America the Vulnerable!

The impact of depleting Earth's nonrenewable natural resources (NNRs)

BY CHRISTOPHER CLUGSTON

INTRODUCTION

"The American way of life is not negotiable!" —*Attributed to President George H.W. Bush at the Rio Earth Summit in 1992. This statement essentially summarizes the outlook of most Americans.*

Unfortunately, the vast majority of Americans do not understand that our American way of life is enabled by *Nonrenewable Natural Resources* (NNRs) — fossil fuels, metals, and nonmetallic minerals — many of which are imported, often from questionable sources, and all of which are subject to the geological limitations of a finite planet.

As the following analysis clearly demonstrates, it would be more accurate to state that our American way of life is not sustainable — physically impossible actually — going forward.

I. NNRs — ENABLERS OF OUR AMERICAN WAY OF LIFE

Our modern industrialized existence — our American way of life — is enabled almost exclusively by enormous and generally increasing quantities of NNRs (nonrenewable natural resources[1]) — the finite and non-replenishing fossil fuels, metals, and nonmetallic minerals that serve as:

- The raw material inputs to our economy;
- The building blocks that comprise our infrastructure and societal support systems; and
- The primary energy sources that power our society.

Chris Clugston has conducted extensive research into the area of "sustainability," with a focus on NNR (nonrenewable natural resource) scarcity. The author received an AB/Political Science, Magna Cum Laude and Phi Beta Kappa from Penn State University, and an MBA/Finance with High Distinction from Temple University.

NNR roles

NNRs play three essential roles in enabling our American way of life:

- NNRs enable renewable natural resources (RNRs) — air, water, soil, forests, and other naturally occurring biota — to be used in ways and at levels that are necessary to support the extraordinary material living standards enjoyed by our ever-increasing population. Examples include water storage/distribution systems, food production/distribution systems, and energy generation/distribution systems, which would support only a negligible fraction of our current population in the absence of NNRs.
- NNRs enable the production and provisioning of infrastructure, goods, and energy that are inconceivable through the exclusive utilization of RNRs. Examples include cars, airplanes, computers, skyscrapers, highway systems, gasoline stations, communication networks, electric power grids, and nuclear power plants.
- NNRs enable the creation of enormous real wealth surpluses, which are necessary to support the thriving middle class population that differentiates industrialized America from pre-industrial, RNR-based, agrarian and hunter-gatherer societies.

In practical terms, NNRs enable American prosperity[2] — i.e., U.S. economic output and material living standards.

NNRs → American Prosperity

NNR criticality

Examples of the critical role played by NNRs in enabling our American way of life:

- NNRs comprise approximately 95 percent of the raw material inputs to the U.S. economy each year.[3]
- During 2006, America used over 7.1 billion tons of newly mined NNRs, which equated to

nearly 48,000 pounds per U.S. citizen.[4]

- A typical American house contains 30+ NNRs; a typical car, 30+ NNRs; a typical computer, 20+ NNRs; and a typical solar panel or wind turbine, 15+ NNRs.[5]

The tightly linked causal relationship between America's NNR utilization and economic output (GDP) is clearly demonstrated by our experience since the inception of the American industrial revolution.

1800-2008 U.S. NNR utilization and GDP

Remarkably, the correlation between the increase in U.S. NNR utilization and the increase in U.S. economic output (GDP) during the past 200+ years is nearly one-to-one.

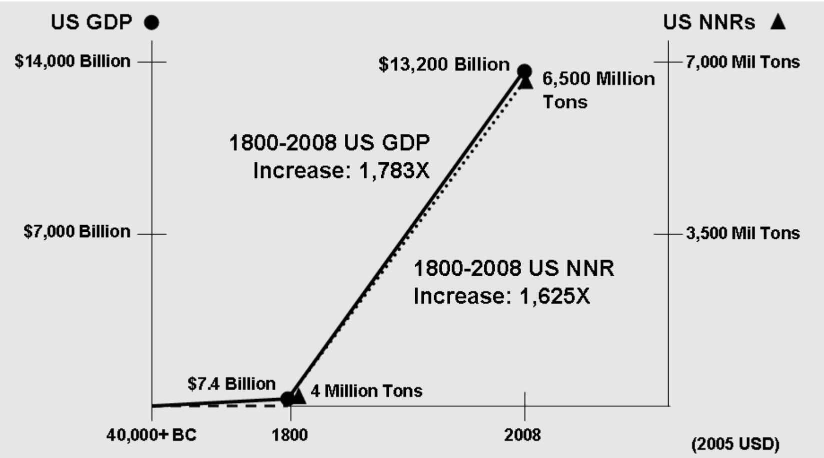
Global NNR occurrence

While NNRs are essentially ubiquitous within Earth's crust, "economically viable" NNRs — i.e., those that are both profitable to produce and affordable to procure — are extremely rare in almost all cases.

Crustal Occurrences: Vast quantities of nearly all NNRs exist within Earth's undifferentiated crust, the outer rocky shell that ranges in thickness from approximately 3 miles to 30 miles.[9] Unfortunately NNR concentrations within Earth's undifferentiated crust are too small in all cases to be economically viable.

Resources: Significantly greater NNR concentrations exist in mineral deposits, which are classified by the U.S. Geological Survey (USGS) as "resources."[10] Resources account for only very small subsets of total NNR occurrences however; and most NNR resources are not economically viable.

Reserves: Economically viable subsets of resources exist in proven NNR deposits that the USGS classifies as "reserves."[11] Reserves are the NNR occurrences that enable us to perpetuate our industrial lifestyle paradigm; they are also the least abundant on Earth.



Between the years 1800 and 2008, total U.S. NNR utilization increased by over 1,600 times, from 4 million tons to 6.5 billion tons. As a result of this spectacular increase in NNR utilization, the size of the U.S. economy (GDP) increased equally as spectacularly, by nearly 1,800 times, from $7.4 billion in 1800 to $13.2 trillion in 2008.[6,7,8]

To put global NNR occurrence into perspective, if the total quantity of an NNR in Earth's crust were represented by the size of Disneyland (150 football fields), the potentially economically viable "resource" would be about the size of a cell phone, and the economically viable NNR "reserve" would be approximately the size of a postage stamp.[12]

U.S. NNR occurrence

No nation on Earth — America included — is self-sufficient with respect to all or even most of the myriad NNRs that enable our modern industrialized existence. Consequently, all nations experience some level of "domestic NNR scarcity."

U.S. NNR import reliance

Domestic NNR scarcity exists when internally available NNR supplies cannot completely address a nation's requirements. In these situations, industrialized nations such as America import NNRs from foreign nations in order to compensate for domestic NNR supply deficiencies.

In fact, of the 87 NNRs that enable our American way of life, we rely on imports to some extent in 66 cases; in 16 cases, the U.S. is entirely import-reliant. In only 19 of the 87 cases is America self-sufficient with respect to NNR supplies.[13] Unfortunately, the inevitable consequence associated with NNR import reliance is NNR import vulnerability.

U.S. NNR import vulnerability

America's vulnerability to imported NNRs, and more precisely our vulnerability to import-related NNR supply disruptions, has been well understood by U.S. government agencies — especially those involved with military affairs — since World War II. As John B. Demille, Consulting Geologist for The Reconstruction Finance Corporation, observed in 1947,[14]

> The relative availability, on March 1, 1944, of metals and minerals essential to the war effort was defined by the Conservation Division of the WPB [War Production Board] as follows: *Group I. insufficient for war uses plus essential industrial demands*; Metals — bismuth, cadmium, platinum, sodium, tantalum, tin; Ferroalloys — columbium [niobium], nickel; Minerals — low-silica bauxite, corundum [aluminum oxide], fluorspar, muscovite and phlogopite mica, quartz crystal, Indian block talc.

Demille concluded, "One of the costliest lessons of unpreparedness for war was stated to have been the danger involved in dependence on foreign sources for certain minerals and other strategic raw materials."

II. U.S. NNR VULNERABILITY ANALYSIS

The following U.S. NNR Vulnerability Analysis assesses the extent to which our American way of life is vulnerable to import-related NNR supply disruptions. It describes the three determinants of import-related NNR vulnerability; it also assesses the "disruptive potential" associated with each of the 87 NNRs that enable our American way of life.[15] (For underlying details, see "Appendix A: U.S. NNR Vulnerability Analysis Summary Data.")

Import-related NNR vulnerability determinants

Three factors determine the extent to which our American way of life is vulnerable to import-related NNR supply disruptions:

- *NNR Criticality*[16] — the significance associated with an NNR in enabling our American way of life.
- *NNR Import Reliance* — the percentage of total American NNR supply attributable to imports.
- *NNR Import Source Reliability* — the dependability associated with suppliers (and supplies) of imported NNRs.

NNR criticality

Although each of the 87 analyzed NNRs plays a role in enabling our American way of life — otherwise it would not be in use — some NNRs play more significant roles than others.[17]

NNR criticality determinants

For purposes of the Vulnerability Analysis, NNR Criticality is determined by the role played by an NNR in providing the societal essentials — i.e., clean water, food, energy, infrastructure, and necessary goods and services — that enable America's modern industrialized existence.

The Vulnerability Analysis classifies NNRs according to their significance in enabling our American way of life:

- Indispensable: the NNR plays a primary role in providing one or more of the societal essentials that enable our American way of life; substitutes, in cases where they exist, are substantially inferior from a price/performance perspective. Indispensable NNRs include primary energy sources; primary metals; primary agricultural additives; ubiquitous construction/industrial materials; and sources of numerous NNR byproducts.
- Critical: the NNR plays a major support role in providing one or more of the societal essentials that enable our American way of life; substitutes that are acceptable from a price/performance perspective are generally limited. Critical NNRs include major alloys, catalysts, dopants, and reagents; secondary agricultural additives; primary "high-tech" and specialty metals and minerals; and sources of a limited number of NNR byproducts.
- Important: the NNR plays a minor support role in providing one or more of the societal essentials that enable our American way of life; substitutes that are acceptable from a price/performance perspective are typically available in most application areas. Important NNRs include fillers, extenders, fluxes, insulators, weighting agents, and absorbents; and secondary "high-tech" and specialty metals and minerals.

Note that as NNR criticality increases, the likelihood of an import-related supply disruption increases — NNR producers are more likely to restrict exports of highly critical NNRs for political, economic, ideological, putative, and other reasons. Too, as NNR criticality increases, the potential severity associated with an import-related NNR supply disruption increases.

NNR criticality summary

Of the 87 NNRs that enable our American way of life, 21 (24 percent) are considered indispensable; 38 (44 percent) are considered critical; and 28 (32 percent) are considered important.

[Given that NNR criticality classification is a subjective process, "borderline NNRs" exist — i.e., NNRs that could be classified as either "indispensable" or "critical," and others as either "critical" or "important".]

NNR criticality — a summary

It is not necessarily the case that the most heavily used NNRs are also the most critical. In the case of "high tech" metals such as gallium, germanium, indium, and tellurium, annual utilization quantities are often relatively small, yet many of the end-products containing these NNRs are essential to our American way of life.

