaneously (different materials, core designs, product lifetimes, fabrication techniques, etc.), each seeking to best serve the market's needs, and improvements will continue to occur as firms race to commercialize their developments. A "steady state" of development capable of sustaining energy production won't be far behind.

Essential Steps to Realizing the Promise of Thorium Energy

Perhaps the single greatest challenge, and a major hurdle to overcome, is the fact that the technology base has stagnated for 40 years. LFTR technology is very different from water-cooled uranium-fueled reactors, and so is generally unfamiliar to those comprising our contemporary nuclear community. There will be resistance within that community due to this lack of familiarity. Also, today's nuclear regulatory environment is based on a completely different nuclear process, and much of it is completely inapplicable to LFTR technology.

For LFTR technology to move forward apace, a great deal of education will be necessary, especially within the scientific and political communities, and the regulatory framework will have to change accordingly to address the serious differences.

Existing Regulations are the Primary Barrier to Thorium Development

Why are we not greatly accelerating energy research and development of true energy solutions like thorium technology? Developing Thorium and LFTRs *shouldn't* be a problem, but Thorium's coalescing champions (see below) do have some hurdles to jump. Unfortunately, Thorium's bright future is essentially foreclosed at the moment (or neglected) by existing U.S. and state government regulatory frameworks, even though that may not have been the intention; any LFTR development effort/process is presently encumbered, unpredictable, unaffordable to most, and dramatically slowed due to today's heavy regulation of the nuclear energy sector. Consequently, what would take five years in an appropriate and sensible regulatory environment will take much longer if all of today's (inapplicable) regulatory hoops remain. Moreover, all government red tape and environmental regulations make new energy technology research and development less likely because it increases costs and risks, which discourages investment by private industry.

Right now, energy from Thorium isn't being produced because existing government regulations governing today's uranium-based nuclear industry are overly broad, protective, onerous, and not well suited for this technology. They derive from a legacy of fear associated with the risks of older uranium-based nuclear technologies. Many thorium/LFTR technology advocates believe they are being held back as a result—the regulatory state of affairs now stifles the development of much simpler and safer thorium-based reactor technologies, and denies us this great and ubiquitous energy source. Because Thorium development stopped 40 years ago a suitable and divergent regulatory framework for this alternate nuclear technology never emerged.

Many would-be private investors could finance the research and commercialization of Thorium LFTR technology if mandatory government licensing and regulatory protocols were not so cost prohibitive. Our regulatory framework is such that it has taken 30 years and billions of dollars to secure approval of just four new nuclear reactors (based on old technology) for construction. How much longer will it take regulators to approve new LFTR-type thorium reactors, and at what cost? If regulatory reform isn't undertaken, America will price itself out of the now-emerging nuclear energy market.

The entirety of the Manhattan Project's conception and development of nuclear energy occurred in four short years in the 1940's, yet it now takes an entire decade just to license an old-technology reactor before the first footer is poured. Today's nuclear regulatory environment is such that the Manhattan Project, if conceived of today, could not accomplish what it did. Unless America finds a way to accelerate development of new-type nuclear reactors, we risk our security, safety, and prosperity.

Regulatory Reform to Drastically Lower the Regulatory Burden

What is needed before commercial thorium-based reactors become available? The nature of LFTRs is such that existing regulations intended for conventional nuclear energy generation are unnecessary and inappropriate. Policy makers need to recognize these fundamental differences in nuclear energy technology, so policy can change and lead us to regulatory change.

America's energy-regulation framework requires updating to clear the road to Thorium. New rules are needed that permit effective development and rapid licensing of this technology (and various emerging designs and innovations) without rendering the process unaffordable—new regulations *suitable for Thorium and LFTRs* that appropriately address these unique processes and issues while lowering development and implementation costs. What's needed is a small set of clearly defined characteristics that achieves a level of safety, but permits quick evaluation and license.

