21st Century NNR Scarcity – Blip or Paradigm Shift?

Introduction

Episodes of temporary nonrenewable natural resource (NNR) scarcity have occurred as a consequence of "commodity boom/bust cycles" since the inception of our industrial revolution over 200 years ago.[1]

Robust demand for fossil fuels, metals, and nonmetallic minerals during a commodity cycle "boom period" typically drives up costs/prices as increasingly expensive resources are exploited – thereby causing NNR scarcity – which temporarily suppresses NNR demand until incremental affordable NNR supplies can be brought online – thereby alleviating NNR scarcity, and simultaneously decreasing NNR costs/prices and re-stimulating NNR demand…

Since the beginning of the 21st century, however, we have experienced an episode of global NNR scarcity that is unprecedented during our modern industrial era with respect to:

- **Magnitude – the number of globally scarce NNRs;**
- **Scope – the size of the impacted industrialized and industrializing population; and**
- **Duration – the time interval during which global NNR scarcity has persisted.**

At issue: is our current episode of global NNR scarcity simply another temporary commodity cycle "blip"; or does it signify a permanent "paradigm shift" in global NNR demand/supply dynamics?

Blip: We Have a Temporary Cyclical Problem

Genesis: We are in the midst of an unusually protracted "boom period" – the duration of which is subject to debate – within an unusually protracted global "commodity boom/bust cycle", which has been driven by inordinately high Chinese NNR requirements/demand over the past decade or so in their efforts to industrialize.

As a result of this historically unprecedented commodity boom period, we are experiencing a temporary imbalance in global NNR "demand/supply dynamics" – specifically, a protracted but temporary Chinese led "demand-side surge" in conjunction with a protracted but temporary delay in the global mining industry's "supply-side response".

Projected Resolution: Going forward, as Chinese NNR requirements decrease and as incremental economically viable NNR supplies are brought online, global NNR abundance will displace global NNR scarcity. NNR prices will decrease to and remain at levels that will stimulate global NNR demand/utilization to levels that will completely address our global NNR requirements for the indefinite future.

Projections regarding the timing associated with the resolution of our temporary global NNR demand/supply/requirement imbalance vary. Those who contend that the protracted global commodity boom period is at or near its end believe that the resolution is in process; while those who contend that the protracted commodity boom period is part of a decades-long global commodity "super cycle" believe that the imbalance could persist for several years to come.

Implications for Future Global Prosperity: In either case, as our global NNR demand/supply/requirement imbalance is resolved, resurgent global NNR abundance will rekindle global prosperity. Continuously increasing economic (GDP) growth trajectories and continuously improving material living standard trajectories will persist indefinitely, as humanity strives toward its goal of universal global prosperity through global industrialization.

Paradigm Shift: We Have a Permanent Structural Problem

Genesis: We are experiencing a permanent "paradigm shift" in global NNR demand/supply dynamics, caused by our incessant quest for global industrialization as the means by which to achieve universal global prosperity.

Our seemingly insatiable requirements for finite and non-replenishing NNRs on the demand-side are manifesting themselves within the context of increasingly expensive, lower quality NNR supplies on the supply-side. The inevitable consequence associated with our permanent global NNR demand/supply/requirement imbalance is increasingly-prevalent, geologically-induced, permanent global NNR scarcity.

Projected Resolution: In an increasing number of cases, persistently high NNR price levels owing to diminishing returns on investments in NNR exploitation, will permanently suppress global NNR demand/utilization to levels at which they will never again be sufficient to completely address our enormous global NNR requirements.

Implications for Future Global Prosperity: Global prosperity – i.e., our global economic output (GDP) level and material living standards – which is currently stagnating, will peak and go into terminal decline within the next few decades as a result of increasingly-prevalent, permanent global NNR scarcity.

The following analysis, which is the second update to the original Global NNR Scarcity Analysis presented in "Scarcity – Humanity's Final Chapter?"[2]:

- Provides an overview of NNRs and why NNRs become scarce;
- Substantiates the existence of 21st century global NNR scarcity through 2012, and assesses its impact on global prosperity through 2012;
- Explores the genesis of our current episode of NNR scarcity, its projected resolution, and its implications for future global prosperity – from the two above-referenced perspectives; and
- Offers insights into which of the two above-referenced perspectives is the more likely to prevail.

Nonrenewable Natural Resources (NNRs)

Our modern industrialized existence is enabled almost exclusively by enormous and ever-increasing quantities of nonrenewable natural resources (NNRs) – the fossil fuels, metals, and nonmetallic minerals that serve as:

- **The raw material inputs to our industrialized economies;**
- **The building blocks that comprise our industrialized infrastructure and support systems; and**
- **The primary energy sources that power our industrialized societies.**

NNRs – The Enablers

NNRs play two essential roles in enabling our industrial lifestyle paradigm:

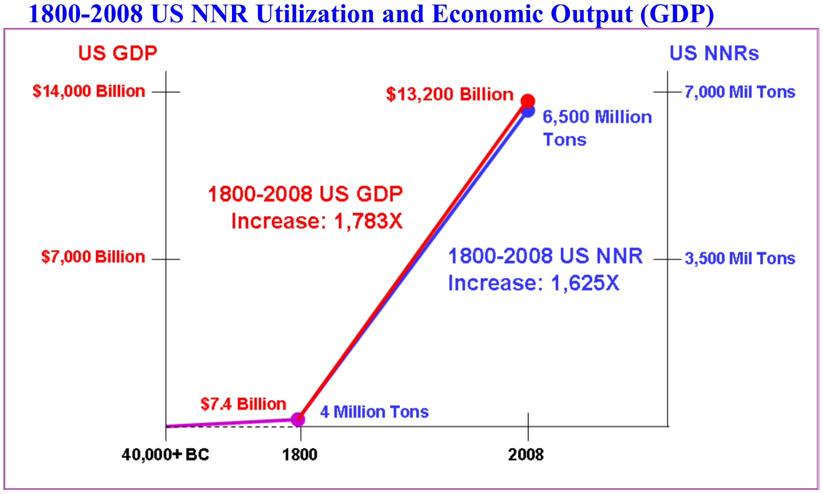
- NNRs enable renewable natural resources (RNRs) – water, soil, forests, and other naturally occurring biota – to be exploited in ways and at levels that are necessary to support the extraordinary population levels and material living standards associated with industrialized human societies. Examples include water storage/distribution systems, food production/distribution systems, and energy generation/distribution systems, which would support only a negligible fraction of today's global human population were they enabled exclusively by RNRs.