INDISPENSABLE NNRS

Aluminum, Bauxite, Cement, Clays, Coal, Copper, Gypsum, Iron Ore, Iron/Steel, Lead, Natural Gas, Nickel, Nitrogen (Fixed), Oil, Phosphate Rock, Potash, Sand & Gravel (Construction), Silicon, Stone (Crushed), Sulfur, Zinc

CRITICAL NNRS

Abrasives, Antimony, Arsenic, Beryllium, Bismuth, Boron, Chromium, Cobalt, Fluorspar, Gallium, Germanium, Graphite, Indium, Iodine, Lime, Lithium, Magnesium Compounds, Magnesium Metal, Manganese, Molybdenum, Niobium, Platinum Group Metals (PGMs), Quartz Crystal, Rare Earth Minerals (REMs), Rhenium, Salt, Sand and Gravel (Industrial), Silver, Soda Ash, Tantalum, Tellurium, Tin, Titanium Mineral Concentrates, Titanium Metal, Tungsten, Uranium, Vanadium, Zirconium

IMPORTANT NNRS

Asbestos, Barite, Bromine, Cadmium, Cesium, Diamond, Diatomite, Feldspar, Garnet, Gold, Hafnium, Helium, Kyanite, Mercury, Mica, Peat, Perlite, Pumice, Rubidium, Selenium, Stone (Dimension), Strontium, Talc, Thallium, Thorium, Vermiculite, Wollastonite, Zeolites

NNR: Indispensable to our American way of life
NNR: Critical to our American way of life
NNR: Important to our American way of life

In other cases, low-volume NNRs enable the effective utilization of extremely significant high-volume NNRs. Import-related supply disruptions associated with low-volume "support" NNRs such as catalysts, alloys, and reagents would be extremely disruptive to our American way of life in scenarios where such disruptions would cause "no build" situations involving essential goods and infrastructure.

NNR import reliance

In situations where U.S. NNR supplies — i.e., domestically mined, recycled, and stockpiled NNRs — are insufficient to completely address our domestic (U.S.) requirements, we must import NNRs from foreign nations.

NNR import reliance definition

For purposes of the Vulnerability Analysis, U.S. NNR Import Reliance is defined as the average percentage of "net" U.S. NNR imports[18] between the years 2009 and 2013. (See "Appendix A: U.S. NNR Vulnerability Analysis Summary Data" for details.)

Note that as U.S. NNR import reliance increases, the potential severity associated with an import-related NNR supply disruption increases as well.

NNR import reliance summary

In 66 of the 87 analyzed NNR cases (76 percent), America is import reliant to some extent — in 16 cases (18 percent), the U.S. is entirely reliant upon NNR imports. In only 19 cases (22 percent) is America not "net" import reliant.

America is also a large net importer of finished goods and infrastructure — much of which is designed, developed, manufactured, and provisioned through the utilization of foreign NNRs. The U.S. is effectively an "indirect" importer of these foreign NNRs.

Because indirect NNR imports are not reflected in available data, the preceding figures understate both America's NNR import reliance and the vulnerability of our American way of life to foreign NNR supplies.

NNR import source reliability

In situations where America is NNR import reliant, the reliability associated with foreign NNR suppliers (and supplies) is of primary concern.

NNR import source reliability determinants

Determinants of U.S. NNR import source reliability include both qualitative factors and quantitative factors.

Qualitative Determinants of U.S. NNR import source reliability involve geology, geography, economics, politics, and ideology:

- Supplier NNR Export Policy — willingness to export NNRs, in what form(s), in what quantities, under what conditions, and to whom;
- Supplier Relationship with the U.S. — adversarial, neutral, or friendly;
- Supplier Societal Stability — political and economic consistency and predictability;
- Supplier Proximity — geographical "closeness" to the U.S.;
- Resource Accessibility — owing to factors such as climate, terrain, infrastructure, and

U.S. IMPORT %	NNR#	NNRS IMPORTED BY THE U.S.
0% No Net Imports	19	*Boron,* Clays, Coal, Diatomite, Feldspar, Gold, Helium, Iron Ore, Kyanite, *Lime**, Mercury, *Molybdenum,* Sand & Gravel (Construction)*, *Sand & Gravel (Industrial),* Selenium, *Soda Ash,* Stone (Crushed)*, Wollastonite, Zeolites
2%-20% Imports	13	Aluminum, Cadmium, Cement, Diamond, Gypsum, Iron/Steel, Lead, Natural Gas, Phosphate Rock, Pumice, Sulfur, Talc, *Zirconium*
21%-40% Imports	9	*Beryllium*, Bromine, Copper, *Magnesium Metal*, Nitrogen (Fixed), Perlite, *Salt*, Silicon, Vermiculite
41%-60% Imports	7	*Chromium, Lithium, Magnesium Compounds,* Nickel, Oil (All Liquids), *Silver, Tungsten*
61%-80% Imports	10	*Abrasives*, Barite, *Cobalt*, Garnet, Peat, Stone (Dimension), *Tin*, *Titanium Mineral Concentrates, Titanium Metal,* Zinc
81%-99% Imports	11	*Antimony, Bismuth, Gallium, Germanium, Iodine, Platinum Group Metals (PGMs),* Potash, *Rare Earth Minerals (REMs), Rhenium, Uranium, Vanadium*
100% Imports	16	*Arsenic,* Asbestos, Bauxite, Cesium, *Fluorspar, Graphite, Indium, Manganese,* Mica, *Niobium, Quartz Crystal,* Rubidium, Strontium, *Tantalum,* Thallium, Thorium
Insufficient Data**	2	Hafnium, *Tellurium*

NNR deposit location;

- Supplier Disaster Propensity — susceptibility to mine cave-ins, rock slides, fires, floods, power outages, and strikes; and
- Supplier Diversity — number of global NNR exporters.

Quantitative Determinants of U.S. NNR import source reliability involve NNR exporter prominence as a U.S. NNR supplier and NNR exporter capacity to influence NNR prices and availability:

- Supplier Share of U.S. NNR Imports.
- Supplier Share of Annual Global NNR Extraction/Production.
- Supplier Share of Proven Global NNR Reserves.

Note that as U.S. NNR import sources become increasingly questionable, the likelihood of an import-related supply disruption increases as well.

NNR import source classifications

For each imported NNR, U.S. import sources are classified as:[19]

Predominantly Reliable

Partially Reliable (Mixed Reliability)

Predominantly Questionable

NNR import source reliability summary

In 11 of the 87 analyzed NNR cases (13 percent), U.S. NNR import sources are predominantly reliable; in 35 cases (40 percent), U.S. NNR import sources are partially reliable; and in 22 cases (25 percent), U.S. NNR import sources are predominantly questionable. In 19 cases (22 percent), the U.S. is not "net" import reliant.

U.S. IMPORT SOURCE RELIABILITY SUMMARY	
No Net Imports	**Reliable**
Boron, Clays, Coal, Diatomite, Feldspar, Gold, Helium, Iron Ore, Kyanite, *Lime*, Mercury, *Molybdenum*, Sand & Gravel (Construction), *Sand & Gravel (Industrial)*, Selenium, *Soda Ash*, Stone (Crushed), Wollastonite, Zeolites	Cesium, Gypsum, Hafnium, Lead, Natural Gas, Peat, Rubidium, *Salt*, Silver, Sulfur, Thallium
Partially Reliable	**Questionable**
Aluminum, Bauxite, Asbestos, Bromine, Cadmium, Cement, Copper, *Fluorspar*, *Gallium*, Garnet, *Indium*, *Iodine*, Iron & Steel, Lithium, *Magnesium Metal*, Mica, Nickel, *Niobium*, Nitrogen (Fixed), Perlite, Potash, Pumice, *Rhenium*, Stone (Dimension), Strontium, Talc, *Tantalum*, *Tellurium*, Thorium, *Tin*, *Titanium Mineral Concentrates*, *Titanium Metal*, *Uranium*, Zinc, *Zirconium*	*Abrasives*, *Antimony*, *Arsenic*, Barite, *Beryllium*, *Bismuth*, *Chromium*, *Cobalt*, Diamond, *Germanium*, *Graphite*, *Magnesium Compounds*, *Manganese*, Oil, Phosphate Rock, *Platinum Group Metals*, *Quartz Crystal*, *Rare Earth Minerals*, Silicon, *Tungsten*, *Vanadium*, Vermiculite

To the extent possible, America obtains imported NNRs from highly reliable sources such as Canada and Mexico. In the event that sufficient NNR imports cannot be obtained from friendly, stable, proximate, and low risk sources, we resort to slightly less reliable sources such as Chile, Peru, and Brazil.

Unfortunately, because America is often unable to obtain sufficient NNR imports from reliable or semi-reliable sources, we must resort to questionable sources such as China, the Former Soviet Union, and nations comprising continental Africa.

In 41 cases (47 percent), the U.S. imports some of its NNR supply from China — 29 of these NNRs are either indispensable or critical to enabling our American way of life.

NNRS IMPORTED FROM CHINA

Abrasives, Aluminum, *Antimony*, *Arsenic*, Barite, *Beryllium*, *Bismuth*, *Boron*, Bromine, Cement, *Chromium*, Coal, *Cobalt*, Diamond, Feldspar, *Fluorspar*, *Gallium*, Garnet, *Germanium*, *Graphite*, *Indium*, *Lithium*, *Magnesium Compounds*, *Magnesium Metal*, Mica, Oil, *Quartz Crystal, Rare Earth Minerals (REMs)*, Selenium, Silicon, *Soda Ash*, Stone (Dimension), Strontium, Talc, *Tantalum*, *Tellurium*, *Titanium Metal*, *Tungsten*, *Vanadium*, Vermiculite, Wollastonite.

In 21 cases (24 percent), the U.S. imports some of its NNR supply from one or more of the nations comprising the Former Soviet Union — 20 of these NNRs are either indispensable or critical to enabling our American way of life.

NNRS IMPORTED FROM THE FORMER SOVIET UNION

Abrasives, Aluminum, *Beryllium, Chromium,* Coal*, Cobalt, Germanium, Manganese,* Nickel, Nitrogen (Fixed), Oil*, Platinum Group Metals (PGMs),* Potash*, Quartz Crystal, Rhenium,* Silicon, *Tantalum,* Thallium*, Titanium Metal, Vanadium, Zirconium*

In 20 cases (23 percent), the U.S. imports some of its NNR supply from one or more of the nations comprising continental Africa — 16 of these NNRs are either indispensable or critical to enabling our American way of life.

NNRS IMPORTED FROM AFRICA

Abrasives, *Arsenic*, Barite, Bauxite, Coal, *Chromium,* Diamond, *Fluorspar,* Kyanite, *Manganese, Niobium,* Oil, Phosphate Rock, *Platinum Group Metals (PGMs),* Silicon, *Tantalum, Titanium Mineral Concentrates, Vanadium,* Vermiculite*, Zirconium*

In 20 cases (23 percent), at least 50 percent of U.S. NNR imports come from China, the Former Soviet Union, and Africa (combined) — 17 of these NNRs are either indispensable or critical to enabling our American way of life.

AT LEAST 50 PERCENT OF GLOBAL RESERVES EXIST IN CHINA, FSU, AND AFRICA

Antimony, *Arsenic*, Barite, *Bismuth*, *Chromium, Cobalt,* Diamond, *Magnesium Compounds, Manganese,* Phosphate Rock, *Platinum Group Metals (PGMs),* Strontium*, Tungsten, Vanadium*

In 37 cases (43 percent), at least 50 percent of current (2013) global NNR extraction/production occurs in China, the Former Soviet Union, and Africa (combined) — 30 of these NNRs are either indispensable or critical to enabling our American way of life.

AT LEAST 50 PERCENT OF U.S. IMPORTS COME FROM CHINA, THE FSU, AND AFRICA

Abrasives, *Antimony*, *Arsenic*, Barite, *Beryllium, Bismuth, Chromium,* Diamond, *Germanium, Magnesium Compounds, Manganese,* Phosphate Rock, *Platinum Group Metals (PGMs), Quartz Crystal, Rare Earth Minerals (REMs),* Silicon (Ferrosilicon), *Tantalum (Metal), Vanadium (Pentoxide),* Vermiculite*, Zirconium (Mineral Concentrates)*

In 14 (29 percent) of the 48 cases for which global NNR reserve data are available,[20] at least 50 percent of proven global NNR reserves are located in China, the Former Soviet Union, and Africa (combined) — 12 of these NNRs are either indispensable or critical to enabling our American way of life.

