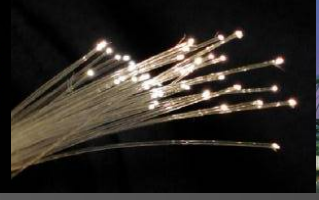

Rare Earths and Thorium are linked

The Future of Technology is linked to Rare Earths
The Future of Energy is linked to Thorium

The U.S. needs a Policy on Thorium & Rare Earths

U.S. Heavy Rare Earth Cooperative

Global Economics of Thorium Energy

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U.S. Policy on Thorium Must Change

U.S. Thorium policy supports China's global advantage and control of Rare Earths (RE).

U.S. Thorium policy undermined the domestic rare earth market -- the closure of Mt. Pass was related, in part, to a tailings spill containing Thorium*.

China has successfully leverage this advantage into consolidated control over the RE market, RE manufacturing and RE technology development.

China's next move is to utilize its advantage to secure global IP for Thorium energy development.

*Mark Smith, the CEO of Molycorp, blames the EPA and the State of California for the original closure of Mt. Pass, not China.

Heavy Rare Earths are linked with Thorium

Regulatory risk prevents U.S. and other 'western' mining companies from developing Thorium rich deposits.

La	Ce	Pr	**Nd**	Sm	Eu	Gd

Low Thorium / No Heavy RE

Y

Expected rare earth recovery from a typical Bastansite deposits such as Molycorp's Mt. Pass deposit.

Expected rare earth recover from a typical Monazite deposit

La	Ce	Pr	**Nd**	Sm	Eu	Gd	**Tb**	**Dy**	Ho	Er	Tm	Yb	Lu

Y	Sc

Monazite is the largest geologic source for heavy REs but it typically contains elevated levels of Thorium so it is avoided by all 'western' mining companies / developers.

New U.S. Strategy in Rare Earths

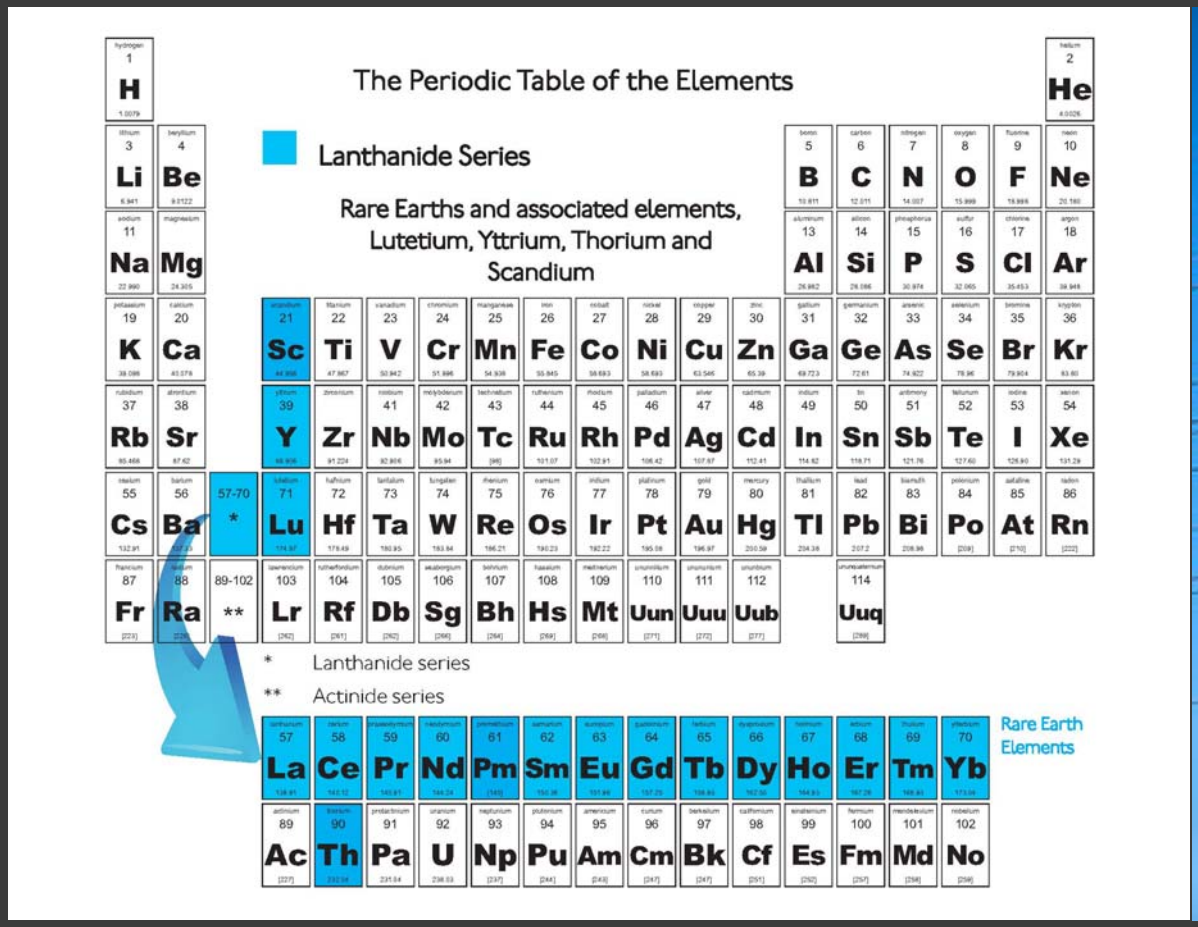
It is critical that the U.S. rationalize its Thorium policy under a centralized rare earth cooperative authority.