- NNRs enable the production and provisioning of manmade goods and infrastructure – e.g., airplanes, computers, skyscrapers, super-highways, refrigerators, light bulbs, communication networks, etc. – that differentiate industrialized societies from pre-industrial agrarian and hunter-gatherer societies; goods and infrastructure that are inconceivable through the exclusive utilization of RNRs.

As an example of the critical role played by NNRs in enabling our industrialized existence, NNRs comprise approximately 95% of the raw material inputs to the US economy each year.[3] During 2006, the year during which aggregate US NNR utilization peaked (to date), America used over 7.1 billion tons of newly mined NNRs, which equated to nearly 48,000 pounds per US citizen.[4]

NNR inputs to our national and global economies generate the economic output (GDP) that enables the material living standards enjoyed by our increasingly industrialized populations.

1800-2008 US NNR Utilization and Economic Output (GDP)



For example, between the years 1800 and 2008, total US NNR utilization increased by over 1,600 times, from approximately 4 million tons to 6.5 billion tons. As a result of this spectacular increase in NNR utilization, the size of the US economy (GDP) increased from approximately $7.4 billion (2005 USD) in 1800 to $13.2 trillion (2005 USD) in 2008 – an increase of nearly 1800 times![5, 6, 7]

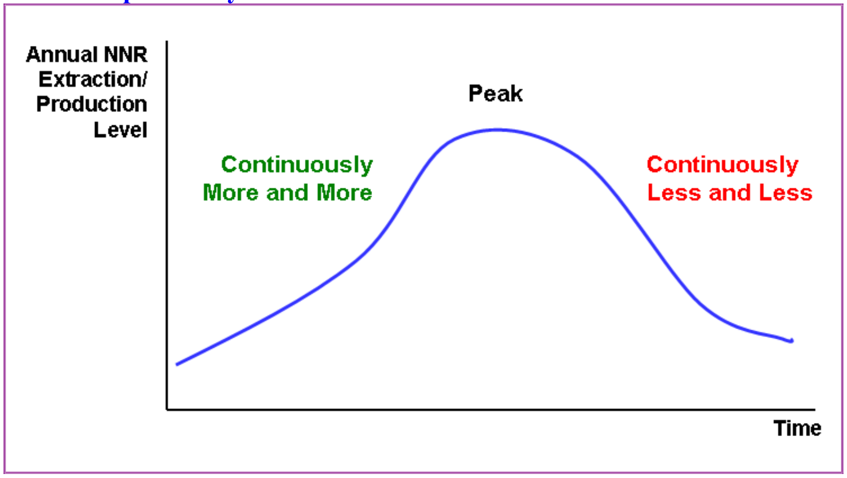
For populations in industrialized and industrializing nations:

NNR Inputs → Economic Output (GDP) → Material Living Standards

NNR Depletion

NNRs are finite; and as their name implies, NNR reserves are not replenished on a time scale that is relevant from the perspective of a human lifespan.

NNR Depletion Cycle



Owing to **diminishing marginal returns** on investments in NNR exploitation – i.e., NNR exploration and production – the typical NNR depletion cycle approximates a "bell-shaped" curve.

The shape of an NNR depletion curve is driven by economics. The curve reaches a pre-peak inflection point and rolls over because NNR quality decreases over time, lower quality NNRs become increasingly complicated and costly to produce, and NNR prices increase accordingly. As NNR costs/prices increase over time, NNR demand – and NNR extraction/production levels – increase at a decreasing rate, then peak, and ultimately enter terminal decline.

Diminishing Marginal Returns Nonrenewable natural resources are not homogeneous – i.e., NNR discoveries and deposits vary with respect to:

- Quality – incidence, size, accessibility, grade, and purity;
- Exploitation complexity and costs over time; and
- Exploitation investment returns (ROI) over time.

We typically exploit the highest quality resources – i.e., the largest, most accessible deposits of highest grade and purity – early in the NNR depletion cycle.

Because early-stage NNRs are typically the least complicated to exploit – and because the cost advantages derived from human innovation and advances in NNR exploitation technology are often complemented by cost advantages attributable to increasing NNR quality early on – these resources are also typically the least costly to exploit.

NNR demand levels, NNR extraction/production levels, and NNR exploitation investment returns tend to increase during the initial phase of the NNR depletion cycle.

As NNR exploitation continues through the depletion cycle, however, the quality associated with remaining NNRs decreases.

Because resources of decreasing quality are increasingly complicated to exploit – and because the cost disadvantages attributable to continuously decreasing NNR quality increasingly outweigh the cost advantages derived from human innovation and advances in NNR exploitation technology – these mid-cycle resources are increasingly costly to exploit.

NNR demand levels, NNR extraction/production levels, and NNR exploitation investment returns, while continuing to increase over time, reach an inflection point and increase at decreasing rates.

As NNR exploitation continues further, the quality associated with still remaining NNRs decreases even more dramatically, and the complexity associated with exploiting these later-stage resources increases even more dramatically.

Cost advantages derived from human innovation and technology ultimately lose the battle against cost disadvantages attributable to continuously decreasing NNR quality, and the costs associated with exploiting these still remaining resources increase dramatically. NNR demand levels, NNR extraction/production levels, and NNR exploitation investment returns peak and go into terminal decline. (Please see Appendix A for evidence regarding diminishing returns on investments in NNR exploitation.)

NNR Occurrence

While NNRs are essentially ubiquitous within the earth's crust, "economically viable" NNR supplies – i.e., those that are both profitable to produce and affordable to procure – are extremely rare in most cases.

Crustal NNR Occurrences: Massive quantities of nearly all NNRs exist in the undifferentiated earth's crust – earth's outer rocky shell, which ranges in thickness from approximately 3 miles to 30 miles.[8] Crustal NNR concentrations range from 27% for silicon and 8% for aluminum, to 60 parts per million for copper and 2 parts per million for tin, to 5 parts per billion for platinum and 0.3 parts per billion for indium.[9]

Because the mass of the earth's crust is enormous, on the order of 20 quintillion metric tons,[10] even NNRs with very small crustal concentrations exist in extremely large quantities within the entire undifferentiated earth's crust. Unfortunately, NNR concentrations in the undifferentiated earth's crust are too small in all cases to be economically viable.