AT LEAST 50 PERCENT OF GLOBAL PRODUCTION OCCURS IN CHINA, THE FSU, AND AFRICA

Abrasives, Aluminum, *Antimony*, *Arsenic*, Asbestos, Barite, *Bismuth*, Cement, *Chromium, Cobalt,* Diamond, *Fluorspar, Gallium, Germanium, Graphite, Indium,* Iron & Steel, Iron Ore, Kyanite, Lead, *Lime*, *Magnesium Compounds, Magnesium Metal*, *Manganese, Mercury,* Mica, Phosphate Rock, *Platinum Group Metals (PGMs),* Potash, *Rare Earth Minerals (REMs)*, Silicon, *Tantalum,* Thallium, *Titanium Metal, Tungsten, Vanadium,* Zeolites

NNR disruptive potential assessment

The U.S. NNR Disruptive Potential Assessment [Assessment] evaluates the capacity of the 87 analyzed NNRs to undermine our American way of life. Disruptive potential in each case is determined by NNR criticality, U.S. NNR import reliance, and U.S. NNR import source reliability.

NNR disruptive potential definition

NNR disruptive potential assesses the likelihood and potential severity associated with an import-related NNR supply disruption.

U.S. NNR disruptive potential assesses the capacity of an NNR to decrease U.S. economic (GDP) output and material living standards by impairing the provisioning of one or more societal essentials — i.e., clean water, food, energy, infrastructure, and necessary goods and services.[21]

In practical terms, the greater the criticality associated with an NNR, and the greater America's reliance upon imported NNR supplies, and the less reliable American NNR import sources, the greater the disruptive potential associated with the NNR.

NNR disruptive potential assessment summary

The Assessment employs a qualitative classification scheme — U.S. NNR disruptive potential is rated as: "very high," "high," "medium," "low," "very low," or "negligible."

U.S. NNR disruptive potential is currently considered "high" in 17 of the 87 analyzed cases (19.5 percent); "medium" in 17 cases (19.5 percent); "low" in 12 cases (14 percent); "very low" in 22 cases"; and "negligible" in 19 cases (22 percent). In no cases is the disruptive potential currently considered "very high."

U.S. NNR DISRUPTIVE POTENTIAL RATING SUMMARY

DISRUPTIVE POTENTIAL	NNR#	NNRs
Very High	0	No NNRs
High	17	*Abrasives*, *Antimony*, *Arsenic*, Bauxite, *Bismuth*, *Cobalt*, *Germanium*, *Graphite*, *Manganese*, Oil, *Platinum Group Metals (PGM)*, Potash, *Quartz Crystal*, *Rare Earth Metals (REMs)*, Silicon, *Vanadium*, Zinc
Medium	17	*Beryllium*, *Chromium*, *Fluorspar*, *Gallium, Indium, Iodine*, *Magnesium Compounds*, Nickel, *Niobium*, Phosphate Rock, *Rhenium*, *Tantalum*, *Tin*, *Titanium Mineral Concentrates*, *Titanium Metal*, *Tungsten*, *Uranium*
Low	12	Aluminum, Asbestos, Barite, Cement, Copper, Iron/Steel, *Lithium*, *Magnesium Metal*, Mica, Nitrogen (Fixed), Strontium, Thorium
Very Low	22	Bromine, Cadmium, Cesium, Diamond, Garnet, Gypsum, Hafnium, Lead, Natural Gas, Peat, Perlite, Pumice, Rubidium, *Salt*, *Silver*, Stone (Dimension), Sulfur, Talc, *Tellurium*, Thallium, Vermiculite, *Zirconium*
Negligible	19	*Boron*, Clays, Coal, Diatomite, Feldspar, Gold, Helium, Iron Ore, Kyanite, *Lime*, Mercury, *Molybdenum*, Sand & Gravel (Construction), *Sand & Gravel (Industrial)*, Selenium, *Soda Ash*, Stone (Crushed), Wollastonite, Zeolites

Disruptive potential assessment findings

• Some level of disruptive potential currently exists with respect to 68 of the 87 analyzed NNRs (78 percent). America would be prudent to ensure access to adequate supplies of these NNRs, especially those with "high" and "medium" disruptive potential ratings.

• While the Assessment reveals no NNRs with "very high" disruptive potential, the fact that "indirect" NNR imports are not considered understates this disruptive potential. To the extent that foreign NNRs are utilized in the provisioning of goods and services that are exported to America, which is typically the case, the disruptive potential associated with these NNRs is greater than assessment ratings indicate.

• Disruptive potential is amplified in situations involving simultaneous or cascading import-related NNR supply disruptions — the "compounding" effect — especially in cases involving multiple critical or indispensable NNRs.

• Catastrophic societal impacts can result from import-related supply disruptions involving seemingly insignificant NNRs (e.g., catalysts, alloys, or reagents) in situations where such disruptions limit the effective utilization of one or more indispensable NNRs (e.g., steel, oil, or potash) — the "Achilles heel" effect.

• An import-related supply disruption associated with a "primary" NNR, such as nickel, could cause supply disruptions of associated "byproduct" NNRs such as cobalt, platinum group metals (PGMs), and tellurium.

• While the Assessment focuses on import-related U.S. NNR vulnerability and disruptive potential, America is also highly vulnerable in many cases to domestic (U.S.) NNR supply disruptions — especially in situations involving advanced-stage U.S. NNR depletion.[22]

Early warning signs

U.S. import-related NNR supply disruptions — typically caused by NNR export controls and access restrictions imposed by major global NNR producers — have occurred historically (e.g., the 1970s oil shocks), and are occurring with increasing frequency today.

According to the OECD,[23] "Prices for many raw materials have increased significantly over the past few years. At the same time, producer countries are making greater use of measures which raise export prices, limit export quantity, or place other conditions on exports."

Specifically,[24] "The number of countries applying export duties (65 of 128 WTO members) during 2003-2009 is higher than it was in the previous analysis (39 of 100 WTO Members during 1997-2002)."

More specifically, the OECD publishes a database — "Restrictions on Exports of Raw Materials (Industrial raw materials)" — that details literally thousands of NNR export controls and access restrictions imposed by global NNR producers.[25]

These NNR export controls and access restrictions increase U.S. vulnerability to import-related NNR supply disruptions — as noted by the Defense Department,[26]

> "Heavy reliance on imported material makes consuming industries vulnerable to fluctuations in the world price and availability of such inputs. China, for example, is a major producer of many of the materials for which

> the United States is heavily import reliant. In addition to tungsten, China produces at least half of the world output of antimony, arsenic, bismuth, fluorspar, indium, and rare earths, for all of which the United States is totally reliant on imports.
>
> In some cases China also maintains a great share of total global reserves, and typically exercises various controls over its exports of these commodities. At the WTO [World Trade Organization] Council for Trade in Goods, in November, 2007, the United States posed questions to China about the justification for maintaining these controls on a dozen materials, including antimony, coke [coal], fluorspar, indium, magnesium carbonate, molybdenum, rare earths, silicon, talc, tin, tungsten, and zinc.
>
> With the increases in world demand for many materials, such policies, if widely adopted, could result in severe distortions of global markets and a difficulty for U.S. manufacturers to obtain raw material inputs in a timely and cost competitive manner.

Going forward, the frequency and severity associated with NNR export controls and consequent U.S. import-related NNR supply disruptions will almost certainly increase as NNR scarcity becomes increasingly prevalent. The net effect will be diminished domestic (U.S.) and global prosperity.

III. AMERICA'S PREDICAMENT — 'the squeeze is on'

As a consequence of ever-increasing exploitation since the inception of our industrial revolution, Earth's NNR supply mix is shifting from "high-quality/low-cost" to "low-quality/high-cost." Continuously decreasing NNR quality in conjunction with our enormous and ever-increasing resource requirements are causing increasingly prevalent scarcity and faltering prosperity — i.e., diminishing economic growth and material living standard improvement — both domestically and globally.

Increasing NNR scarcity → faltering prosperity

Increasing NNR Scarcity

While there will always be plenty of NNRs in the ground (we will never "run out" of any NNR), and over the near term there will likely be more NNRs of nearly every type supplied each year, in an increasing number of cases there are not enough economically viable NNRs to completely address our global requirements — i.e., to increase human prosperity at a rate that we consider "acceptable."

Increasing Domestic (U.S.) NNR Scarcity

U.S. NNR import reliance — domestic scarcity — has increased significantly during our modern (post WWII) industrial era, a trend that is likely to persist going forward. Historically, America was able to mitigate the effects associated with increasing domestic NNR scarcity through fiscal profligacy[27] — i.e., by procuring imported NNRs with fiat currency and borrowed money — a trend that is not likely to persist going forward.

Historical NNR Scarcity

While the U.S. has always been NNR import reliant to some extent, American reliance upon imported NNRs has increased significantly during the past several decades. As recently as 1995, the U.S. was import reliant with respect to 45 NNRs; by the year 2013, that number had increased to 63. During the same period, the number of NNRs for which the U.S. was 100 percent import reliant increased from 8 to 19.[28]

Of the 87 NNRs considered in the Vulnerability Analysis, the U.S. is currently import reliant in three quarters of the cases (66 NNRs) — 16 of which are indispensable enablers of our American way of life, and 22 of which are imported from predominantly questionable sources.

Future NNR Scarcity

Going forward, domestic (U.S.) NNR scarcity will almost certainly increase as American NNR requirements increase and U.S. NNR reserves become increasingly depleted.

The Census Bureau expects the U.S. population level to increase from 317 million in 2013 to 400 million in 2050.[29] Even if future per capita U.S. NNR requirements remain unchanged, aggregate annual U.S. NNR requirements will increase by over 25 percent by the year 2050.

Moreover, should the highly touted American "manufacturing renaissance" become a reality,[30] future U.S. NNR requirements will increase even more dramatically.

Unfortunately, juxtaposed against increasing future U.S. NNR requirements, is the continuing drawdown of domestic (U.S.) NNR reserves, many of which are already significantly depleted. Of the 87 NNRs considered in the Vulnerability Analysis, U.S. extraction/production levels peaked (to date) prior to the year 2000 in 70 cases (80 percent).[31]

Of the 70 cases in which domestic (U.S.) NNR extraction/production peaked (to date) prior to the year 2000, it is very likely that U.S. extraction/production has peaked permanently and is in terminal decline. The inevitable consequence is generally increasing American import reliance with respect to the vast majority of these 70 NNRs.

PEAK (TO DATE) DOMESTIC (U.S.) NNR EXTRACTION/PRODUCTION YEARS		
US PEAK	NNR#	NNRs
Pre-1950	15	*Antimony*, *Arsenic*, Bauxite, *Fluorspar*, *Graphite*, Lead, *Magnesium Metal*, *Manganese*, Mercury, *Niobium*, *Silver*, Strontium, *Tantalum*, *Tin*, *Zirconium*
1950-1974	22	Asbestos, Cadmium, Cesium, *Chromium*, Clays, *Cobalt*, Helium, *Indium*, Iron/Steel, Iron Ore, *Lithium*, *Magnesium Compounds*, Oil (Crude), Potash, Selenium, Stone (Dimension), *Tellurium*, Thorium, *Titanium Minerals*, *Tungsten*, Vermiculite, Zinc
1975-1999	33	*Abrasives (Manufactured)*, Aluminum, Barite, *Beryllium*, *Bismuth*, *Boron*, Bromine, Copper, Feldspar, *Gallium*, Garnet, *Germanium*, Gold, Hafnium, *Iodine*, Mica (Scrap), *Molybdenum*, Nickel, Nitrogen (Fixed), Peat, Perlite, Phosphate Rock, *Quartz Crystal*, Rare Earth Minerals (REMs), *Rhenium*, Rubidium, Silicon, Sulfur, Talc, Thallium, *Titanium Metal*, *Uranium*, *Vanadium*
2000-2012	17	Cement, Coal, Diamond, Diatomite, Gypsum, Kyanite, *Lime*, Natural Gas, *Platinum Group Metals (PGMs)*, Pumice, *Salt*, Sand & Gravel (Construction), *Sand & Gravel (Industrial)*, *Soda Ash*, Stone (Crushed), Wollastonite, Zeolites

Increasing global NNR scarcity

Global NNR scarcity has been increasing as well — especially during the new millennium — as evidenced by persistently high NNR price levels.[32] Global NNR scarcity differs fundamentally from domestic (U.S.) NNR scarcity, however, in the sense that global NNR scarcity cannot be resolved through imports — there is only one Earth.