- Creating centralized RE refinery to manage Thorium-bearing Heavy REs levels the field:
  - Eliminates redundant capital cost for U.S. RE producers
  - Expands currently available RE resources
    - 2nd Largest source of REs, but 1st largest for heavy REs
  - Expedites development of resources via waste byproducts
  - Ensures a stable U.S. supply of REs for potential OEMs
  - Ensures environmental control / safe storage of Thorium

Energy as a byproduct of RE Refining

- A single Thorium / Rare Earth cooperative refinery producing just 20,000 tpy of rare earths from a typical Monazite concentrates would:
  - Produce 130% of current domestic rare earths needs
  - Undermine China's advantage in heavy REs
    - Make U.S. the only supplier of heavy RE outside of Asia
  - Produce enough Thorium to power the entire Western Hemisphere via Thorium Molten Salt Reactors (Th-MSR), a proven U.S. technology.
    - Establishing the groundwork for a Th-MSR energy economy under U.S. Control.

Heavy Rare Earths & Energy



Solving the U.S. Rare Earth / Thorium issue puts the U.S. on the path to clean, safe energy independence.

Th-MSRC and the U.S. Government as partners in the global deployment of a proven, safe, carbon free energy system

GLOBAL ECONOMICS OF TH-MSR

Economics of Th-MSR

- Th-MSR will be the leading form of base-load energy world-wide for the following reasons*:
  - No significant technical hurdles – proven U.S. technology
  - Thorium is a fertile mono-isotope – no enrichment necessary**
  - CAPEX costs lower than Coal/Steam power***
    - It offers the safest form of base-load energy
    - It offers lowest cost base-load energy per Kwh****
    - It offers a clean, carbon free energy solution

*China has a fully funded Th-MSR program and 2 European groups are also seeking IP & commercial development.

**High purity Th-232 is a no cost byproduct of rare earth refining that does not constitute any new proliferation risk.

***Assumes mass deployment of modular assembly-line built Th-MSR & Brayton turbines (see pages 14 -18).

****Assumes capex on 35 to 50 year lease agreements and/or implementation of carbon tax. Fuel cost will be nominal and stable vs all other forms of energy. Nuclear energy generation is cheaper and cleaner than all forms of coal, oil or gas energy. However, capital and permitting cost for LWR have made continued development / deployment of this technology impractical.