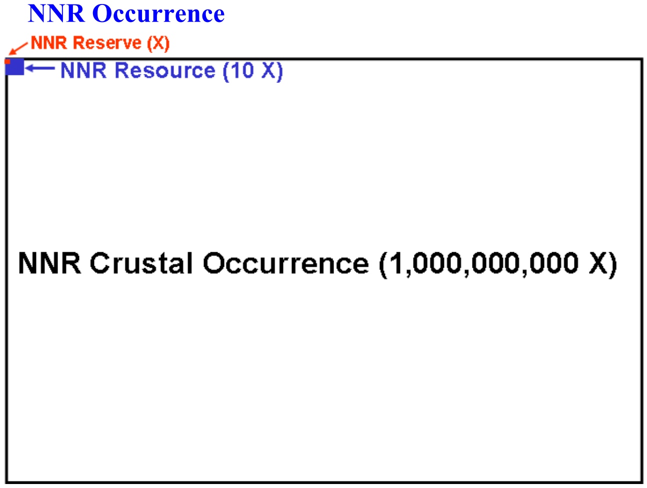
NNR "Resources": Significantly greater NNR concentrations exist in mineral deposits classified by the US Geological Survey (USGS) as "resources". The USGS defines a resource as a "concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or *potentially* feasible."[11] [emphasis mine]

Resources represent only a very tiny subset of NNR occurrences however; and only small percentages of NNR "resources" are considered economically viable.

NNR "Reserves": Economically viable NNR concentrations exist in proven deposits that the USGS classifies as "reserves". An NNR reserve is "(t)hat part of the reserve base which could be economically extracted or produced at the time of determination."[12]

As a subset of "resources", economically viable "reserves" represent the least abundant NNR occurrences on earth. To put global NNR occurrence into perspective…

NNR Occurrence



…if the quantity of an NNR in the undifferentiated earth's crust was the size of Disneyland (150 football fields), the NNR "resource" would be about the size of a cell phone, and the economically viable NNR "reserve" would be about the size of a postage stamp.[13]

So while there will always be plenty of NNRs in the ground, in an increasing number of cases there are not enough economically viable NNRs in the ground to completely address our enormous and ever-increasing global requirements. This phenomenon – NNR scarcity – has become increasingly prevalent and persistent since the beginning of the new millennium.

NNR Scarcity

In a general sense, scarcity exists when there is not enough of something. And in that sense, all NNRs are perpetually scarce, because available NNR supplies are never sufficiently abundant to enable us to utilize them on an unlimited basis. Scarce NNRs must be allocated in some manner; and within the context of a market economy, they are allocated by the pricing mechanism.

In a more practical sense, NNR scarcity exists when the "affordable" NNR supply available to a society is insufficient to completely address the society's requirement – which is defined as the NNR quantity necessary to generate the mix and levels of goods and services required to provide the society's "expected" economic output (GDP) level and material living standards.

And, since NNRs are generally allocated in global markets based on price, "…a rising long-term price for a commodity [NNR] indicates increasing scarcity of supply relative to demand." (USGS)[14]

NNR scarcity is caused therefore by an unfavorable NNR "demand/supply/requirement imbalance", within which inordinately high NNR prices, resulting from inordinately expensive NNR supplies, suppress a society's NNR **demand** to a level at which it is insufficient to completely address the society's NNR **requirement**.

"Demand" versus "Requirement" In order to understand NNR scarcity, it is essential to understand the difference between the terms "NNR requirement" and "NNR demand" – the term "demand" is often used inappropriately in place of "requirement".

An NNR "requirement" is the NNR quantity that a society **needs** as an input to its economy in order to generate the level of economic output (GDP) "expected" during a given period of time. NNR "demand" is the NNR quantity that the society **actually procures** during that period of time.

During a period of NNR abundance, a society's NNR demand level will equal or exceed its NNR requirement; that is, the society will be able to afford and thus procure an NNR quantity sufficient to completely address its requirement.

During a period of NNR scarcity, the society's NNR requirement will exceed its NNR demand level; that is, the society will not be able to afford and procure an NNR quantity sufficient to completely address its requirement.

Confusion results when, for example, analysts claim that global NNR "demand" is increasing as a consequence of global industrialization, when they actually mean that our global NNR "requirements" are increasing as a consequence of global industrialization. NNR demand is likely to fluctuate cyclically over time, even as our global NNR requirements continue to increase.

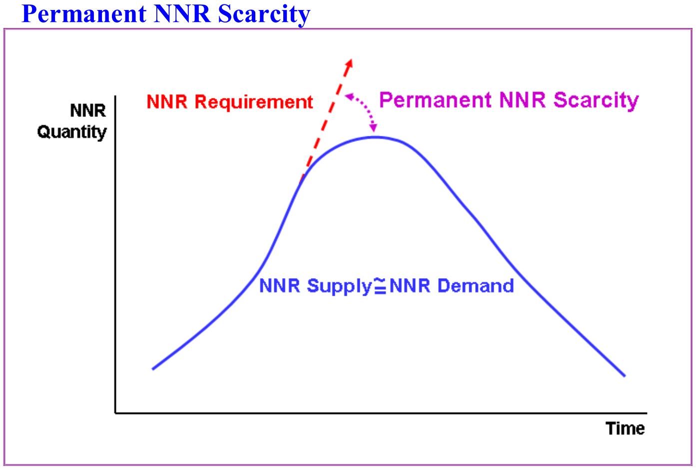
NNR scarcity exists precisely because a society's NNR demand level cannot keep pace with its NNR requirement during a specified time interval, typically owing to inordinately high NNR prices. The "gap" between the society's NNR requirement and its NNR demand level could be considered "latent demand" or "pent up demand" – demand that the society's population would gladly exercise if it could afford to do so, but it cannot.

For example: suppose that in order to generate 5% annual GDP growth this year – our "expected" economic (GDP) growth rate – our requirement for NNR A as an input to our economy is 100 units. Suppose further that in our efforts to completely address our 100 unit requirement, we are forced to exploit increasingly-expensive, lower-quality supplies of NNR A; and that as a result, the price of NNR A increases to a level at which we can afford to procure – demand – only 90 units of NNR A.