Historical global NNR scarcity

Humanity's quest for universal "American way of life" prosperity through global industrialization during the latter decades of the twentieth century caused fundamental shifts in global NNR demand/supply dynamics.

• On the "demand side," approximately 1 billion people occupied industrialized and industrializing nations during the mid/late twentieth century.[33] By the year 2000, as a consequence of the industrialization initiatives launched by China, India, Brazil, and other emerging nations in Asia, Africa, and Latin America, that number had increased to over 5 billion.

As a result, global NNR requirements increased nearly instantaneously and extraordinarily during the early years of the new millennium. More importantly, early twenty-first century NNR utilization levels within these newly industrializing nations represented only tiny fractions of their longer-term requirements.

• On the "supply side," owing to persistent and increasing exploitation since the beginning of our industrial revolution, the quality associated with the vast majority of NNRs has been decreasing — i.e., global NNR discoveries and deposits are generally fewer in number, smaller in size, less accessible, and of lower grade, and purity.[34]

Increasingly, the cost advantages derived from new exploration, extraction, and processing technologies are failing to offset the cost disadvantages attributable to exploiting Earth's lower quality NNR deposits. The result is diminishing returns on NNR-related investments — i.e., each incremental dollar invested in NNR exploitation yields smaller quantities of economically viable NNRs.[35]

Global NNR supplies, which had remained sufficiently "low cost" in most cases during the mid-to-late twentieth century to enable relatively low price levels, became increasingly "high cost" during the early years of the twenty-first century, as increasingly expensive marginal NNR deposits were exploited in order to address rapidly increasing global demand. By the year 2008, costs (and prices) associated with most NNRs had increased to historically unprecedented levels — global NNR scarcity had become epidemic.[36]

In fact, 63 of the 89 NNRs analyzed in "Scarcity — Humanity's Final Chapter?" — including aluminum, chromium, coal, copper, gypsum, iron/steel, magnesium, manganese, molybdenum, natural gas, oil, phosphate rock, potash, rare earth minerals, titanium, tungsten, uranium, vanadium, and zinc — were scarce globally in 2008.[37]

Future global NNR scarcity

Some analysts contend that our current episode of global NNR scarcity is simply the result of a temporary, albeit protracted, "commodity super cycle." They expect substantial quantities of high quality/low cost NNRs to be brought online immediately and for the foreseeable future, which will suppress NNR prices and bring an end to our current episode of global NNR scarcity.[38]

While it is unclear at this point whether our current scarcity will prove to be permanent, it is clear that future episodes of global NNR abundance and improving human prosperity, should they occur, will be brief and temporary.[39]

The prevailing trend going forward will be increasingly prevalent global NNR scarcity, which will exacerbate domestic (U.S.) NNR scarcity. Imports will come under increasing pressure in a geological sense — historically reliable U.S. NNR sources will have fewer NNRs available for export — and in an economic sense — an increasing number of industrialized and industrializing nations will compete against the U.S. for diminishing NNR exports.

Faltering prosperity

During the course of our modern industrial era, as relative NNR abundance has transitioned to increasingly prevalent NNR scarcity, both domestically and globally, robustly increasing prosperity has transitioned to faltering prosperity — i.e., we are experiencing diminishing economic growth and material living standard improvement — both domestically and globally.[40]

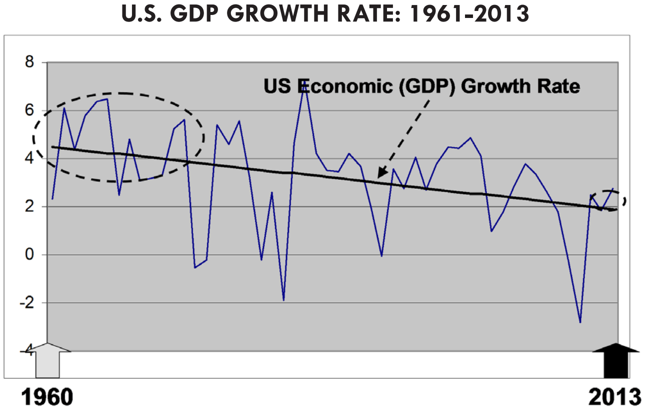
Faltering domestic U.S. prosperity

Vigorously increasing prosperity — i.e., generally robust economic (GDP) growth and improving material living standards (per capita GDP) — that we in America historically took for granted, has been displaced by persistent malaise.

U.S. economic (GDP) growth

Between 1961 and 2013, the overall trajectory associated with annual U.S. economic (GDP) growth was decidedly negative (downward tending). The average annual U.S. GDP growth rate plunged from a relatively robust 4.56 percent between 1961 and 1973 (prior to the oil shocks) to 2.75 percent thereafter (1974-2012). Annual U.S. GDP growth currently hovers slightly above 2 percent, approximately half the 1960s rate!

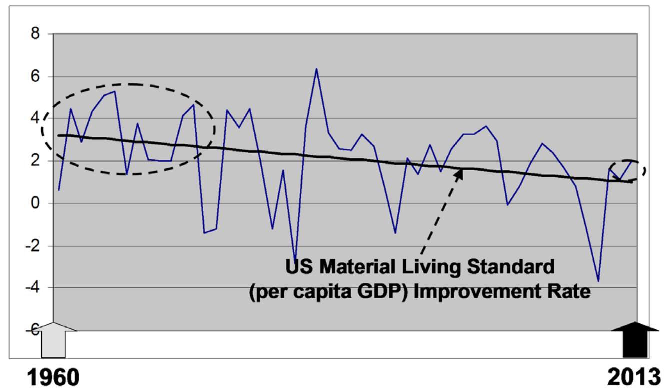
INFLATION ADJUSTED ANNUAL U.S. GDP GROWTH RATE: 1961-2013



U.S. material living standard (Per Capita GDP) improvement

Not surprisingly, the trajectory associated with U.S. material living standard (per capita GDP) improvement paralleled the negative trajectory in America's economic (GDP) growth during our modern industrial era. The average annual U.S. per capita GDP growth rate decreased from a relatively strong 3.29 percent between 1961 and 1973 to 1.72 percent thereafter (1974-2012).

INFLATION ADJUSTED ANNUAL U.S. PER CAPITA GDP GROWTH RATE: 1961-2013



Faltering global prosperity

As is the case with U.S. prosperity — while global prosperity is still increasing, it is increasing at a decreasing rate on average.

Global economic (GDP) growth

Between the years 1961 and 2013, the trajectory associated with annual global economic (GDP) growth declined even more precipitously than did that of the U.S. The average annual global GDP growth rate plunged from a very healthy 5.34 percent between 1961 and 1973 to 2.86 percent between 1974 and 2012. At approximately 2 percent, the current annual global GDP growth rate is significantly less than half the 1960s rate!

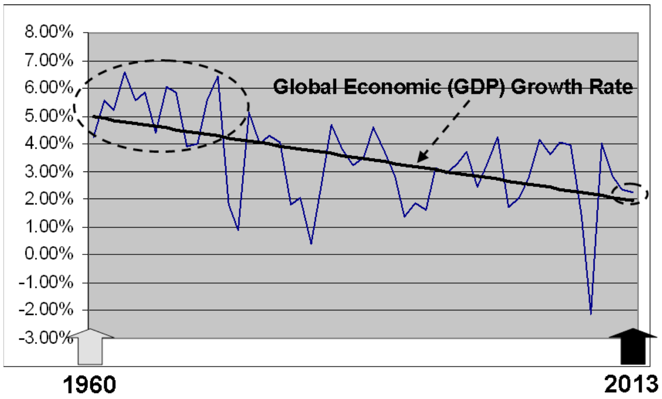
Global material living standard (Per Capita GDP) improvement

The trajectory associated with global material living standard (per capita GDP) improvement tracked with the negative trajectory in global economic (GDP) growth during the 1961-2013 period. The average annual global growth rate in per capita GDP decreased from a relatively strong 3.3 percent between 1961 and 1973, to 1.36 percent between 1974 and 2012. The current global per capita GDP growth rate, at approximately 1 percent per annum, is less than one third of its 1960s rate!

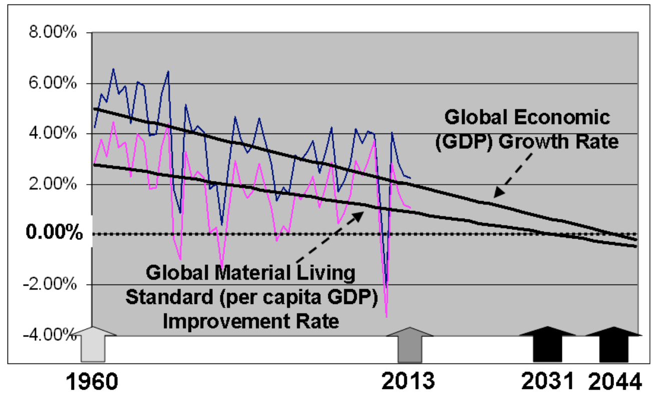
The 2009 Great Recession "lows" with respect to both domestic (U.S.) and global prosperity indicators were historically unprecedented during our modern industrial era; and the post-recession "recovery" has been anemic by any standard,[41] despite historically unprecedented injections of fiscal and monetary "stimulus."

What Happened?

INFLATION ADJUSTED ANNUAL GLOBAL PER CAPITA GDP GROWTH RATE: 1961-2013



PROJECTED GLOBAL PROSPERITY GROWTH TRAJECTORIES



During our modern industrial era, but increasingly over the past several decades, continuously decreasing NNR quality has prevailed over human ingenuity.[42] That is, significant cost increases associated with NNRs of continuously decreasing quality have overwhelmed human technology, resourcefulness, innovation, efficiency improvements, and productivity enhancements.

Our enormous and generally increasing global NNR requirements within the context of lower quality/higher cost (less affordable) global NNR supplies have brought about ever-increasing NNR scarcity, which has caused faltering prosperity, both domestically (U.S.) and globally. We are "rolling over" from our old normal of "continuously more and more" to our new normal of "continuously less and less."[43]

Going forward, diminishing global prosperity will increasingly govern U.S. prosperity — the "global squeeze" will exacerbate the "American squeeze."

IV. REQUIEM FOR A SPECIES — humanity's unraveling

It would be convenient if humanity's unraveling would commence in 1,000 years, or 500 years, or even 50 years. We could then dismiss it as a concern for future generations and continue to enjoy our industrialized way of life in the meantime. Unfortunately, our unraveling is occurring now.

Should currently declining global prosperity growth trajectories persist going forward, both global economic output and global material living standards will peak and enter terminal decline prior to mid-century.[44]

Irrespective, however, of humanity's actual unraveling scenario,[45] the ultimate outcome will be the same. Global competition for increasingly scarce renewable and nonrenewable natural resources will devolve into resource wars, which will devolve into global societal collapse through an ecological/economic/societal chain of events that is being driven by ever-increasing, geologically induced, global NNR scarcity.[46]

The "squeeze is on," as evidenced by increasing social unrest both domestically and globally. The disenfranchised — the hundreds of millions who have attained some level of industrialized prosperity and are watching it slip away; and the dejected — the billions who aspired to industrialized prosperity and are realizing that they will never attain it; are becoming increasingly frustrated, angry, and violent.

No happy ending

Over the coming decades, increasingly frequent and severe resource wars will disrupt our critical natural resource supplies and impair our critical societal support systems such as water storage/distribution, food production/distribution, energy generation/distribution, sanitation, healthcare, transportation, communications, defense, and law enforcement.