21st Century Paradigm Shift

- Whoever controls Th-MSR will control the future of clean energy globally.*
  - Peak Oil suggests ever increasing costs for petroleum based energy.
    - U.S. controlled petroleum resources are shrinking.
  - Energy cost for coal will increase with substitution, but substitution is environmentally unsustainable.
    - Converting to '*clean coal systems'* will only increase the costs of coal energy.

As energy prices rise Th-MSR can eventually replace all other forms of energy* - ***including liquid fuels.***

*Th-MSR can eventually produce liquid and gas fuels as these forms of energy become much more scarce.
**Recent events demonstrate that solid fuel Uranium based LWR technology continues to have meltdown and explosion risks. Iran, North Korea and laser enrichment technology demonstrate ever increasing proliferation risks for all Uranium based fuels.

Controlling Global IP

- U.S. not active in global Th-MSR development
  - China has a $1 billion program in place to capture global IP and commercially develop of Th-MSR.*
  - Private international groups are also seeking IP control of Th-MSR, but these groups are intentionally avoiding U.S. / NRC jurisdiction.
  - If Th-MSR is developed outside the U.S., NRC permitting status becomes irrelevant outside U.S.

The U.S. must control energy to remain relevant.

*The Chinese Academy of Science and Technology announced its plans to commercially develop Th-MSR technology and specifically stated its intention to capture and control global IP.

Future Fiscal/Monetary Meltdown

- Without a radical change in U.S. tax receipts deficits will continue to grow.
- Without a radical change in the balance of trade U.S. interest rates eventually increase
  - The Fed cannot indefinitely purchase U.S. Govt. Debt.
- As interest rates increase the deficit will increase exponentially.

Energy is the only market in the world large enough to restore fiscal and monetary balance.*

Energy is the Alternative to Instability

- Reversing fiscal/monetary meltdown requires:
  - Commercial development of Th-MSR by a single U.S. based corporation, not a multinational, with the U.S. government as a partner.*
    - Multiple Th-MSR energy providers would drive energy prices to near-cost – offering no protection for competing Th-MSR investors, other energy stakeholders (oil, coal and existing electric generation industry) and little or no tax revenues to the federal government.
    - Multinationals avoid taxation / don't share revenues.
  - Developing patents with the U.S. government / military as a partner (U.S. military patents).
  - Top line revenue sharing of world-wide lease income with the U.S. Government.**
  - Top line revenue sharing with participating nations who agree to IP protection and enforcement.

*The current definition of '*free market*' is incompatible with global economics (and has no place in U.S.'s developmental history). China has redefined markets around mercantilism, the original basis of "free markets (see Adam Smith)". The U.S. cannot continue to subject itself to the prevailing definition of '*free markets*' and survive.
**Due to the development of patents and IP in conjunction with National Laboratories and the Military.

Clean Energy's Future

Assumptions: Future Global Energy Revenues

- The global electric utility market exceeds $1 trillion per year.*
- All modern nations will employ clean energy.
- Clean, carbon free, energy will command an average retail price of $.08 to $.10 per Kwh.**
- Non participants in clean energy will become pariah nations.

*The global electricity market exceeded $1 trillion in 2008, with over 15,223.2 TWh in generation.
**2010 average U.S retail rate for electricity was $.115 (63% of sales) and the average industrial rate Was $.068 (37% of sales) per Kwh.

Revenue Sharing | Global Partnerships

A possible Th-MSR global energy economy

- Maintain utilities current income at $.02 per Kwh*
- Th-MSR energy cost could equal $.02 or less**
- Amortization of all capital cost for Th-MSR between $.02 to $.04 per Kwh***
- The remaining $.02 would be shared with U.S. Government and participating governments****

*Utilities currently earn less than $.02 for generation & transmission, resulting in a positive change in profitability.
**Assumes generation cost only ($.02 generation / opex + $.02/.04 Amortized capex = $.04/.06 total cost).
***Assumes $.02/.04 amortized capex for modular assembly-line built Th-MSR/Brayton systems (over 35/ 50 years)
****Offer financial incentives to governments for promoting carbon-free technology integration, thus accelerating adoption of technology and extending control of energy platform well beyond IP life.