Given the inherent safety advantages of LFTRs (and Molten Salt Reactors generally), appropriate regulations should be far less onerous, and compliance with new regulations should be much easier to achieve. This isn't to say that anyone should be permitted to build nuclear reactors in their basement, but a far simpler, streamlined regulatory approach is appropriate given the differences between LFTR technology and uranium-fueled reactors. This will keep the cost of entering the thorium-LFTR-related space low, thus ensuring a robust and timely development effort. We're not advocating zero regulation. We support and advocate reasonable, effective regulatory oversight, but at levels requiring orders of magnitude less time and money than the regulatory framework presently governing existing light-water-based nuclear energy production.

The objective of these regulatory reforms is to clear a path to private-sector development and implementation of this technology, and delivery of this energy to users. Development is best done by the private sector for a number of reasons, including efficiency, timeliness, financial rewards justify the risks (incentives), accountability to the market, performance expectations, and financial realities, maximizing innovation, etc. In a free market, LFTR technology will compete very favorably against all other energy options, now or in the foreseeable future. With regulatory changes, private industry can build and implement LFTRs without government (taxpayer) funds, with minimal government intervention, on a very reasonable timetable.

It's essential that the federal government undertake regulatory reform to accommodate Thorium development; the alternative is economic decline. With wise regulatory reform, getting from here to there is mostly a straight path forward.

The Time is Now — A Sense of Urgency

Why must this technology be fully (not half-heartedly) embraced and pursued now? We need much more energy at lower prices to ensure future economic success, jobs, growth, stability, and prosperity. Other "alternative" or "green" energy solutions will contribute to U.S. energy needs, but not at levels sufficient to stimulate and sustain significant economic growth.

We also must have energy that has a much lower impact on the environment—not only because we all want a good clean environment, but because energy's high impact on the environment has significant costs that put downward pressure on economic growth.

The unending geopolitical turmoil destabilizing the Middle East has significant overt and hidden costs to the U.S. Widely available energy from Thorium will likely dampen this turmoil and lower these costs.

Expensive, intermittent alternative energy is not the solution to our long-term economic needs—it's unaffordable for most consumers, even when it's heavily subsidized. We can gain significant economic advantages by reducing the need to construct transmission lines over long distances to use energy generated in remote areas and instead taking the power-generation source to the areas where power is needed (portability). The Energy From Thorium Foundation advocates LFTRs in part because their small size and portability lower capital and infrastructure requirements for delivering energy.

If we're going to truly pursue the broadest possible energy base, LFTR-produced Thorium has to be included. It is a natural, abundant and remarkably inexpensive, safe, clean source of energy. The U.S. has already proven LFTRs' underlying molten salt technology. LFTRs and Thorium portend nothing less than an energy renaissance. The combined ability to generate massive amounts of low-cost electricity *and* convert coal and natural gas to transportation (liquid) fuels, will transform our economy by dramatically increasing its capabilities.

An International Race — Any country that gains early expertise and dominance in producing and perfecting LFTRs will attain powerful long-term economic advantages and *strength*. The question remains whether the U.S. will again lead the world in harnessing Thorium's energy potential, or be left behind by China, India and other countries that are actively developing this energy source apace, right now. If the U.S. gets ahead on this we can solve our energy problems forever. Any other country that brings energy from Thorium online in commercial quantities before the U.S. does will gain an almost incalculable economic advantage over the U.S. This would change the world's economy, geopolitics, and energy landscape in profound ways to the great and lasting disadvantage of American interests and American lives.