Historically Unprecedented Global Requirements for Finite and Non-replenishing NNRs Within the Context of
NNR Supplies of Continuously Decreasing Quality →
Diminishing Returns on Investments in NNR Exploitation →
Persistently High/Increasing NNR Cost/Price Levels →
Stagnating/Decreasing NNR Demand/Utilization Levels →
Stagnating/Decreasing Economic Output Levels →
Stagnating/Decreasing Material Living Standards →
Increasing Economic, Political, and Social Instability/Unrest/Conflict →
Collapsing National Economies followed by Global Societal Collapse

As global NNR supply shortages become increasingly acute, NNR-dependent industrialized nations will no longer be able to generate the economic output levels necessary to fund their ballooning debt service, social entitlement, and social services obligations; nor will they be able to obtain sufficient credit to offset their declining real wealth generation capabilities. The world's interconnected and interdependent national economies will experience cascading defaults.

As global NNR supply shortages become permanent, our bankrupt and war ravaged global industrial mosaic[47] will be unable to provide societal essentials

— clean water, food, energy, infrastructure, and necessary goods and services — at levels sufficient to support our increasingly angry, confused, and desperate populations. Escalating social unrest will devolve into chaos.

It will become universally understood that the only way to "stay even" within a continuously contracting operating environment — much less to improve one's lot — is to take from someone else. Life will become a "negative sum game" within the "shrinking pie" of "continuously less and less."

All industrialized and industrializing nations, irrespective of their economic systems and political orientations, will collapse, taking the aid-dependent, non-industrialized nations with them.

But we're Americans — we're exceptional!

It is certainly not the case that our quest for perpetual prosperity through industrialization, and the natural resource utilization behavior that enables our quest, are inherently evil. We have simply applied our boundless human ingenuity — our technical prowess, resourcefulness, innovation, efficiency improvements, and productivity enhancements — over the past several centuries toward dramatically improving our level of societal wellbeing through ever-increasing NNR utilization.

It is the case, however, that despite our possibly justifiable naïveté during our meteoric rise to "exceptionalism", and despite the fact that our predicament is undoubtedly an unintended consequence of our understandable efforts to continuously improve the material living standards enjoyed by our ever-expanding population, globally available, economically viable NNR supplies are not sufficient to perpetuate our industrial lifestyle paradigm, either domestically or globally.[48]

Humanity's fate was sealed during the eighteenth century with the advent of industrialism; the NNR genie had been released from the bottle and could not be put back. We remained oblivious to our fate throughout the nineteenth and twentieth centuries by misconstruing our windfall of temporary NNR abundance as permanent NNR sufficiency.[49]

The episode of epidemic global NNR scarcity that has occurred during the early twenty-first century is a wake-up call to the fact that our American way of life — the industrial lifestyle paradigm that we consider "normal" — is anything but normal. Our American way of life is a one-time, NNR-enabled anomaly that is coming to an end. Our self-inflicted predicament will culminate in our self-inflicted demise — almost certainly by the year 2050.[50] But…

"*The American way of life is not negotiable!*"

Over the past several generations, as America emerged as the primary global superpower, we have become accustomed to dictating the terms of engagement associated with any and all encounters.

We will soon realize that nobody dictates terms to Nature… ■

Appendix A: U.S. NNR Vulnerability Analysis Summary Data Table (pages 27-32).

The U.S. NNR Vulnerability Analysis Summary Data Table, which follows, contains information pertaining to NNR criticality, U.S. NNR import reliance, and U.S. import source reliability associated with the 87 NNRs that enable our industrialized existence — our American way of life.

Information contained in the table, which serves as the basis for the U.S. NNR Vulnerability Analysis and the U.S. NNR Disruptive Potential Assessment, was obtained from the following sources.

- "Mineral Commodity Summaries 2014," U.S. Geological Survey, 2014 — http://minerals.usgs.gov/minerals/pubs/mcs/2014/mcs2014.pdf.
- "Historical Statistics for Mineral and Material Commodities in the United States," U.S. Geological Survey, 2014 — http://minerals.usgs.gov/ds/2005/140/.
- "International Energy Statistics," U.S. Energy Information Administration, 2014; http://www.eia.gov/cfapps/ipdbproject/
- IEDIndex3.cfm; fossil fuels page for the U.S. — http://www.eia.gov/countries/country-data.cfm?fips=US.
- "U.S. Natural Gas Imports by Country," U.S. Energy Information Administration, 2014 — http://www.eia.gov/dnav/ng/ng_move_impc_s1_a.htm.
- "How dependent are we on foreign oil?" U.S. Energy Information Administration, 5/13 - http://www.eia.gov/energy_in_brief/article/foreign_oil_dependence.cfm.
- "Supply of Uranium," World Nuclear Association, 8/12 — http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Supply-of-Uranium/;
- "Uranium mining in the United States," Wikipedia, 2014 — http://en.wikipedia.org/wiki/Uranium_mining_in_the_United_States;
- "Top 10 Uranium Producing Countries in 2010," International Atomic Energy Association, 2011 — http://www.iaea.org/OurWork/ST/NE/NEFW/Technical_Areas/NFC/images/uranium_cycle/Topten_RBwp.jpg.
- "Reconfiguration of the National Defense Stockpile Report to Congress," U.S. Department of Defense, 4/09 — http://www.acq.osd.mil/mibp/docs/nds_reconfiguration_report_to_congress.pdf; for listings of "Selected Strategic Materials" (DOD), see Appendix C: Summary Risk Assessment (The Institute for Defense Analyses, 9/08).
- "Strategic and Critical Materials 2013 Report on Stockpile Requirements," U.S. Department of Defense, 2013 — http://mineralsmakelife.org/assets/images/con-

tent/resources/Strategic_and_Critical_Materials_2013_Report_on_Stockpile_Requirements.pdf; for additional information (and listings) regarding NNRs considered "strategic" by the U.S. DOD, see "Appendix 2: Materials Studied."

• "Rare and Critical Minerals as By-Products and the Implications for Future Supply," L. Peiro et al. INSEAD, 2011 — http://www.insead.edu/facultyresearch/research/doc.cfm?did=48916; for a listing of metals considered "critical" by various international studies, see page 6; for a table of byproduct (or "hitchhiker") metals, see page 18.

• "By-product Elements and Coupled Elements," M. Leidke, D. Homberg-Heumann, polinaires, 3/12 — http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter6.pdf; for a nice graphic of "carrier" and "byproduct" metals, see page 4.

• "Scarcity — Humanity's Final Chapter?" C. Clugston, 2012, Booklocker.com – www.nnrscarcity.com; see Appendix A: NNR Profiles, pages 143-375, for detailed information on each NNR.

Regarding data under the "Import percent" heading:

• All U.S. NNR import data with the exception of fossil fuels and uranium are averages of United States Geological Survey (USGS) figures (2009–2013).

• U.S. fossil fuels import data are averages of EIA figures between 2008 and 2012

• U.S. uranium import data were obtained from the World Nuclear Association and Wikipedia

Regarding data under the "Questionable U.S. Import Sources" heading:

• U.S. NNR import data is the 2009-2013 average (USGS); with exceptions as noted above

• Global NNR production data are for the year 2013; with the exception of fossil fuels (EIA, 2012) and uranium (see sources listed above, 2012)

• Global NNR reserves data are 2013 (USGS); with the exception of fossil fuels (EIA, 2012) and uranium (see sources listed above, 2012)

Regarding data under the "Disruptive Potential" heading:

• The term "very high," "high," "medium," "low," "very low," or "negligible" is the disruptive potential rating associated with the NNR

• The two metrics are the "import reliance" metric and the "import source reliability" metric

• The summary metric is used in conjunction with NNR criticality to determine U.S. NNR disruptive potential (See Appendix B for additional details)

U.S. NNR VULNERABILITY ANALYSIS SUMMARY DATA TABLE

NNR	Major Uses/Applications	U.S. Import %	Questionable U.S. Import Sources	Disruptive Potential
Abrasives	Finishing agent used to shape, finish, or polish a work-piece through rubbing; strategically significant (DOD).	71% Silicon Carbide	Imports: China (76% fused aluminum oxide; 58% silicon carbide); Global Production: China (72% fused aluminum oxide; 45% silicon carbide)	High 4+5=9
Aluminum	Most widely used non-ferrous metal in the world; application areas include transportation, packaging, building & electrical; gallium & vanadium are byproducts; strategically significant (DOD).	13%	Imports: China & Russia (12%); Global Production: China (45%)	Low 1+3=4
Antimony	Flame retardant (aircraft & clothing); transportation (hardness alloy in lead batteries); semiconductor (ultra-high conductivity); strategically significant (DOD).	85%	Imports: China (71%); Bolivia (5%); Global Production: China (80%); Global Reserves: China & Russia (70%)	High 5+5=10
Arsenic	Wood preservative; pesticide; herbicide; insecticide; alloy; medicine; pigment; high performance semiconductor (solar cell, telecommunication, optical & infrared) applications.	100%	Imports: China (87% metal, 20% trioxide); Global Production: China (56% trioxide)	High 5+5=10
Asbestos	Chloralkali industry applications (electrolysis of sodium chloride to produce chlorine and caustic soda); roofing products; flame retardants (brake pads).	100%	Global Production: China & Russia (72%)	Low 5+3=8
Barite	Weighting agent (gas & oil well drilling fluids, paints, plastics & rubber); filler (paper), extender; radiation shield (barium).	77%	Imports: China (86%); Global Production: China (45%); Global Reserves: China & Kazakhstan (53%)	Low 4+5=9
Bauxite	By far the most price/performance effective source of alumina & aluminum; production of abrasives, chemicals & refractories; strategically significant (DOD).	100%	Imports: Guinea (24%); Global Production: China & Indonesia (30%); Global Reserves: Guinea (26%)	High 5+3=8