U.S. Taxation of Global Energy

- The U.S. Government would enjoy 1/8th of top-line global energy revenues.*
- U.S. State/Local and Foreign Governments would split remaining 1/8th of revenues.
- U.S., State/Local Governments, Th-MSRC and Public Utilities would offer discounted rates for Mfg, Ag and mining industries to promote U.S. competitive advantage.

U.S. can avert U.S. fiscal/monetary meltdown and provide clean energy to the world

*The Federal Government would share top-line patent / IP royalty income in addition to taxation on net income.
**State, Local and Foreign governments would be incentivized into deployment and long term IP protection.

Protecting all Energy Stakeholders

- With U.S./Th-MSRC setting global energy prices for safe, carbon free electric all stakeholders are protected.*
- Oil remains *'competitive'* below $200 pbl.
- Reduced energy rates for 'clean coal' production to subsidize the conversion of coal to liquid fuels – making the U.S. totally energy independent.**
- The U.S. will become the largest energy exporter in the world.

*A single Th-MSR provider can set prices that are non-disruptive to global energy markets. Whereas, multiple competing Th-MSR systems would drive energy prices down to cost, even below cost, in the battle for market share. As energy prices collapsed, all other energy producers, coal, oil, natural gas, wind, solar, would be subject to financial instability, losses and eventually failure.
**Energy independence should be a top National Priority and low cost energy subsidies from Th-MSR to help develop liquid fuels from 'clean coal' would help coal producers transition into the new energy economy.

Global Investment Partnerships

- There is considerable domestic and foreign buy-in interest if the U.S. offers a regulatory pathway.*
  - Non-U.S. potential developers are recruiting from a very small talent-pool of qualified nuclear physics, engineers and radio chemists, including top people from our own National Laboratories.
- Private industry / investment can develop Th-MSR if provided a clear regulatory pathway.
- Foreign public and private investment will strengthen global IP, acceptance / deployment.

All competing interest will be forced to buy into U.S. development - *if we move first*.

*Sovereign funds, strategic partners, energy providers, financial institutions and large energy users.

The Future of Energy & Economics

- The future of energy and economics will be decided in the next few years.
  - China is committed to commercial development within 5 years, but the battle for IP will be decided within 24 months.
  - China has a lead of at least 12 months, possibly 18 months.
  - It will be difficult for the U.S. to ignore international laws governing IP if China wins.

If the U.S. intends to win this race we must initiate action before the end of this summer.

Energy, Economics & Resources

Th-MSR is the future / Oil is the past

China is engaged in the *New Warfare* of Economic Primacy - *state sponsored industrial development is the weapon*.

- *This warfare does not require aircraft carriers, drone missiles or military bases – it is self funding*

The United States is engaged in the *Old Warfare* of Military Domination – *global military presence and client states.*

- *This form of warfare is ultimately dependent on the health of the underlying economy – without a sound economy the money eventually runs out*

We must change tactics or collapse like the USSR

Risk / Cost: Thorium-MSR vs. Uranium LWRs

Key Safety Issues	**Uranium Light Water Re: Current Design**	**Thorium Molten Salt Re: Advanced MSR**
***Meltdown Risk**	More	Less
Explosion Risk	More	Less
Proliferation	More	Less
Safety Failures	More	Less
Nuclear Waste	More	Less
Th-MSR has no Meltdown Risk		
Total Cost per Kwh Economics & Nuclear Waste Issues	**U-LWR**	**Th-MSR**
Cost to Build	More	Less
Cost of Generation	More	Less
Modular & Distributed Power	More	Less
Waste Disposal Cost/Existing Waste	More	Less
Cost of Fuel Production & Security	More	Less
Th-MSR has lower expected costs.		

*Th-MSR Safety is 100% Passive or Walk Away Safe: Th-MSR cannot meltdown.