- LFTR technology, having been proven in the U.S. long ago, is now being reproduced and refined by massive projects in China and India. France, Russia, and Norway are also pursuing thorium development.
- Using the liquid-fuel ideas pioneered by U.S. physicists at Oak Ridge National Lab in the 1960s as a springboard, China launched a $350m thorium-fueled molten-salt reactor research and development program in 2011, and plans to build commercially viable plants in the 2030s, while India, which has 16 percent of the world's thorium reserves, hopes to build four new fast-breeder reactors by 2020.[8]
- The China NAS program is directed by Jiang Mianheng, son of former leader Jiang Zemin, already has 140 PhD scientists working full-time on thorium technology development at the Shanghai Institute of Nuclear and Applied Physics, and is expected to have a staff of 750 by 2015.[9] This very serious commitment to thorium is a likely fast track to significant breakthroughs leading to commercialization.
- Xu Hongjie of the Chinese Academy of Sciences (CAS) in Shanghai says a 100-megawatt demonstrator version of one of the two reactors he's developing should be ready by 2024. Both reactors in development under Xu Hongjie are thorium molten salt reactors—a solid fuel version using "pebble bed" fuel and molten salt coolant, and a liquid version using thorium fuel mixed with molten salt. In the shorter term, Hongjie expects to complete a 2-megawatt solid fuel pilot molten salt reactor in 2015, and expects that a 2-megawatt "experimental" liquid molten salt reactor could be operational by 2017.[10]

- Seeking to implement new nuclear energy production with an "entirely different" technology in order to rebuild public trust, Japan's International Institute for Advanced Studies (IIAS), led by thorium enthusiast Takashi Kamei, is researching liquid fuel molten salt reactors as an alternative means of safely generating electricity.[11] Tokyo-based Thorium Tech Solution (TTS) plans to build a 160-megawatt electric MSR and a smaller 7-megawatt model and is basing its designs on Dr. Weinberg's ORNL work. Masaaki Furukawa, the company's president, expects TTS will build a working prototype by 2018 to prove the concept. TSS aims to build commercial thorium molten salt reactors by 2025.[12] For Japan, the need for safe alternatives is now urgent because Japan's fleet of conventional nuclear reactors remains mostly shut following the Fukushima meltdowns two years ago.

Today, inexplicably, the U.S. has not undertaken any serious, organized political action to support, foster, organize, drive, or ensure *domestic* Thorium energy development in either the private sector or national laboratories. But, the U.S. Department of Energy is quietly collaborating with China's Beijing-based CAS under a "CAS and DOE Nuclear Energy Cooperation Memorandum of Understanding" to develop liquid thorium reactors in China based on the molten salt technology developed at Oak Ridge National Laboratory in the 1960s—and scientists from MIT and Berkley in the U.S. are on the MOU committee.[13]

This is somewhat shocking given that China **plans to *develop and control* thorium *and the associated intellectual property* for its own benefit**, and that the U.S. government has not publicly declared or defined its interest in or objectives for thorium energy development or the nature of its collaborative relationship with China. Since the U.S. denied Oak Ridge National Laboratory, the LFTR pioneer, a clear path to Thorium commercialization in the 1970s, and demonstrated a lack of commitment to the technology, today's China collaboration leads some observers to believe that the U.S. government is, officially, actually *giving* our Thorium technology to the Chinese, rather than developing it here in the U.S. for the benefit of U.S. citizens and to serve this nation's strategic and security interests. If the collaboration framework lacks an assured path to U.S. protection and control of the technology being developed, it may betray our energy needs and America's future—a tragic and avoidable outcome.

LFTR technology promises dramatic long-term economic advantages to the country that succeeds in delivering it to market (i.e., wins the commercialization race). The U.S. needs to be that country for many reasons! Handing the advance and control of this crucial energy technology to China could prove extremely foolish and very damaging to American energy security. If China or India begins producing thorium-based energy at commercial levels before America, they will quickly dominate almost all manufacturing markets as their cost of energy to produce components of any manufactured product declines. As core production and resource costs are reduced, manufactured products can carry lower price points, which improves competitiveness—a boon to any economy.

After allowing the thorium blueprints and intellectual property developed at Oak Ridge to collect dust since the early 1970s, the U.S. has allowed them to be published for all to see; and China, seeing the potential of thorium and LFTRs, has jumped on it with all due seriousness—and funding. Jiang Mianheng even took the initiative to visit the Oak Ridge labs to obtain the designs.[14] China's very strong and committed dash for thorium has suddenly (within the last few years) changed the geopolitical energy game. China's program is the largest national thorium-MSR initiative anywhere. By successfully designing a thorium-based molten-salt reactor China could cement a lead position in the race to build environmentally safe, cost-effective reactors, and thereby pose a very real threat to U.S. economic competitiveness.