In this case, we demand 90 units of NNR A and the market supplies 90 units of NNR A, so demand equals supply. However, because our NNR A requirement is 100 units, our requirement is not completely addressed by the 90 units we can afford to demand (procure). NNR A is therefore scarce this year – and our economy grows by less than 5% as a result.

Of primary concern during an episode of NNR scarcity is whether scarcity is temporary or permanent.[15] During episodes of temporary NNR scarcity, which we have experienced historically, NNR price levels eventually decrease as sufficient economically viable NNR supplies are brought online, thereby restoring NNR demand, NNR utilization, economic output (GDP), and material living standards to their "expected" or "normal" levels.

Permanent NNR Scarcity



In the event that NNR scarcity is permanent, economically viable NNR supplies will never again be sufficient to completely address our NNR requirements – i.e., to restore NNR demand, NNR utilization, economic output (GDP), and material living standards to their "expected" or "normal" levels.

21st Century NNR Scarcity

During the mid/late 20th century (1960-1999), a barrel of oil cost $19 on average; during the years immediately prior to the Great Recession (2000-2008), the average price of a barrel of oil had increased to $47; and during the years immediately following the Great Recession (2010-2012), the average price of a barrel of oil had further increased to $81.

During the same three time periods, the average price of a metric ton of copper increased from $3,085, to $3,713, to $6,817; the average price of a metric ton of iron ore increased from $36, to $57, to $124; and the average price of a metric ton of potash increased from $114, to $185, to $343. (Prices are inflation adjusted.)

The simple fact is that we cannot grow our global economy and improve our global material living standards on $81 oil, $6,817 copper, $124 iron ore, and $343 potash like we did on $19 oil, $3,085 copper, $36 iron ore, and $114 potash.

It should come as no surprise that our NNR-dependent global economy experienced the Great Recession during 2009. Nor should it come as a surprise that we have yet to recover from the Great Recession as we enter 2013. Nor will our industrialized and industrializing economies ever recover, so long as price levels associated with the vast majority of NNRs remain at their inordinately high levels.

Global NNR Scarcity Through 2012

The following 2013 Global NNR Scarcity Analysis (Analysis), the second update[16] to the original Global NNR Scarcity Analysis presented in **"Scarcity"**, assesses the incidence of global NNR scarcity during our modern industrial era – i.e., between the years 1960 and 2012 – and assesses the impact of global NNR scarcity on global prosperity during that time.

Analyzed NNRs The Analysis considers 15 NNRs – fossil fuels, base metals, and major fertilizer components – for which the World Bank maintains inflation adjusted pricing data between the years 1960 and 2012 (exceptions are coal, 1970-2012; and potash, 1970-2012). Included in the Analysis are the following NNRs:

- Fossil Fuels: coal, natural gas, and oil.
- Metals: aluminum, copper, iron ore, lead, nickel, platinum, silver, tin, and zinc.
- Non-metallic Minerals: phosphate rock, potash, and urea (nitrogen).

These 15 NNRs represent a viable subset of the 89 NNRs that were analyzed in **"Scarcity"**, and provide a good proxy for the global trends and trajectories in NNR price, supply, demand, and scarcity that prevailed during the 1960-2012 period. (As always, ongoing NNR analyses are necessary as new data become available.)

Analysis Periods The Analysis considers four time intervals:

- Mid/Late 20th Century (1960-1999),
- Pre Great Recession (2000-2008)
- Great Recession (2009), and
- Post Great Recession (2010-2012).

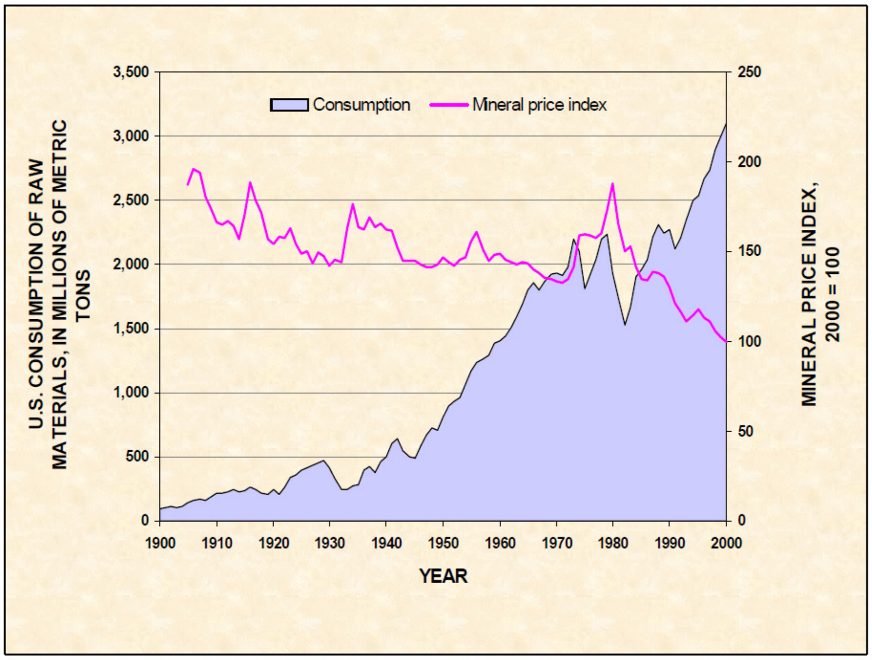
Inflation Adjusted Average NNR Prices (2005 USD)				
NNR\Interval	1960-1999	2000-2008	2009	2010-2012
	20th Century	Pre-GR	GR	Post-GR
Fossil Fuels				
Coal	42	50	66	**89**
Oil	19	47	56	**81**
Natural Gas	27	83	81	**86**
Metals				
Aluminum	1,776	**1,937**	1,523	1,851
Copper	3,085	3,713	4,710	**6,817**
Iron Ore	36	57	73	**124**
Lead	86	105	157	**185**
Nickel	8,107	15,602	13,405	**17,495**
Platinum	452	897	1,101	**1,370**
Silver	772	802	1,339	**2,410**
Tin	1,227	839	1,242	**1,892**
Zinc	122	160	151	**177**
Nonmetallic Minerals				
Phosphate Rock	52	75	111	**138**
Potash	114	185	**577**	343
Urea [Nitrogen]	174	202	228	**311**

Mid/Late 20th Century (1960-1999)

The mid/late 20th century was a period of relative prosperity – i.e., generally robust economic growth and generally improving material living standards – especially for nations in the industrialized "West", which were rebuilding after WWII, and for newly industrializing nations such as the four Asian tigers: South Korea, Taiwan, Singapore, and Hong Kong.