Managing Risk: Thorium-MSR vs. Uranium LWRs

MELTDOWN, EXPLOSION & RADIATION RISKS	Uranium Light Water Re: Current Design	Thorium Molten Salt Re: Advanced MSR
Nature & Stability of Fuel - Potential for Criticality	High	N/A – Thorium cannot go critical
Loss of Coolant	High	N/A - Air Cooled
Active Backup Safety Systems - Failed containment device / reservoir	High	Low - System is Passive
Loss of water: Spent Fuel Cooling Requirements – Storage issues at nearly 100 active reactor sites	High	Low - Fraction of LWR Waste
*Rapid Reactor shut down - Disposal of fuel to safe containment	Not Possible	Instantaneous - Passive/Automatic

*Th-MSR can instantly drop its fuel into secure storage tanks, with our without human intervention; shutting down the reaction.

Proliferation: Thorium-MSR vs. Uranium LWRs

PROLIFERATION RISK	Uranium Light Water	Thorium Molten Salt
FUEL : LWR U-235/U-238 vs. MSR Th-232/U-233*	High	Low – Uses a small amount of U-233
Risks in fuel production cycle & proliferation risk	High	Low *Only the U-233
Access to fuel in operating system - Terrorist hardened facilities	Low	N/A
**Ability to denature (kill) fuel in operating reactor under terrorist threat	N/A	High
Security of 'spent fuel' stored on site for dirty bombs, etc., - No Yucca Mt.	Low	Low
*Th-MSR uses a small amount of U-233 to initiate a sustainable reaction.		**U-233 is not a good weapons material***

**Th-MSR has reactor / fuel "kill" options that can be automatic / remote.
***U-233 has low proliferation risk due to its radioactive characteristics.

Cost Ranking: Thorium-MSR vs. Uranium LWRs

Cost to Build	Uranium Light Water	Thorium Molten Salt
Site Build – Individual Permit vs. modular assembly line production	More*	Less – Due to Assembly Line Certification
High Pressure Containment Issues	More	Less - Minimal
Water Resource Access	More	Less - Air Cooled
Redundant Backup and waste management control issues	More - Mostly Active / Mechanical	Less - Mostly Passive
Terrorist Hardened	More	Less
*Individual permits, pressurized systems and containment add cost to LWR		

Th-MSR can be assembly line certified and permitted, they do not operate under pressure (reducing containment cost) and primary safety features are 100% passive .

Th-MSR vs. Light Water Reactors

Build & Operational Cost Advantages vs. LWR

- Mass Produced on an assembly line - thousands of units
- Limited build out, construction & infrastructure cost vs. LWR
  - No massive pressure containment structures & cooling towers
  - Much lower terrorist and proliferation hardening costs
- Brayton generation for increased efficiency
  - Increasing unit output by 50%
- Operating cost are minimal vs. LWR
- Th-MSR is a load follower – reducing dependence on peak power capacity
- One time permitting of assembly line built units.
- 35 to 50 year lease financing with utility industry.

Infrastructural Build-Out, Waste & Decommissioning Costs vs. LWR

- Th-MSR offers potential for distributed power vs. current LWR
  - Distribution upgrade cost are estimated at $34 billion.
- Minimal fuel production and fabrication cost vs. LWR.
  - Minimal proliferation security necessary for Th vs. U.
- Reduced cost for used fuel / waste storage
  - Reduced cost of proliferation and environmental risks
  - Th-MSR can burn existing waste
- Limited decommissioning cost vs. LWR systems, infrastructure & waste
  - Total development cost for Th-MSR may be less than '*true cost*' of decommissioning current LWR

Th-MSR's value in burning existing waste may offset its total

Supplemental Data and Slides

Rare Earth Distributions | By Mineralization

Distribution of rare earth elements in selected rare earth deposits (All data - USGS).
*Pea Ridge RE resources: Breccia Pipes (primarily Monazite / limited Xenotime).
**Rare Earth Enriched Apatite (Monazite / Xenotime), a no cost byproduct of iron ore mining.