Meanwhile, the U.S. government sits in idle showing no real interest in protecting or advancing this valuable domestically-developed technology, and betraying little understanding of the urgency at hand and the need to avoid being on the wrong side of other countries' hegemony. America chose, politically, and for what then seemed sound economic reasons, to do nothing with its historic innovation for decades, and now China has picked up America's fumbled ball and is running toward the end zone. It will be a tragic reflection of failing U.S. technological prowess should we end up importing the very technology our premier national R&D facility originally developed 40 years ago.

The West's Position in this International Race — Fortunately, outside of the U.S. DOE's China "collaboration," there are at least three companies in the West privately developing thorium reactors: Flibe Energy, Huntsville, Ala, which has dusted off 1960s ORNL technology;[15] Thorenco, San Francisco; and Ottawa Valley Research, Ottawa. Flibe Energy's Kirk Sorensen seeks to have liquid thorium reactors operating within five to eight years, and is focusing on smaller, "modular"-sized 20- to 30-megawatt reactors that will cost hundreds of millions at first. Mass production of these reactors will likely reduce the cost of each in half.[16] In addition, the test reactor in Halden, Norway, started burning thorium combined with plutonium (thorium MOX or mixed oxide) in a four-year test program that commenced in April 2013, under the direction of Oslo-based Thor Energy. The Halden program is backed by Westinghouse and the U.S. division of Japan's Toshiba.[17] Significantly, France's Areva, one of the world's biggest reactor companies, has recently announced a joint R&D program with Belgian chemical maker Solvay to investigate thorium as a nuclear fuel.[18]

Aside from the U.S. government's lack of leadership, support, and sense of urgency on this issue, other factors help explain why U.S. industry is not more aggressively developing thorium technology. One reason is that existing regulations and regulators stand in the way. The U.S. Nuclear Regulatory Commission's approval of LFTRs is not assured, and, at this point remains quite unpredictable, creating a questionable risk for private thorium technology developers and investors. China doesn't face this regulatory barrier to thorium development, and if the U.S. doesn't quickly clear the path to private investment in the development effort, the U.S. will be beat by China again, this time in energy, as capital is drawn to those who are pursuing game-changing energy innovation. The U.S. would become dependent on China and others owning advanced thorium reactor IP for energy solutions—a distinctly unhelpful outcome for a nation seeking to establish its energy independence and reduce its debt.

Another reason is that the entrenched uranium-based nuclear industry and its supply chain have vested interests to protect, have a comfortable chair in the realm of large traditional reactors, and are resistant to change—and to potential threats to their dominance. They have invested 50 years in building an infrastructure around uranium and aren't going to be inclined to walk away from it. The nuclear industry, wanting to keep costs low, is highly incentivized to stay with the technology it already knows well. They are unlikely to move rapidly into disruptive next-generation technologies like LFTRs despite the dramatic potential. In fact, because the conventional nuclear industry is built on uranium, its reluctance to change and desire to avoid the costs and risks of change lead it, and its regulators, to ignore or diminish thorium's prospects and advantages. Unfortunately for everyone who uses energy, uranium-based reactor technology is today the same, essentially, as it was 50 years ago. Every other field of technology development has gone through many generations of dramatic improvements in 50 years (no one still uses 50 year old computer or automobile technology). But, we're still using 50-year-old reactor technology to generate electricity.

America can't afford to continue ignoring the historic and compelling advantages of energy from high energy-density Thorium, especially while standing by and watching other nations gain the immeasurable economic advantages presented by Thorium, LFTRs, and the vast quantities of cheap, environmentally sound energy they deliver.