Notwithstanding episodes of temporary NNR scarcity associated with "boom periods" during normal commodity "boom/bust cycles", and with the geopolitically induced 1970s "oil shocks", global NNR supplies generally remained sufficiently inexpensive and **abundant** to support flat or declining NNR price level trajectories between 1960 and 1999, which enabled global NNR demand to keep pace with our steadily increasing global NNR requirements in most cases, most of the time.

NNR Abundance The following excerpt from a USGS paper on (the lack of) 20th century NNR scarcity, **"Economic Drivers of Mineral Supply",**[17] explains the conditions requisite to NNR abundance, which generally prevailed in the US throughout the 20th century. "The U.S. composite raw mineral production index has an increasing long-term trend, exhibiting nearly a 3 percent average annual growth rate over its 94-year span. In contrast, during its 95 year history the composite price index exhibited an annual average decline of slightly more than one half of a percent. How can the production index increase over this time period while the price index, a major driver of mineral supply decline? Such factors as the development of giant mining trucks, faster and more efficient conveyor systems, and other technologic advancements, as well as the discovery of additional large-scale economic deposits led to reduced costs of production. These lower costs of production, plus an increased global supply contributed to decreased prices."



With respect to 20th century NNR scarcity, the USGS correctly concluded:

"The fact that production of mineral commodities has been able to keep up with or exceed the demand for minerals is, in part, an indicator that based on the past, **scarcity has not been an issue for mineral resources in general."**[18] [emphasis mine]

Unfortunately, they misinterpreted temporary NNR abundance as permanent NNR sufficiency.

Pre-recession (2000-2008)

Owing to the industrialization initiatives launched by China, India, Brazil, and other emerging nations in Asia, Africa, and Latin America during the late 20th century, and to the continuation of the consumption orgy fueled by **pseudo purchasing power (PPP)** in most Western nations, our global NNR requirements experienced a nearly instantaneous increase during the early years of the new millennium.

Pseudo Purchasing Power (PPP) Through pseudo purchasing power – fiscal profligacy – populations in Western nations such as the US have been able to increase their consumption of NNRs and derived goods and services during the past several decades through unsustainable economic behavior – that is, by:

- Liquidating their previously accumulated economic wealth reserves—e.g., depleting savings, "cashing out" home equity, and selling physical assets;
- Exchanging ever-increasing quantities of fiat currency – "printed money" that has no intrinsic value – for real wealth, such as food, NNRs, and NNR-derived products and infrastructure;
- Incurring ever-increasing levels of unrepayable debt – debt that they have neither the capacity nor the intent to repay – at the personal, corporate, and government levels; and

- Underfunding investments critical to their future wellbeing—e.g., “social entitlements”, pensions, retirement accounts, and infrastructure upgrades and maintenance.

While living beyond their means economically has enabled Western nations to maintain (temporarily) the industrialized lifestyles to which they have become accustomed, their unsustainable fiscal profligacy has also caused increasingly frequent and severe economic bubbles and recessions, which in turn have caused intensifying political instability and social unrest.

Global supplies associated with the vast majority of NNRs, which had remained sufficiently inexpensive and abundant to support flat or decreasing NNR price level trajectories through the end of the 20th century, became increasingly scarce and expensive during the 2000-2008 period, to the extent that by the year 2008, NNR prices had increased to inordinately high levels in the vast majority of cases.[19]

Of the 15 NNRs considered in the Analysis, average pre-recession (2000-2008) price levels exceeded average mid/late 20th century (1960-1999) price levels in all but one case, tin.

Increasing NNR price levels between 2000 and 2008 suppressed global NNR demand to levels that fell increasingly short of our global NNR requirements. As a result, NNR scarcity became increasingly prevalent in an increasing number of cases.

In fact, by 2008, immediately prior to the Great Recession, 63 of the 89 NNRs that enable our modern industrial existence – 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.[20]

Global NNR scarcity had become epidemic, thereby precipitating the onset of the Great Recession and derailing global prosperity. Economic growth among newly industrializing nations slowed dramatically; economic growth among industrialized Western nations went negative.

Great Recession (2009)

In order to address our historically unprecedented and ever-increasing global NNR requirements between the years 2000 and 2008, we were forced to exploit increasingly expensive NNR supplies of continuously decreasing quality. NNR price levels increased accordingly in most cases.

By late 2008, prices associated with the vast majority of NNRs had increased to levels at which many of their planned uses in 2009 and beyond had become unprofitable or unaffordable – plans, projects, and associated NNR purchases were cancelled or postponed indefinitely. The results were collapsing global NNR demand/utilization levels – **demand destruction** – and collapsing global prosperity, especially for excessively PPP-reliant Western nations. The Great Recession ensued.

Demand Destruction refers to a scenario in which inordinately high NNR prices essentially “destroy” NNR demand – that is, high NNR price levels cause NNR demand levels to decrease, sometimes precipitously, as was the case with respect to the vast majority of NNRs during the Great Recession.

Unfortunately, “low” NNR prices that exist within the context of NNR abundance and increasing NNR demand, which had been the case during the 20th century, differ fundamentally from “low” NNR prices that exist within the context of NNR scarcity and NNR demand destruction, which has been the case during 21st century.

In the former case, increasing NNR demand/utilization levels within the context of persistent NNR abundance fuel continuous economic (GDP) growth and improving material living standards. In the latter case, decreasing NNR demand/utilization levels within the context of NNR scarcity stifle economic (GDP) growth and material living standard improvement.

Moreover within the context of NNR scarcity, as suppressed NNR demand is re-stimulated by temporarily depressed NNR price levels, NNR prices rebound as well, thereby causing a subsequent episode of NNR demand destruction as NNR price levels once again become inordinately high. This is the scenario that unfolded globally during 2010, 2011, and 2012, as we attempted repeatedly and unsuccessfully to recover from the Great Recession.

“Spontaneous” global NNR supply surpluses were created during the Great Recession as a result of collapsing global NNR demand, which caused most NNR price levels to collapse as well from their pre-recession highs. Ironically, the cripplingly high NNR price levels that precipitated the Great Recession were temporarily mitigated by the Great Recession.