	Mt. Pass Bastansite	China Byan Obo	HRE-China Laterite	Selected Monazite		Pea Ridge* Breccia	Pea Ridge** RE-Apatite	
Lanthanum		33.8	27.1	1.8	17.5		27.5	18.6
Cerium	49.6	49.8	0.4	43.7		38.8	34.6	
Praseodymium	4.1	5.15	0.7	5.0		4.4	3.5	
Neodymium	**11.2**	**15.4**	**3.0**	**17.5**		**15.4**	**12.7**	
Samarium	0.9	1.15	2.8	4.9		2.1	2.5	
Europium	0.1	.19	0.1	0.2		0.3	.3	
Gadolinium		0.2	0.4	6.9	6.6		1.5	2.8
Terbium	**0.0**	**0**	**1.3**	**0.3**		**.27**	**.5**	
Dysprosium	**0.0**	**0.3**	**6.7**	**0.9**		**1.5**	**2.8**	
Holmium	0.0	0	1.6	0.1	**Heavy Lanthanides**	.28	.5	
Erbium	0.0	0	4.9	Trace		.81	1.8	
Thulium	0.0	0	0.7	Trace		.13	.2	
Ytterbium	0.0	0	2.5	0.1		.96	1.5	
Lutetium	Trace	0	0.4	Trace		0.1	.2	
Yttrium* **	**0.1**	**0.2**	**65.0**	**2.5**		**5.7**	**17.5**	
Percent Heavy	**.1%**	**.5%**	**83.1%**	**3.9%**		**9.7%**	**25%**	
RE in Ore	8%	5%	.2%	10 to 15%		12%	1.4	
Percent Thorium	.1%	.3%	>.1%	4 – 12%		3.5%	1%	

*** Yttrium is technically not a Lanthanide – but classified as a heavy rare earth element

Below | Heavy RE dependent technologies

Tb	Magnets, Lighting & Phosphors, Fuel Cells – Automotive, Wind Turbines, Defense Applications: Terfenol-D Sonar , Guided Ordinance, Lasers
Dy	Magnets, Nuclear Control Rods, Lasers – Automotive, Wind Turbines Defense Applications: Terfenol-D Sonar , Guided Ordinance
Ho	Magnets, Nuclear Control Rods, Lasers, Microwave Equipment Defense Applications: CTH YAG Lasers
Er	Industrial & Medical Lasers, Fiber Optics, Nuclear Control Rods,
Tm	Super Conductors, X-Ray, Industrial & Medical Lasers, Optic Display Defense Applications: CTH YAG Lasers
Yb	X-Ray, Optics, Steel Alloy, Stress Instrumentation, Solar Cells, Lasers
Lu	Nuclear Dating, Metal Alloys, Catalysts, PET Scanners, Medical Applications
Sc	Supper Alloys, Specialty Lighting, Lasers, Fuel Cells Defense Applications: Air Frame and Missile Hardening

- Not present in most low Thorium RE deposits -

Thorium Risks

- Thorium has ZERO proliferation risk and cannot be used to make a nuclear bomb.
- Thorium is an Alpha emitter and is essentially harmless relative to more common things in the natural environment.
- The following emit more dangerous radiation than Thorium: sunlight, Radon from a gas stove top, Potassium in a banana, X-rays, frequent air travel, high altitude exposure, TSA full body scans, etc.
- Alpha particles have no penetrating strength and cannot pass through human skin or thin plastic film.