Support for Thorium is Solid, and Gaining Strength Rapidly

There are many thorium advocates, and the number is increasing. The scientific literature is significant. While most people haven't heard of Thorium or molten salt reactors, this energy resource is gaining traction in the scientific and energy communities, and has a long list of high-profile supporters and advocates, many of whom are names we all recognize:

Bill Gates—Chairman of Microsoft, and Chairman of TerraPower, a nuclear-development company, Gates has been interested in energy innovation for years. Gates' TerraPower team has made clear that it is getting into thorium and molten salt reactors research and innovation to examine potential, though their plans have considerable departures from the old thorium standard (Oak Ridge).[19]

Joe Sestak—Former U.S. Congressman

Senators Harry Reid and Orrin Hatch have supported providing $250 million in federal research funds to revive the ORNL research and draft specific resolutions.[20]

Hans Blix—former head of the International Atomic Energy Agency and the United Nations Monitoring, Verification and Inspection Commission. Blix urges nuclear scientists to develop thorium as a new fuel, and calls on the nuclear industry to start powering reactors with thorium instead of uranium, because thorium may prove much safer in reactors than uranium and is more difficult to weaponize.[21]

Carlo Rubbia—Nobel Prize winning physicist, and former director of the CERN laboratory.

Activist Groups and Organizations Advocating for Thorium

- The Weinberg Foundation — a UK-based not-for-profit organization dedicated to advancing the research, development and deployment of safe, clean and affordable nuclear energy technologies. http://www.the-weinberg-foundation.org/thorium/
- Energy from Thorium Foundation — a U.S.-based non-profit organization dedicated to advancing the safe, clean and affordable energy based on Liquid Fluoride Thorium Reactor technology (LFTR) for improving the human condition. http://energyfromthorium.com/

  EFTF's objective is to facilitate research, development and deployment of the Liquid Fluoride Thorium Reactor (LFTR). Top priorities are support of LFTR development and to inculcate "LFTR" as a household name, and a recognized inexpensive, safe, clean and abundant energy source to benefit the world for millennia. EFTF recognizes that other promising advanced reactor design concepts exist and supports their pursuit as well, but strongly believes the LFTR class of reactor architectures is the most promising of design classes, and that a focused effort on LFTR will facilitate a quick path to regulatory reform and development.

  Readers can support the foundation in its advocacy in a number of ways: http://energyfromthorium.com/contribute/

- Thorium Energy Alliance —TEA is a group of advocates and technology enthusists. They strongly advocate Thorium, LFTRs, and MSRs to ensure our energy future. http://www.thoriumenergyalliance.com/

These individuals and groups have the resources and determination to *build* a thorium-power industry.

There is a worldwide discussion about Thorium and the momentum is building rapidly for the embrace and development of this safe nuclear energy source. In June of 2013 Pandora's Promise was released in theaters, a documentary film explaining why nuclear energy is essential to powering the future. The emergence of such a film illustrates that even environmentalists realize that nuclear is not an enemy, but the solution to the world's future energy needs.

The fact that Thorium energy has so many, and a growing number of, diverse and ardent supporters makes it increasingly difficult for political, nuclear industry, and business leaders to ignore. As this coalition of advocates strengthens, communication about Thorium is likely to become such a powerful drumbeat that politicians will ignore it at their peril. There is a certain inevitability to this movement, provided advocates persist deliberately—which, given the stakes, can be expected.

Overcoming Objections and Fears

The public's fear of nuclear meltdowns and nuclear waste is real and ingrained through 50 years of anti-nuclear dogma. With the compelling truth about Thorium, and the advocacy of diverse, credible, and trusted individuals and organizations, the uncertainty and fear about nuclear energy can be quashed. Objections and fears are overcome through education. The dramatic safety advantages of LFTRs afford an opportunity to truly secure the benefits of nuclear energy without the risks of light water, high-pressure, meltdown-prone reactors.

It is not surprising that those who yield to fear and myth advocate waiting and taking no action. But the United States of America was not built by those who feared, waited, and rested, content to revel in past accomplishments. It was built by forward-thinking, action-taking individuals and institutions deploying uniquely American ingenuity. Thorium technology is American ingenuity at its finest. Our forebears made sure this country prospered through repeated industrial and technological revolutions. This is no time for today's Americans to surrender their legacy of ingenuity and flounder in the backwash of the greatness of others.