[Although it is interesting to note that despite decreasing (sometime considerably) from their pre-recession highs, Great Recession (2009) price levels associated with 11 of 15 analyzed NNRs remained above their average pre-recession (2000-2008) price levels; and in 14 of 15 cases, Great Recession (2009) price levels remained above their mid/late 20th century (1960-1999) average price levels.]

Post-recession (2010-2012)

Fueled by a seemingly endless series of central government and central bank fiscal and monetary “stimulus” programs since 2009, the industrialized and industrializing nations of the world sought to recover from the Great Recession and restore pre-recession prosperity.

Stimulus-provided “liquidity” and severely depressed NNR prices served to re-stimulate global NNR demand by 2010, albeit within the context of still severely constrained global NNR supplies – i.e., expensive and of decreasing quality – thereby quickly driving post-recession NNR prices to pre-recession levels, or higher.

In 14 of the 15 analyzed cases, with aluminum being the exception, average post-recession (2010-2012) NNR price levels exceeded average pre-recession (2000-2008) levels. And for 13 of the 15 analyzed NNRs, aluminum and potash being the exceptions, average post-recession (2010-2012) price levels exceeded average price levels during any of the three previous intervals.

Three attempted global economic recoveries – in 2010, 2011, and 2012 – were aborted, as global NNR demand was suppressed in each case by increasing NNR price levels. Our global economic malaise persisted through 2012, and the restoration of our quest for universal global prosperity remained an elusive goal.

NNR Scarcity and Global Prosperity Through 2012

Global Economic Output (GDP)

Global economic output (GDP) increased at a relatively robust 3.81% compound annual rate during the mid/late 20th century (1960-2000)[21]

Compound Annual Growth Rate (CAGR) in Global Economic Output (GDP)		
1960-2000 CAGR	2000-2008 CAGR	2008-2012 CAGR
3.81%	2.90%	1.75%

Data Source: World Bank

The compound annual growth rate in global economic output (GDP) then decreased to 2.9% during the pre-recession period (2000-2008), and further decreased to 1.75% from the Great Recession forward (2008-2012).[22]

Global Material Living Standards

Global material living standards, as proxied by per capita global GDP, improved at a 2.01% compound annual rate during the mid/late 20th century (1960-2000).[23]

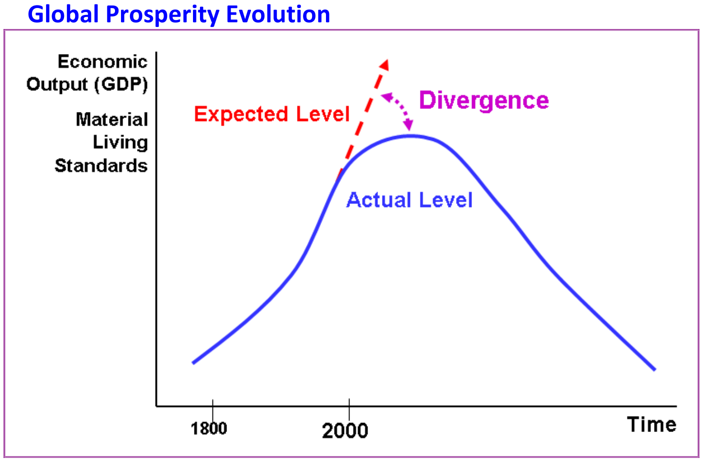
Compound Annual Growth Rate (CAGR) in Global Material Living Standards (Per Capita GDP)		
1960-2000 CAGR	2000-2008 CAGR	2008-2012 CAGR
2.01%	1.66%	0.60%

Data Source: World Bank

The compound annual growth rate in global material living standards (global per capita GDP) then decreased to 1.66% during the pre-recession period (2000-2008), and further decreased to a meager 0.6% from the Great Recession forward (2008-2012).[24]

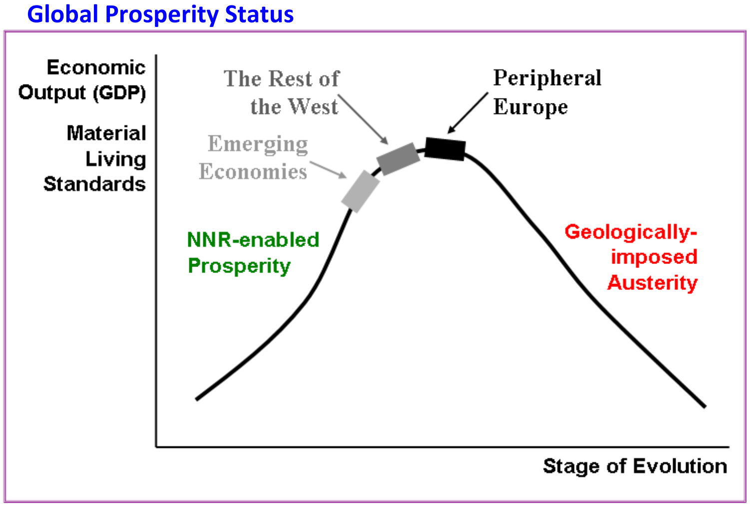
Global Prosperity Trends and Trajectories

Global Prosperity Evolution



As the vast majority of NNRs became increasingly scarce and expensive during the new millennium, both the annual growth rate in global economic output (GDP) and the annual growth rate in global material living standard improvement (per capita GDP) diverged from their expected levels and decreased continuously.

Global Prosperity Status



We are, in essence, "rolling over" from our old normal of NNR-enabled prosperity to our new normal of geologically-imposed austerity, a scenario that will persist going forward…

…UNLESS we can discover, extract, and provision sufficient quantities of economically viable NNRs to reverse prevailing economic and societal trends.

The ecological, economic, and societal causal relationships associated with ever-increasing, geologically-induced, global NNR scarcity and their impact on global prosperity can be summarized as follows:

Historically Unprecedented NNR Requirements
Within the Context of Continuously Decreasing NNR Quality →
Diminishing Returns on Investments in NNR Exploitation →
Persistently High NNR Cost/Price Levels →
Diminishing NNR Demand/Utilization Levels →
Diminishing Economic Output (GDP) Levels →
Diminishing Material Living Standards

NNR Scarcity in 2013

Through the first four months of 2013, NNR price levels have generally remained persistently high, owing to the fact that insufficient economically viable NNR supplies have been brought online in most cases to completely address our global requirements. As a result, global NNR scarcity persists in the vast majority of cases, as does our global economic malaise.