Beryllium	Aerospace (satellites, space vehicles, space optical system components); defense (inertial guidance systems, military aircraft brakes, nuclear weaponry); computers & communications; strategically significant (DOD).	29%	Imports: Russia, Kazakhstan & China (76%)	Medium 2+5=7
Bismuth	Nontoxic replacement for lead in solder; alloy; pharmaceuticals; electronics; superconductor (bismuth-tellurium oxide alloy); strategically significant (DOD).	92%	Imports: China (55%); Global Production: China (86%); Global Reserves: China (75%)	High 5+5=10
Boron	Fiberglass; detergents; glass (Pyrex); ceramics; insecticides; preservatives; neodymium magnet component (wind turbines); jet engine fuel ignition material, superconductor, fertilizer micronutrient.	0%	Imports: Turkey (78% boric acid); Global Production: Turkey (61%); Global Reserves: Turkey & Russia (48%)	No Net Imports
Bromine	Fire retardant; oil/gas well drilling fluid; dye; pharmaceuticals, pesticide; removes mercury from coal power plants.	<25%	Imports: China (11%)	Very Low 2+3=5
Cadmium	Nickel cadmium batteries; cadmium telluride solar panels; pigment; plastic stabilizer; corrosion-resistant plating; strategically significant (DOD).	4%	Global Production: China (34%); Global Reserves: China (18%)	Very Low 1+3=4
Cement	Ubiquitous building material – binder in mortar & concrete.	8%	Imports: China (8%); Global Production: China (58%)	Low 1+3=4
Cesium	Oil/gas well drilling fluid; atomic clocks (GPS); photoelectric cells; cancer treatment.	100%	Global Reserves: Zimbabwe (~40%)	Very Low 5+1=6
Chromium	Stainless steel alloy; electroplating; anodizing; pigment; dye; wood preservative; catalyst; superalloy (jet engines & gas turbines); strategically significant (DOD).	52%	Imports: South Africa, Kazakhstan & Russia (62%); Global Production: South Africa & Kazakhstan (58%); Global Reserves: Kazakhstan & South Africa (90%)	Medium 3+5=8
Clays	Tile; ceramics; pottery; bricks; pipes (drainage, sewer); paper; rubber; fiberglass; oil/gas well drilling mud; refractory agent; sealant.	0%		Negligible
Coal	Primary energy source (electricity generation, heating & cooking); coking coal used in iron & steel making.	0%	Global Production: China (45%); Global Reserves: Russia & China (32%)	Negligible
Cobalt	Alloy; pigment; cancer treatment agent; superalloy in gas turbine blades & jet aircraft engines; lithium-ion, nickel-cadmium & nickel-metal-hydride batteries; catalyst; super magnet applications; strategically significant (DOD).	77%	Imports: China & Russia (30%);Global Production: Congo (48%); Global Reserves: Congo (47%)	High 4+5=9
Copper	Thermal conductor; electrical conductor; building material; metal alloy (brass & bronze); super-conductor; antibacterial; fertilizer micronutrient; arsenic, antimony, cobalt, gold, molybdenum, PGMs, rhenium, selenium, silver, tellurium & thallium are byproducts; strategically significant (DOD).	32%	Imports: Chile & Peru (65%);Global Production: Chile & Peru (39%); China (9%); Global Reserves: Chile & Peru (38%)	Low 2+3=5
Diamond	Industrial cutting, grinding & polishing applications; niche semiconductor applications.	3%	Imports: China (77% synthetic diamond); Global Production: Botswana, Congo & Russia (68%); Global Reserves: Congo & Botswana (37%)	Very Low 1+5=6
Diatomite	Mild abrasive; filtration aid; cement additive; filler; insecticide; absorbent; component of dynamite.	0%		Negligible
Feldspar	Container glass; ceramics (flux); geopolymers; filler; insulator (fiberglass); abrasive; solar cells; mica is a byproduct.	0%	Global Production: Turkey & China (40%)	Negligible
Fluorspar	Steel & aluminum production (flux); petroleum refining; opalescent glass manufacture, feedstock for hydrofluoric acid & fluorine bearing chemicals; water fluoridation; strategically significant (DOD).	100%	Imports: China (15%); Global Production: China (64%); Global Reserves: South Africa (17%)	Medium 5+3=8

Gallium	Fuel cells; solar cells (CIGS); high-temperature thermometric applications; alloy; electronic components (microwave, infrared, LEDs); high performance semiconductors; strategically significant (DOD).	99%	Imports: China (21%); Global Production: "China, Germany, Kazakhstan, and Ukraine were the leading producers" (USGS)	Medium 5+3=8
Garnet	Abrasive (sand blasting, water jet cutting & polishing); water filtration medium.	66%	Imports: China (10%); Global Production: China (30%)	Very Low 4+3=7
Germanium	Catalyst (satellite based solar cells); infrared optics; optical fiber cores; thermal imaging, semiconductor (memory & wireless communication applications); nanowires (emerging application); strategically significant (DOD).	88%	Imports: China & Russia (75%); Global Production: China (71%)	High 5+5=10
Gold	Coinage; dentistry; alloy; semiconductors; corrosion resistance applications; mercury & silver are byproducts; strategically significant (DOD).	0%	Global Production: China (15%); Global Reserves: South Africa & Russia (20%)	Negligible
Graphite	Fuel cells; "lead" pencils; refractory; brake linings; semiconductors; zinc-carbon batteries; lubricant; composites (carbon fibers); strategically significant (DOD).	100%	Imports: China (48%); Global Production: China (69%); Global Reserves: China (42%)	High 5+5=10
Gypsum	Wallboard & plaster; (portland) cement; soil conditioner.	12%	Global Production: China & Iran (40%)	Very Low 1+1=2
Hafnium	Cladding material for nuclear fuel rods; strategically significant (DOD).	N/A		Very Low ?+1<8
Helium	Cryogenics (very low temperature); superconducting magnets (MRI scanners); superconductivity (electronics); arc welding; strategically significant (DOD).	0%		Negligible
Indium	LCDs; computer touch screens (ITO); thin-film solar cells; semiconductor component; lubricant: alloy: lead-free solders; control rods (nuclear reactors); strategically significant (DOD).	100%	Imports: China (23%); Global Production: China (57%)	Medium 5+3=8
Iodine	Biocides; iodized salts; LCDs; synthetic fabric treatments; x-ray contrast media.	96%	Imports: Chile (86%); Global Production: Chile (64%); Global Reserves: Japan (66%)	Medium 5+3+8
Iron Ore	Primary feedstock for pig iron, which is used to make steel; niobium, REMs, scandium & vanadium are byproducts.	0%	Global Production: China (45%); Global Reserves: Russia (17%)	Negligible
Iron/Steel	Iron & steel account for approximately 95% of all metals used globally; strategically significant (DOD).	10%	Global Production: China (Iron 62%; steel 31%)	Low 1+3=4
Kyanite	Refractory (iron & steel production); ceramics (plumbing fixtures & dishware); electronics (insulator).	0%	Imports: South Africa (81%); Global Production: South Africa (50%)	Negligible
Lead	Automotive batteries (Starting-Lights-Ignition, lead-acid); ammunition; solder; pewter; alloy; radiation shielding; arsenic, bismuth, cadmium, cobalt, gallium, germanium, indium, silver, thallium & vanadium are byproducts; strategically significant (DOD).	18%	Global Production: China (56%)Global Reserves: China & Russia (26%)	Very Low 1+1+2
Lime	Building mortar, plaster & concrete; chemical feedstock (steelmaking); flue gas desulfurization; water & soil treatment; pulp & paper production.	1%	Global Production: China (63%)	Negligible
Lithium	Heat-resistant glass & ceramics; high strength alloy (aircraft parts); coolant; batteries (lithium-ion); rocket propellant manufacture; production of H-bombs; cesium & rubidium are byproducts; strategically significant (DOD).	58%	Imports: Argentina & Chile (96%); Global Production: Chile & China (50%); Global Reserves: Chile & China (85%)	Low 3+3=6
Magnesium Compounds	Refractories (furnace linings); fertilizer macronutrient; carbon dioxide sequestration.	49%	Imports: China (56%); Global Production: China & Russia (73%); Global Reserves: Russia, China & North Korea (67%)	Medium 3+5=8

Magnesium Metal	**Third most commonly used structural metal; alloy (cars, aerospace equipment, electronic devices, beverage cans); iron & steel desulphurization; reducing agent for uranium & titanium production.**	**31%**	**Imports: China (8%); Global Production: China (88%)**	**Low 2+3+5**
Manganese	**Aluminum, iron & (stainless) steel alloy; gasoline additive; pigment; batteries; fertilizer micronutrient; strategically significant (DOD).**	**100%**	**Imports: South Africa & Gabon (54%); Global Production: China & Gabon (30%); Global Reserves: South Africa & Ukraine (51%)**	**High 5+5=10**
Mercury	**Chlorine & caustic soda production; meters, valves & switches; compact florescent light bulbs; gold & aluminum amalgams; strategically significant (DOD).**	**0%**	**Imports: Chile, Peru & Argentina (85%); Global Production: China (75%); Global Reserves: China (22%)**	**Negligible**
Mica	**Electronics & electrical equipment (insulator); joint (drywall) compound; oil-well drilling additive; paint, plastics, roofing & rubber products additive.**	**100%**	**Imports: China (scrap/flake 29%, sheet 25%); Global Production: China & Russia (scrap/flake 79%); Russia (sheet 41%)**	**Low 5+3=8**
Molybdenum	**High temperature iron & steel alloy (aircraft parts, electrical contacts, industrial motors, automotive, solar cells, wind turbines, tool steels & filaments); superalloy; catalyst; fertilizer micronutrient; rhenium is a byproduct; strategically significant (DOD).**	**0%**	**Global Production: China (41%); Global Reserves: China (39%)**	**Negligible**
Natural Gas	**Primary energy source (cooking, central heating, electricity generation, industrial); fertilizer feedstock; hydrogen fuel cells.**	**11%**	**Global Production: Russia (18%); Global Reserves: Middle East (41%); Russia (25%)**	**Very Low 1+1=2**
Nickel	**Batteries (rechargeable); alloy (stainless steel & cast iron); nonferrous alloy & superalloy; catalyst; plating; magnets (wind turbines);alkaline fuel cells; cobalt, PGMs, selenium & tellurium are byproducts; strategically significant (DOD).**	**42%**	**Imports: Russia (16%); Global Production: Indonesia, Philippines & Russia (45%)**	**Medium 3+3=6**
Niobium	**Alloy (steel strengthening); superalloy (jet & rocket engines & gas turbines); superconducting magnets (MRI); electronics (capacitors); strategically significant (DOD).**	**100%**	**Imports: Brazil (84%); Global Production: Brazil (88%); Global Reserves: Brazil (95%)**	**Medium 5+3=8**
Nitrogen (Fixed)	**Ammonia (anhydrous ammonium sulfate, urea); inorganic (NPK) fertilizers; pharmaceuticals; explosives; cleaning products.**	**38%**	**Imports: Trinidad & Tobago (62%); Russia (7%); Global Production: China & Russia (40%)**	**Low 2+3=5**
Oil (All Liquids)	**Motor fuels (gasoline, diesel, jet fuel); plastics; pharmaceuticals; pesticides; solvents & thousands of industrial & consumer products.**	**50%**	**Imports: Saudi Arabia (13%); Venezuela (9%); Russia (5%) Global Production: Middle East (30%); Russia (12%); Global Reserves: Middle East (52%); Venezuela (14%)**	**High 3+5=8**
Peat	**Limited primary energy source (cooking and heating); soil conditioner; oil absorbent; filtration medium.**	**61%**		**Very Low 3+1=4**
Perlite	**Plaster, mortar, ceiling tiles & insulation; filler; horticultural aggregate; filtration applications.**	**24%**	**Imports: Greece (100%)**	**Very Low 2+3=5**
Phosphate Rock	**Primary NPK (nitrogen, phosphorous, potassium) fertilizer component (macronutrient); animal feed supplements; industrial chemicals.**	**7%**	**Imports: Morocco (70%); Global Production: China (43%); Global Reserves: Morocco (75%); China & Algeria (9%)**	**Medium 1+5=6**
Platinum Group Metals (PGMs)	**Catalysts (chemicals); catalytic converters; fuel cells; computer & communication devices; glass fibers; nuclear reactors; rhodium & ruthenium are byproducts of platinum & palladium; iridium & osmium are byproducts of platinum; strategically significant (DOD).**	**89% Platinum 58% Palladium**	**Imports: South Africa (platinum 18%); Russia & South Africa (palladium 61%); Global Production: South Africa & Russia (platinum 86%; palladium 78%); Global Reserves: South Africa (95%)**	**High 5+5=10**
Potash	**Primary NPK (nitrogen, phosphorous & potassium) fertilizer component (macronutrient); soap; glass; ceramics; chemical dyes; medicines; synthetic rubber; explosives.**	**81%**	**Imports: Russia (10%); Global Production: Russia, Belarus & China (26%); Global Reserves: Belarus & Russia (56%)**	**High 5+3=8**
Pumice	**Light-weight concrete & cinder blocks; soil conditioner; abrasive; absorbent.**	**6%**	**Imports: Greece (89%)**	**Very Low 1+3=4**