What can be done to Ensure that the United States has a Pro-Growth Thorium Energy Policy that Works? A Call to Action

The United States is at an historic crossroads. How does the U.S. bridge the gap between our technological heritage and meeting today's energy needs, and avoid losing perhaps the most promising energy technology ever discovered? Nothing less than a groundswell of public support and demand for this technology will do.

First, we seek to dramatically expand the dialog, and broadly inform the public about energy from Thorium. An effective grassroots education initiative is needed to ensure the country continues on the highway to energy (and economic) success. The object of a broad public dialog is to stimulate acceptance, demand and development action. The public needs to become engaged in the dramatic, life-changing implications of energy from Thorium.

Second, as the public learns about and embraces the value and potential of energy from thorium solutions, mechanisms must be established to permit the public to communicate with their legislators.

Third, political candidates must be prepared to support this important part of our national-energy dialog and our future. By including their support for government policy designed to liberate the private market to develop and commercialize energy from thorium and LFTRs candidates will distinguish themselves as well-informed, pro-energy and pro-environment.

Fourth, we encourage voters and grassroots groups to support candidates focusing on thorium as an important energy solution.

Fifth, political office holders and candidates are encouraged to sign a pledge of support for policies designed to foster, accelerate and protect domestic thorium development.

Sixth, individuals are encouraged to financially support the various thorium energy foundations and advocacy groups, and to educate others about the promise of thorium and the need for action.

Please join this important national conversation. Visit the energy from thorium website for more information about its energy-reform-related activities and forums: http://www.energyfromthorium.com Send questions about Thorium, and how you can contribute to this campaign to bthesling@th90.org.

Conclusion / Closing

Thorium could quite literally power the world and save the planet. Thorium and LFTRs combine to provide a viable, long-term, serious solution to our energy and economic needs. The impact of this energy source on humanity's future is mind bending. Yet, policy makers and other leaders have uniformly overlooked, or ignored, this energy source.

Building LFTRs on a scale sufficient to solve our energy needs is not prevented by any scientific or monetary problem. The technology exists and is affordable. What stand in the way are an insufficiently informed public, politics, and the powerful lobbying of vested energy and financial interests. Established energy stakeholders will resist any perceived emerging threat—which thorium surely is.

But, big, important things can happen quickly in the United States if the political will and private market incentives are present (consider the buildup for WWII, putting a man on the moon, and development of many great industries and technologies too numerous to mention). Enterprising America has always accomplished important things fast when needed, and free to do so. America has done great things and mastered great technological feats throughout its history, things that have changed the world. It can still do great things. And today the U.S. stands at another historic crossroads, this one in the realm of energy.

Developing and deploying successful commercial LFTRs in a short time frame can be done, should be done, and must be done if we're serious about transcending the limitations of carbon-based energy.

Developing thorium technology and unlocking this energy source could be the greatest feat imaginable in terms of its lasting impact on human prosperity. This is perhaps one of the most important, life-changing choices America has ever faced. We must wisely make this choice now.

The fact that we shelved this promising energy resource and technology 40 years ago through politics and fear is a most unfortunate and distressing outcome, to say the least, but it's readily resurrected with the right focus, public support, and political will.

Do we want to wait any longer for the future that thorium promises? We don't need to choke the life out of our economy by relying on energy resources that are inefficient or carry environmental consequences. Our energy policy must "put growth first," and overcome the byzantine and inappropriate regulations born of 50-year-old fears and objections. Without all available energy, especially affordable and abundant energy, we risk permanent economic stagnation and competitive loss.

History shouldn't be allowed to forget this powerful game-changing energy source. Development of the LFTR has the greatest potential to positively change the world for all of humanity.

THORIUM AND LFTR TOP ATTRIBUTES

Abundance and Energy Independence — Thorium's abundance throughout Earth's crust promises widespread energy independence through Liquid Fluoride Thorium Reactors (LFTR) technology. A mere 6,600 tons of thorium could provide energy equal to all energy consumed globally each year (that is, 5 billion tons of coal, 31 billion barrels of oil, 3 trillion cubic meters of natural gas, and 65,000 tons of uranium). With LFTR, a handful of thorium can supply an individual's lifetime energy needs; a grain silo full could power North America for a year; and known thorium reserves could power civilization for many thousands of years.