However, as had been the case during 2010, 2011, and 2012, prices associated with many NNRs, especially fossil fuels and metals, decreased during the spring of 2013, in some cases significantly. These NNR price decreases are likely the result of global NNR demand destruction, amplified by investors/speculators exiting commodity markets in favor of US equity (stock) markets in combination with recent strength in the US dollar relative to other major global currencies.

[Note that the temporary NNR price level decreases that occurred during 2010, 2011, 2012, and 2013 resulted from global NNR demand destruction within the context of persistent global NNR scarcity, not from increasing global NNR demand within the context of global NNR abundance.

Had these NNR price decreases resulted from increasing NNR demand within the context of global NNR abundance, global economic (GDP) growth during the post-recession years would have been robust. In fact, annual global economic (GDP) growth decreased significantly during the post-recession years, from 4.3% in 2010, to 2.7% in 2011, to 2.3% in 2012 – and is projected to remain essentially stagnant at 2.4% in 2013.[25]]

At issue are future NNR price trajectories, as we once again attempt to restore "expected" global economic (GDP) growth by increasing global NNR demand. If NNR prices continue to decrease over the next 3-5 years within the context of persistently strong global NNR demand, abundant and affordable global NNR supplies, and persistently strong global economic (GDP) growth, then our current episode of global NNR scarcity will have proved to be temporary.

If, on the other hand, NNR prices increase during the summer or fall of 2013 as a consequence of increasing global demand – as was the case during 2010, 2011, and 2012 – thereby suppressing global NNR demand and aborting our next attempted global economic (GDP) recovery, then our current episode of global NNR scarcity will persist as before, appearing all the more likely to be permanent as it does so.

Only time will tell…

Two Perspectives Regarding NNR Scarcity

The only relevant issue going forward is whether our current episode of NNR scarcity proves to be a temporary "blip" or a permanent "paradigm shift".

That is, will sufficient globally available, economically viable NNR supplies be brought online to completely address our global requirements for the indefinite future, thereby enabling us to achieve our goal of universal global prosperity through global industrialization?

Or, will NNR demand remain permanently suppressed by increasingly expensive NNR supplies of continuously decreasing quality, the affordable quantities of which will diverge increasingly over time from humanity's enormous and ever-increasing NNR requirements, thereby continuously eroding our global economic output (GDP) levels and material living standards going forward?

Blip: We Have a Temporary Cyclical Problem

The "optimistic" perspective is well articulated by Dr. David Humphreys, independent consultant, prior chief economist at Rio Tinto and Norlisk Nickel, and a 35+ year commodities industry analyst, and Alan Heap, (now deceased) former commodities analyst at Citigroup Global Markets (Smith Barney), whose comments are interspersed below.

Genesis

We are in the midst of an unusually protracted "boom period" – the duration of which is subject to debate – within an unusually protracted global "commodity (NNR) boom/bust cycle", which has been driven by inordinately high Chinese NNR requirements/demand over the past decade or so in their efforts to industrialize.

Humphreys views our current episode of NNR scarcity as a short-term cyclical phenomenon – "The extraordinary surge in China's metals use during the boom has to be seen more as a product of these highly specific developments [related to Chinese industrialization] rather than as the beginning an enduring multi-decade trend of persistently strong demand, tight markets, and upward trending prices."[26]

He sees the current commodities boom period as "…reflecting a one-time shift in global production and in global factor costs, rather than the basis of a continuing long-term trend.[27]

While Heap also viewed our current episode of NNR scarcity as a temporary phenomenon, he saw it as the consequence of a commodity "super cycle" – "(a) prolonged (decade or more) trend rise in real commodity prices, driven by urbanization and industrialization of a major economy"[28] – in this case, China.

As a result of this historically unprecedented commodity boom period, we are experiencing a temporary imbalance in global NNR "demand/supply dynamics" – specifically, a protracted but temporary Chinese led "demand-side surge" in conjunction with a protracted but temporary delay in the global mining industry's "supply-side response".

With respect to the global imbalance in NNR demand/supply dynamics, Heap stated, "Higher trend demand growth will be met by higher cost production. Industry average margins will remain constant. As a consequence, prices will trend higher."[29]

Humphreys differs regarding the duration and severity associated with the NNR demand/supply imbalance, “Much of the global tightness in the metals markets over these years arose simply from the difficulties the industry had in mounting an effective supply response to a cyclical recovery in demand after years of slow growth and under investment. It was a problem of adjustment, not a problem of lasting structural significance. There is no reason why, given a little time, supply growth should not adapt to a slightly higher trajectory of demand growth.”[30]

Projected Resolution

Going forward, as Chinese NNR requirements decrease and as incremental economically viable NNR supplies are brought online, global NNR abundance will displace global NNR scarcity. NNR prices will decrease to and remain at levels that will stimulate global NNR demand/utilization to levels that will completely address our global NNR requirements for the indefinite future.

Per Heap on the demand-side, “Declining intensity of [commodity] use brings super cycles to an end as the driving economy evolves from materials intensive infrastructure and manufacturing towards more service based.”[31]

And Humphreys on the supply-side, “…it is important to emphasise, the market does work and while there may be delays in the supply response, given time, *the supply necessary to balance the market is always forthcoming*.”[32] [emphasis mine]

Projections regarding the timing associated with the resolution of our temporary global NNR demand/supply/requirement imbalance vary. Those who contend that the protracted global commodity boom period is at or near its end believe that the resolution is in process; while those who contend that the protracted commodity boom period is part of a decades-long global commodity “super cycle” believe that the imbalance could persist for several years to come.

While Heap believed that the commodity super cycle could persist through the current decade, Humphreys believes that the resolution is imminent, “As to when exactly the current shortages will be alleviated, this will similarly reflect a combination of how the global economy develops and more specific sector influences. However, if LME [London Metals Exchange] stock levels are anything to go by [in March 2012], then it would appear that some metal markets have already eased significantly.”[33]

Implications for Future Global Prosperity

In either case, as our global NNR demand/supply/requirement imbalance is resolved, resurgent global NNR abundance will rekindle global prosperity. Continuously increasing economic (GDP) growth trajectories and continuously improving material living standard trajectories will persist indefinitely, as humanity strives toward its goal of universal global prosperity through global industrialization.