Quartz Crystal	Electronics (frequency controls, timers & gauges); optical (lenses); oscillators & filters (computer circuits); communication equipment; strategically significant (DOD).	100%	Imports: "Although no definitive data exist listing import sources for cultured quartz crystal, imported material is thought to be mostly from China, Japan, and Russia." (USGS)	High 5+5=10
Rare Earth Minerals (REMs)	Renewable energy (wind turbines, solar cells); electric vehicles; batteries, lasers, magnets; motors; superconductors; alloy; catalyst (petroleum cracking); strategically significant (DOD).	>75%	Imports: China (79%); Global Production: China (91%); Global Reserves: China (39%)	High 4/5+5=9/10
Rhenium	Alloy & superalloy; superconductor; chemical industry catalyst (petroleum reforming); jet engine (F-15, F-16, F-22 & F-35) & gas turbine engine blades; strategically significant (DOD).	84%	Imports: Chile (metal powder 91%); Kazakhstan (ammonium perrhenate 27%); Global Production: Chile (51%); Global Reserves: Chile (52%)	Medium 5+3=8
Rubidium	Chemical & electronic R&D applications; medical research; GPS frequency standard; atomic clocks; potential superconductor.	100%		Very Low 5+1=6
Salt	Food seasoning; food preservation; highway deicing; chemical industry feedstock (chlorine & caustic soda); water treatment.	22%	Global Production: China (27%)	Very Low 2+1=3
Sand & Gravel (Construction)	Brick making; road base; road coverings (asphalt); concrete production.	<1%		Negligible
Sand & Gravel (Industrial)	Glassmaking; hydraulic fracturing (shales); well packing; foundries (casting); abrasive (sandblasting); icy highway treatment; water filtration.	0%		Negligible
Selenium	Glass; chemicals (catalyst); manganese refinement; pigment; photocells; solar cells; strategically significant (DOD).	0%	Imports: China (17%); Global Reserves: China & Russia (38%)	Negligible
Silicon	Alloy (aluminum & steel); natural stone component (construction); semiconductor (electronics, solar cells & wind turbines); glass; plastics; ceramics; cement; abrasive; sealant; bonding agent; strategically significant (DOD).	39%	Imports: Russia (silicon 21%); China & Russia (ferrosilicon 69%); Global Production: China & Russia (75%)	High 2+5=7
Silver	Electrical conductor; coinage; chemical catalyst; dental amalgam; germicide; optical coating; photographic films; solar cells; mercury is a byproduct; strategically significant (DOD).	60%	Global Production: China & Russia (29%)	Very Low 3+1=4
Soda Ash	Fiber glass; specialty glass; flat glass; chemical industry (acidity regulator); water acidity neutralizer; medicine; electrolyte; water softener.	0%	Imports: China (12%)	Negligible
Stone (Crushed)	Macadam road construction; cement manufacture; riprap; railroad track ballast; filter stone; soil conditioner.	1%		Negligible
Stone (Dimension)	Building, construction & refurbishment applications (masonry, counter tops, tile).	80%	Imports: China (29%); Turkey (22%)	Very Low 4+3=7
Strontium	Pyrotechnics & flares; ceramic ferrite magnets; drilling fluid; alloy (aluminum & magnesium); pigment; filler; CRT glass.	100%	Imports: China (4%); Global Production: China (39%)	Low 5+3=8
Sulfur	Sulfuric acid feedstock; fertilizer macronutrient, fertilizer production (phosphate extraction); rubber (car tires); black gunpowder; insecticide & fungicide.	17%	Global Production: China & Russia (25%)	Very Low 1+1=2
Talc	Lubricant; astringent; filler (paper, plastic & paint); coating; pharmaceuticals; ceramics (automotive & construction industries).	6%	Imports: China (35%); Pakistan (18%); Global Production: China (30%)	Very Low 1+3=4
Tantalum	Electronics (capacitors); alloys (carbide tools, jet engine components, nuclear reactor components, missile parts, surgical instruments); superconductors; catalyst (optical glass); refractory metal; strategically significant (DOD).	100%	Imports: China & Kazakhstan (30%); Global Production: Rwanda & Congo (42%)	Medium 5+3=8

Tellurium	Electronics (CDs, DVDs, far-infrared detectors & optical fibers); alloy (iron, steel, copper & lead); vulcanizing agent (rubber); thermal imaging; solar cells; catalyst (synthetic fibers); strategically significant (DOD).	N/A	Imports: China (23%); Global Production: Russia (#2 – specifics N/A)	Very Low? ?+3<8?
Thallium	Electronics; medical imaging; pharmaceutical; glass manufacturing; infrared detectors; pesticide & insecticide; high temperature superconductor.	100%	Imports: Russia (19%); Global Production: "China, Kazakhstan and Russia were believed to be leading producers of primary thallium." (USGS)	Very Low 5+1=6
Thorium	Nuclear fuel (breeder reactors); alloy (magnesium); heat resistant ceramics; glass additive; catalyst.	100%	Imports: UK (monazite [thorium source] 100%)	Low 5+3=8
Tin	Alloy (bronze, pewter, solder); metal coating; food packaging; window glass; superconducting magnets; LCD monitors; circuit boards; indium, niobium & tantalum are byproducts; strategically significant (DOD).	73%	Imports: Peru, Bolivia & Indonesia (77%); Global Production: China & Indonesia (61%)	Medium 4+3=7
Titanium Mineral Concentrates	Titanium dioxide (TiO_2) pigments (paints, paper, toothpaste & plastics); metal feedstock; photocatalyst.	73%	Imports: South Africa (35%); Global Production: South Africa & China (ilmenite 30%); South Africa (rutile 16%); Global Reserves: China (ilmenite 29%); South Africa (rutile 17%)	Medium 4+3=7
Titanium Metal	Alloy (iron, molybdenum, vanadium & aluminum) in aerospace (jet engines, missiles, airframes & spacecraft) applications; chemicals & petro-chemicals; pulp & paper; orthopedic implants; thorium is a byproduct; strategically significant (DOD).	64%	Imports: Kazakhstan & China (metal 44%); China (dioxide 12%); Global Production: China & Russia (70%); Global Reserves: China (ilmenite 29%); South Africa (rutile 17%)	Medium 4+3=7
Tungsten	Cutting & wear-resistant materials (construction, mining & metal working); x-ray tubes; high temperature alloy & superalloy (rocket engine nozzles & turbine blades); catalyst; incandescent light bulb filament; bismuth is a byproduct; strategically significant (DOD).	50%	Imports: China (45%); Global Production: China & Russia (88%); Global Reserves: China & Russia (61%)	Medium 3+5=8
Uranium	Primary energy source (20% of US electricity); weapons; scandium is a byproduct.	91%	Imports: Russia, Kazakhstan & Namibia (48%); Global Production: Kazakhstan & Namibia (43%) Global Reserves: Kazakhstan & Russia (21%)	Medium 5+3=8
Vanadium	Iron & steel alloy (aerospace & automotive applications); catalyst (sulfuric acid); superconducting magnets; surgical instruments; lithium batteries (anode).	90%	Imports: China, Russia & South Africa (vanadium pentoxide 95%); Global Production: China, Russia & South Africa (99%); Global Reserves: China, Russia & South Africa (96%)	High 5+5=10
Vermiculite	Insulator (refractories & buildings); soil conditioner; packing material; fireproofing agent; absorbent; lightweight concrete/plaster aggregate.	29%	Imports: South Africa & China (80%); Global Production: South Africa (31%)	Very Low 2+5=7
Wollastonite	Plastics; rubber products; ceramics (additive)	0%	Imports: China (% N/A)	Negligible
Zeolites	Animal feed; pet litter; cement (drilling industry); water purification; odor control; wastewater cleanup; gas absorbent; fertilizer carrier; catalyst.	0%	Global Production: China (74%)	Negligible
Zinc	Galvanizing; die casting; batteries; alloy (brass); dietary supplement; fertilizer micronutrient; consumer products (deodorant & shampoo); arsenic, bismuth, cadmium, cobalt, gallium, germanium, indium, silver & thallium are byproducts; strategically significant (DOD).	74%	Global Production: China (37%); Global Reserves: China (17%)	High 4+3=7
Zirconium	Alloy (nuclear power plants, space vehicles, jet engines & gas turbine blades); refractory & foundry material; abrasive; ceramics; armaments; hafnium & thorium are byproducts; strategically significant (DOD).	3%	Imports: South Africa (52%); Global Production: South Africa (25%); Global Reserves: South Africa (21%)	Very Low 1+3=4

Appendix B: U.S. NNR Disruptive Potential Assessment Methodology

U.S. NNR Disruptive Potential Assessment Overview: The U.S. NNR Disruptive Potential Assessment [Assessment] evaluates the capacity of the 87 analyzed NNRs to undermine our American way of life. Disruptive potential in each case is determined by NNR criticality, U.S. NNR import reliance, and U.S. NNR import source reliability.

In practical terms, the greater the criticality associated with an NNR, and the greater America's reliance upon imported NNR supplies, and the less reliable American NNR import sources, the greater the disruptive potential associated with the NNR.

U.S. NNR Disruptive Potential Assessment Classifications and Metrics; U.S. Import Reliance Classifications and Metrics; U.S. NNR import reliance metrics range from 0 to 5 based on increasing U.S. NNR import reliance, with 0 being no (net) U.S. NNR import reliance* and 5 being 81 percent-100 percent U.S. NNR import reliance.

- 0 percent - 1 percent Imports – 0
- 2 percent - 20 percent Imports – 1
- 21 percent - 40 percent Imports – 2
- 41 percent - 60 percent Imports – 3
- 61 percent - 80 percent Imports – 4
- 81 percent - 100 percent Imports – 5

*NNRs for which U.S. import reliance is 1 percent are considered "no U.S. import reliance."

U.S. Import Source Reliability Classifications and Metrics; U.S. NNR import source reliability metrics range from 0 to 5 based on increasingly questionable U.S. NNR import sources, with 0 being no (net) U.S. NNR imports and 5 being predominantly questionable U.S. NNR import sources.

No (Net) U.S. Imports – 0

Predominantly Reliable Import Sources – 1

Partially Reliable (Mixed Reliability) Import Sources – 3

Predominantly Questionable Import Sources – 5

NNR Criticality Classifications

NNR criticality is incorporated into the Assessment based on the following rules pertaining to NNR significance in enabling our American way of life.

"*Indispensable*" NNRs can be assigned any of the six disruptive potential ratings

"*Critical*" NNRs cannot be assigned a "very high" disruptive potential rating

"*Normal*" NNRs cannot be assigned a "very high" or "high" disruptive potential rating

U.S. NNR Disruptive Potential Classification Criteria; U.S. NNR disruptive potential is determined by summing the U.S. import reliance metric (0-5) and the U.S. import source reliability metric (0-5), then considering the criticality associated with the NNR. The following table summarizes U.S. NNR disruptive potential classification criteria.

U.S. NNR Disruptive Potential Examples

Barite

In the case of barite, the U.S. imports 77 percent of its annual supply — the U.S. import reliance metric is therefore "4."

Because 86 percent of U.S. barite imports come from China, 45 percent of global barite production occurs in China, and 53 percent of global barite reserves are located in China and Kazakhstan (combined), U.S. barite import sources are considered predominantly questionable — the U.S. import source reliability metric for barite is therefore "5."

With respect to its significance in enabling our American way of life (criticality), barite is considered "important," the lowest of the three NNR criticality designations (right hand column).

Given that the summary metric is "9" and the criticality designation is "important," the disruptive potential associated with barite is considered "low." That is, even though U.S. export reliance is high and import source reliability is predominantly questionable, the capacity of barite to undermine our American way of life is relatively low.

Potash

In the case of potash, the U.S. imports 81 percent of its annual supply — the U.S. import reliance metric is therefore "5."

Because 10 percent of U.S. potash imports come from Russia, 26 percent of global potash production occurs in Russia, Belarus, and China (combined), and 56 percent of global potash reserves are located in Belarus and Russia (combined), U.S. potash import sources are considered partially reliable (mixed reliability) — the U.S. import source reliability metric for potash is therefore "3."

With respect to its significance in enabling our American way of life (criticality), potash is considered "indispensable," the highest of the three NNR criticality designations (left hand column).

Given that the summary metric is "8" and the criticality designation is "indispensable," the disruptive potential associated with potash is considered "high." That is, owing to its extremely significant role in enabling our American way of life, the capacity of an NNR such as potash to undermine our American way of life is far greater than that of an NNR such as barite, despite the lower summary metric ("8" versus "9") ascribed to potash.