Very Safe, Low-Pressure, Low Cost Operation — LFTR operates at low pressure, is chemically and operationally stable, and passively shuts down without human intervention. Low pressures eliminate high-pressure releases to the atmosphere, the need for massive pressure containment vessels, and related safety issues. Its liquid-salt fuels have a thousand-degree-liquid range, eliminating the possibility of overheating, meltdown, or fuel failure scenarios. LFTRs, unlike traditional light-water reactors, dramatically reduce environmental impact and offer significant cost and efficiency gains.

Liquid Salt Fuels cannot Fail or Meltdown — The liquid-fuel form is a key differentiator from conventional solid-fueled Light Water Reactors. Liquid FLiBe salts serve as both a fuel carrier and coolant. The chemically inert salts do not react with water or the atmosphere. Fuel can be readily added to the liquid salts and byproducts removed while the reactor remains online.

Versatile, Sustainable, Carbon-Free Electricity — LFTR produces sustainable, carbon-free electricity and a range of radioisotopes useful for medical imaging, cancer therapy, industrial applications and space exploration. LFTR waste heat can be used to desalinate sea water, and its high-temperature primary heat can drive ammonia production for agriculture and synthesis of hydrocarbon liquid fuels.

LFTR is Highly Efficient — LFTR consumes 99% of its thorium-derived fuel and extracts significantly more energy from abundant, inexpensive thorium than traditional reactors do from more scarce and costly uranium. Also, LFTR elevates limited fissile reserves as a "catalyst" for ongoing power-generation capacity rather than burning them as a one-time consumable.

LFTR Consumes a Range of Fuels; Doesn't Leave Dangerous Waste — LFTR can be fueled solely by common, inexpensive thorium, or by long-lived plutonium and other transuranics from spent solid nuclear fuel stockpiles. Most LFTR byproducts have commercial value and stabilize within a decade; the remainder has a half-life of less than 30 years, stabilizing within hundreds rather than tens of thousands of years. LFTR waste does not include unspent fuel, fuel cladding, or long-lived transuranics typical of traditional spent nuclear fuel.

LFTR is a Demonstrated Technology — Its sound operational fundamentals are proven through 20,000 hours of operation at Oak Ridge National Laboratory's pilot plant in the late 1960's. Despite recognized, compelling advantages, LFTR development stalled when political and financial capital (and military imperatives) were concentrated instead on fast-spectrum plutonium-breeding reactors.

LFTRs can be Factory-Produced and Portable — As modular units, LFTR production reduces capital costs and build times; they can be delivered to and reclaimed from utility sites. Higher temperatures and turbine efficiencies enable air-cooling away from water bodies. Modular installation near points of need also eliminates long transmission lines.

LFTR is Proliferation Resistant — Thorium and its derivative fuel, uranium-233, are impractical and undesirable for weaponization; none of the world's tens-of-thousands of nuclear weapons are based on the thorium fuel-cycle. So, use of Thorium does not portend geopolitical risks.

Next Steps

If you would like to learn more about the promise of Thorium and the dramatic role it can play in Ensuring our economic liberty and success, or the organizations supporting this publication, please contact us.

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The National Association of Entrepreneurship
216-244-1544
research@naeonline.org

Resources for Readers:

Podcast Interview — Dr. William Thesling (Executive Chairman of the Energy from Thorium Foundation) makes the case for development of the element thorium as an energy source. He says using the element in a LFTR Liquid Fluoride Thorium Reactor would generate electricity less expensively than that generated by coal, much less wasteful, toxic, and more safe than electricity generated by today's modern light water reactors, and would produce baseload electricity more practically, cleanly, and economically than renewable energy sources. Dr. Thesling is interviewed by Jim McIntyre of Ohio's WHK 1420 AM radio station.

Learn more at www.flibe-energy.com/media and http://energyfromthorium.com/

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Pandora's Promise – a documentary about nuclear energy debunking many nuclear myths.

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