Thorium Regulations

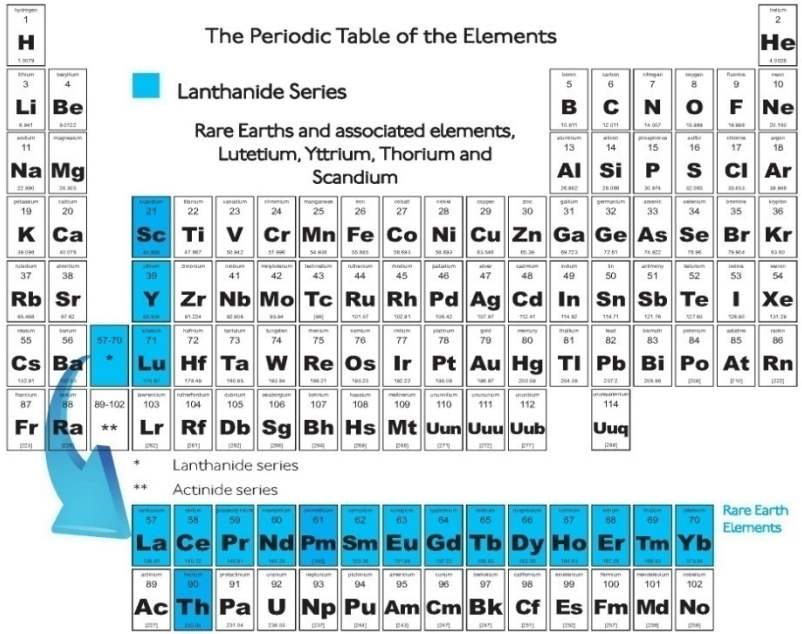
- When you refine Thorium bearing rare earths highly enriched Thorium drops out.
- Thorium is an Actinide that is regulated by the DoE and NRC, etc.
- Thorium currently has very few commercial uses and any new supply would simply accumulate.
- NRC-compliant storage* and the potential for future environmental liabilities are *unknown,* making the mining / refining of Thorium-bearing REEs outside of China or Malaysia impractical / unrealistic.

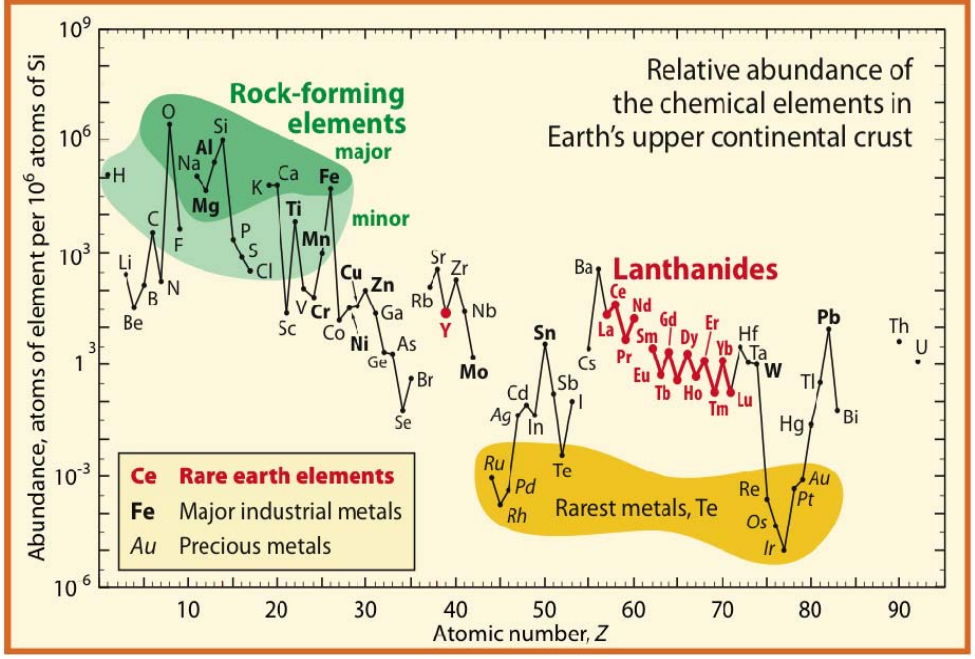
**Yucca Mountain type* Permanent Geologic Storage

Thorium's Commercial Potential

Thorium's other potential commercial uses:

- Metallurgy | Super Alloys
  - Military & Commercial Airframes
- Catalysts | Chemical and Petroleum Catalysts
- Medical Isotopes
- MOX Fuel
- Rare Earth Substitution | High Efficiency Lighting


The Periodic Table of the Elements
Lanthanide Series
Rare Earths and associated elements, Lutetium, Yttrium, Thorium and Scandium
* Lanthanide series
** Actinide series
Rare Earth Elements


Relative abundance of the chemical elements in Earth's upper continental crust
Rock-forming elements
major
minor
Lanthanides
Abundance, atoms of element per 10^6 atoms of Si
Atomic number, Z
Ce Rare earth elements
Fe Major industrial metals
Au Precious metals
Rarest metals, Te


SYLVANIA
clean energy