Endnotes

1. NNRs are considered "nonrenewable" because their supplies do not naturally replenish on a time scale that is relevant from the perspective of a human lifespan, in the event that they replenish at all.

2. As used in the paper, the term human "prosperity" is defined by quantifiable criteria: economic output (GDP) and material living standards (per capita GDP).

3. "Economic Drivers of Mineral Supply," U.S. Geological Survey Open-File Report 02-335, page 21; 2002, Lorie A. Wagner, Daniel E. Sullivan, and John L. Sznopek - http://pubs.usgs.gov/of/2002/of02-335/of02-335.pdf.

4. Mineral Information Institute (Historical US NNR utilization data compiled by the Mineral Information Institute are available upon request from coclugston at Verizon dot net.) – www.mii.org.

5. NNR contents of American infrastructure and goods: house (building) - http://www.mine-engineer.com/mining/min_house.htm and http://www.nma.org/index.php/minerals-publications/40-common-minerals-and-their-uses; car - http://www.truthaboutsurfacemining.com/SurfaceMining101/Documents/surface_mining_hybrids.pdf; computer - http://www.nma.org/pdf/m_computer.pdf; wind turbine - https://www.mineralseducationcoalition.org/sites/default/files/uploads/mec_fact_sheet_wind_turbines_0.pdf; and solar panel - http://www.mineralseducationcoalition.org/pdfs/Solar-Panel.pdf.

6. Estimated total U.S. mineral utilization in the year 1800: per capita U.S. mineral utilization in 1776 was about 1200 lbs./year - http://www.mii.org/pdfs/Minerals1776vsToday.pdf; I increased the per capita number to 1500 lbs. for the year 1800; so total U.S. mineral utilization was 1500 lbs. times 5.3 million people, which equals (3,975,000 tons) ~ 4 million tons.

7. Estimated U.S. total mineral utilization in the year 2008: per capita U.S. mineral utilization in 2008 was ~42,719 pounds, per Mineral Industry Information, pg. 2 - http://www.mii.org/pdfs/Baby_Info.pdf; times 304 million people, which equals ~6.5 billion tons total.

8. U.S. year 1800 and year 2008 inflation adjusted GDP data from Measuring Worth - http://www.measuringworth.com/.

9. "Crust", Wikipedia, 2011 - http://en.wikipedia.org/wiki/Crust_(geology).

10. USGS NNR "resource" definition; "Mineral Commodities Summary 2009", page 191; USGS, 2009 - http://minerals.usgs.gov/minerals/pubs/mcs/2009/mcs2009.pdf.

11. USGS NNR "reserve" definition; "Mineral Commodities Summary 2009", USGS, page 192.

12. Crustal occurrences, resources, and reserves vary widely among NNRs; the example provides an indication of the scale of the relationship among the three metrics, on average. Crustal NNR occurrences can be found at "Abundance of Elements in Earth's Crust", Wikipedia, 2010 - http://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth's_crust; globally available NNR "resources" and "reserves" as of 2012 are available in "Mineral Commodities Summary 2013", USGS, 2013 – http://minerals.usgs.gov/minerals/pubs/mcs/2013/mcs2013.pdf.

13. See Section II, "US NNR Vulnerability Analysis", for details.

14. "Strategic Minerals – A Summary of Uses, World Output Stockpiles, Procurement"; J. Demille; McGraw Hill, 1947, page 4 and Section 6: "Strategic Minerals" - http://archive.org/stream/strategicmineral031804mbp/strategicmineral031804mbp_djvu.txt

15. Author note: The Vulnerability Analysis is my initial attempt to assess comprehensively the vulnerability of our American way of life to import-related NNR supply disruptions. While the overall analytical framework appears to be viable, additional work is required in refining specific metrics.

My definitions and underlying assumptions are clearly articulated in all cases to facilitate improvement in the results associated with future analyses of this type.

16. NNR criticality is NOT determined by the likelihood of a supply disruption and/or by the potential severity associated with such a disruption. NNR criticality is purely a function of the significance associated with the NNR in enabling our modern industrialized existence.

17. For additional information regarding NNR criticality, see "Scarcity – Humanity's Final Chapter?" ("Appendix A: NNR Profiles"), pages 143-375; C. O. Clugston, Booklocker.com, 2012 – www.nnrscarcity.com.

18. "Net" import is the difference between total imports and total exports over a specified period of time (typically a year). A positive "net" import quantity indicates that total imports exceed total imports during the year in question. Note that it is often the case that America imports some quantity of an NNR even though the US is a "net exporter" of that NNR. Ironically, in some of these cases, the US may be vulnerable to import-related supply disruptions in the event that economically viable supplies of the imported NNR varieties are unavailable domestically.

19. Examples of highly reliable U.S. NNR import sources include Canada and Mexico; generally reliable import sources include Western European nations and Australia; moderately reliable import sources include Latin American nations; marginally reliable import sources include developing Asian and Middle Eastern nations; and questionable import sources include China, the Former Soviet Union (FSU), and African nations.

20. In 39 of the 87 analyzed cases, global NNR reserve estimates are not available because: 1) the NNR is produced as the byproduct of another NNR, and global reserve estimates for the byproduct NNR are not reported – e.g., beryllium, germanium, and indium; or 2) the global NNR reserve is considered "large" and reserve estimates are not reported – e.g., cement, lime, and sand & gravel. It is quite likely that China, the FSU, and Africa (combined) possess at least 50 percent of global NNR reserves in many more than 14 cases.

21. U.S. NNR disruptive potential IS NOT a probability estimate that an import-related NNR supply disruption will induce a lifestyle-debilitating disruption to our American way of life within a specified period of time. (Regrettably, such precision is not attainable.)

22. For additional information regarding U.S. NNR depletion, see "Scarcity – Humanity's Final Chapter?" pages 37-50.

23. "Trade in Raw Materials: Breaking Free from Export Restrictions"; OECD, February, 2011 – http://www.oecd.org/tad/facilitation/47236352.pdf.

24. "Recent Trends in Export Restrictions", J. Kim, OECD (Trade and Policy Papers No. 101), page 6, 2010 - http://www.oecd-ilibrary.org/docserver/download/5kmbjx63sl27.pdf?expires=1402399779&id=id&accname=guest&checksum=ADD0A0BCDA72CB05CFB47A8DE105036E.

25. "Restrictions on Exports of Raw Materials (Inventory of export regulations on industrial raw materials)", OECD, 2012 - http://qdd.oecd.org/subject.aspx?subject=8F4CFFA0-3A25-43F2-A778-E8FEE81D89E2.

26. "Reconfiguration of the National Defense Stockpile (NDS) Report to Congress", page E-4, US Department of Defense; 2009 - http://www.acq.osd.mil/mibp/docs/nds_reconfiguration_report_to_congress.pdf.

27. For additional detail regarding American fiscal profligacy – Pseudo Purchasing Power – see "21st Century NNR Scarcity – Blip or Paradigm Shift?", pages 10-11; Chris Clugston, 2013 – http://www.wakeupamerika.com/PDFs/21st-Century-NNR-Scarcity_Blip-or-Paradigm-Shift.pdf.

28. "1995 U.S. Net Import Reliance for Selected Nonfuel Mineral Materials", USGS, 1996" – http://minerals.usgs.gov/minerals/pubs/mcs/1996/nir.gif; (1995 and 2013 data were reconciled to accommodate USGS reporting differences between the two years).

29. "Table 1. Projections of the Population and Components of Change for the United States: 2015 to 2060; U.S. Census Bureau; 2014 –https://www.census.gov/population/projections/files/summary/NP2012-T1.xls.

30. "IMF Paper: No U.S. Manufacturing Renaissance"; Wall Street Journal, I. Talley and E. Morath; 2/14/14 - http://blogs.wsj.com/economics/2014/02/12/imf-paper-no-u-s-manufacturing-renaissance/; and "Is There a US Manufacturing Renaissance?" D. Dray; Citi, 1/24/13 - http://blog.citigroup.com/2013/01/is-there-a-us-manufacturing-renaissance.shtml.

31. "Historical Statistics for Mineral and Material Commodities in the United States"; U.S. Geological Survey, 2014 - http://minerals.usgs.gov/ds/2005/140/; "The Gassiest Country"; Peak Oil.com; 8/7/13; - http://peakoil.com/production/the-gassiest-country; and "Uranium"; Wikipedia; 2014 - http://en.wikipedia.org/wiki/Peak_uranium.

32. For additional information regarding NNR pricing, see "Whatever Happened to the 'Good Old Days'?", pages 5-6; C. Clugston; Negative Population Growth, Inc. 2014 - http://www.npg.org/wp-content/uploads/2014/03/WhatEverHappenedGoodOldDays.pdf.

33. The global industrialized population estimate of approximately 1 billion is based on the assumption that roughly 25% of Earth's 4.1 billion people lived in industrialized regions in 1975. These included most of Europe, Russia, North America, Japan, and the four Asian tigers.

34. For industry expert commentary regarding decreasing global NNR quality, see "21st Century NNR Scarcity – Blip or Paradigm Shift?" pages 21-24 (Appendix A: Evidence of Diminishing Returns).

35. For additional information regarding diminishing returns on NNR exploitation, see "21st Century NNR Scarcity – Blip or Paradigm Shift?" pages 4-5.

36. A complete listing of NNR price changes between the years 2000 and 2008 is available in "Scarcity – Humanity's Final Chapter?" (Appendix B: 2000 and 2008 Global NNR Extraction/Production Levels and Price Levels), pages 376-378.

37. A complete listing of globally scarce NNRs in the year 2008 is available in "Scarcity – Humanity's Final Chapter?" pages 51-53.

38. For an excellent overview of this perspective, see "Mining Investment Trends and Implications for Mineral Availability", page 4; Dr. David Humphreys, Polinares, 2012 - http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter3.pdf.

39. "Whatever Happened to the 'Good Old Days'?", pages 10-13 (Future Global Prosperity).

40. Inflation adjusted global and domestic (U.S.) GDP data and per capita GDP data were obtained from "World Development Indicators", World Bank, 2014, – http://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&met_y=ny_gdp_mktp_cd&idim=country:USA&dl=en&hl=en&q=us+gdp#!ctype=l&strail=false&bcs=d&nselm=h&met_y=ny_gdp_mktp_cd&scale_y=lin&ind_y=false&rdim=region&idim=country:USA&ifdim=region&tdim=true&hl=en_US&dl=en&ind=false.

41. "Whatever Happened to the 'Good Old Days'?", pages 7-8.

42. For industry expert commentary regarding the ongoing battle between decreasing NNR quality and human ingenuity, see "21st Century NNR Scarcity – Blip or Paradigm Shift?" (Appendix A: Evidence of Diminishing Returns), pages 21-24.

43. For additional details regarding humanity's transition from "continuously more and more" to "continuously less and less", see "21st Century NNR Scarcity – Blip or Paradigm Shift?" page 13.

44. The graph is a linear extrapolation of World Bank "World Development Indicators" through the year 2050.

45. For details regarding humanity's four possible unraveling scenarios, see "Whatever Happened to the 'Good Old Days'?" pages 11-13.

46. For a detailed description of the consequences associated with increasing global NNR scarcity, see "Scarcity – Humanity's Final Chapter?" pages 87-94.

47. For additional information regarding humanity's global industrial mosaic, see "Scarcity – Humanity's Final Chapter?" pages 9-10.

48. For details regarding the myth of global prosperity, see "21st Century NNR Scarcity – Blip or Paradigm Shift?" page 17.

49. For details regarding humanity's era of relative NNR abundance, see "Whatever Happened to the 'Good Old Days'?" pages 4-5.

50. For additional perspective on the projected timing of humanity's self-inflicted global societal collapse, see "The Most Endangered Species", C. Clugston; Humanist Perspectives, Issue 189, 2014; pages 8-9.