Per Humphreys, “We can supply minerals to nine billion people with rising living standards. Although they may in some cases need to pay a bit more for these minerals than they have been required to pay in the past. The raw minerals are there in the ground, the technologies exist to recover them, the mining industry is organized to develop and manage the projects required and the financial world is perfectly capable of providing the funding.”[34]

The Myth of Universal Global Prosperity "Prosperity" can be defined in practical terms as "the American way of life" – i.e., the average material living standard enjoyed by today's 315 million Americans. "Universal global prosperity" can therefore be defined as the American way of life for each of earth's 7+ billion human inhabitants. In numeric terms, universal global prosperity translates into US per capita GDP for every human being on earth.

US per capita GDP in 2010 was approximately $48,000 – that is, $48,000 of goods and services were produced/consumed in the US during 2010 for every American man, woman, and child. The total global GDP required to provide $48,000 per capita GDP for each of the approximately 6.5 billion global inhabitants in 2010 was approximately $312 trillion – 5.5 times the actual 2010 global GDP level of $57 trillion.[35] (All dollar figures in 2010 USD)

Assuming that NNR input levels scale at approximately the same rate as economic output (GDP) levels, which has been the case in America during the past 200 years (Please see the diagram on page 3), the globally available, economically viable NNR supplies required to generate $48,000 of per capita GDP for each of earth's inhabitants in 2010 were approximately 5.5 times greater than actual NNR supply levels that year. Such a scenario was both economically impossible and physically impossible.

Paradigm Shift: We Have a Permanent Structural Problem

Despite phenomenal innovation and advances in our NNR exploitation technologies since the inception of our industrial revolution, global supplies associated with the vast majority of NNRs are experiencing diminishing marginal investment returns – at the time in human history when our enormous global NNR requirements are greater than ever, and are generally increasing.

Genesis

We are experiencing a permanent "paradigm shift" in global NNR demand/supply dynamics, caused by our incessant quest for global industrialization as the means by which to achieve universal global prosperity.

Because NNRs are finite and non-replenishing, permanent global NNR scarcity was inevitable. The persistent utilization of finite and non-replenishing natural resources, especially at levels required to perpetuate our industrial lifestyle paradigm, is unsustainable by definition.

Our accelerated quest for global industrialization during the past several decades merely expedited the onset of permanent, geologically-induced, global NNR scarcity by causing a fundamental shift in global NNR demand/supply dynamics.

Our seemingly insatiable requirements for finite and non-replenishing NNRs on the demand-side are manifesting themselves within the context of increasingly expensive, lower quality NNR supplies on the supply-side. The inevitable consequence associated with our permanent global NNR demand/supply/requirement imbalance is increasingly-prevalent, geologically-induced, permanent global NNR scarcity.

On the demand-side, whereas the number of people who occupied industrialized and industrializing nations until the late 20th century totaled approximately 1.5 billion, that number increased nearly instantaneously by the beginning of new millennium to over 5 billion with the inclusion of China, India, and countless other nations in Asia, Africa, and Latin America – most of whom have yet to even remotely approach their full NNR utilization potential.

On the supply-side, NNR discoveries/deposits are fewer in number, smaller in size, less accessible, and of lower grade and purity. NNR exploration, extraction, production, and processing technologies are failing to keep pace with lower quality NNR supplies, thereby causing diminishing marginal returns on investments in NNR exploitation – i.e., each incremental dollar of investment in NNR exploration and production (E&P) yields smaller incremental quantities of economically viable NNRs. (Please see Appendix A for evidence regarding diminishing returns on investments in NNR exploitation.)

Interestingly, in his more recent writings Humphreys also acknowledges the likelihood of some degree of permanence associated with our current global NNR demand/supply/requirement imbalance. "It seems to me entirely possible that something has happened to the underlying economics of the [mining] industry in the past few years which may have longer lasting implications. We may be more deeply into the depletion of our resources than we had thought."[36]

Projected Resolution

In an increasing number of cases, persistently high NNR price levels owing to diminishing returns on investments in NNR exploitation, will permanently suppress global NNR demand/utilization to levels at which they will never again be sufficient to completely address our enormous global NNR requirements.

NNR prices will remain inordinately and "unaffordably" high, notwithstanding periodic temporary decreases due to episodes of global NNR demand destruction, such as that which occurred during the Great Recession (2009), which was precipitous and nearly universal, and those that occurred during the years following the Great Recession in 2010, 2011, and 2012, which were less dramatic.

In an increasing number of cases, globally available, economically viable NNR supplies will become permanently scarce – i.e., there will be "more" globally available, economically viable supplies, but not "enough" to completely address our global NNR requirements. At present, it would appear that there are only "enough" remaining globally available, economically viable NNRs in the aggregate to enable our persistent global economic malaise.

Implications for Future Global Prosperity

Global prosperity – i.e., our global economic output (GDP) level and material living standards – which is currently stagnating, will peak and go into terminal decline within the next few decades as a result of increasingly-prevalent, permanent global NNR scarcity.

While our global economic output (GDP) levels and average material living standards have never been higher, both are increasing at decreasing rates, or "rolling over". Increasingly-prevalent, permanent global NNR scarcity will increasingly throttle economic growth and material living standards going forward, initially for high-cost, less-competitive, PPP (pseudo purchasing power)-reliant nations in "the West"; and ultimately for "the Rest".

Increasingly Scarce and Expensive NNR Inputs → Slowing Economic (GDP) Growth → Moderating Material Living Standard (Per Capita GDP) Improvement

And as we "roll over" –

Permanently Scarce and Prohibitively Expensive NNR Inputs → Economic Collapse → Global Societal Collapse

We will not accept gracefully our transition from "continuously more and more" to "continuously less and less" – i.e., from our old normal of NNR-enabled prosperity to our new normal of geologically-imposed austerity…

Attempting to Square the Circle

Summarizing the "Optimistic" Perspective

Those who believe that our current episode of global NNR scarcity is a temporary cyclical phenomenon contend that our current global NNR demand/supply/requirement imbalance will be resolved favorably in the not-too-distant future as Chinese NNR requirements decrease, and as sufficient economically viable NNR supplies are brought online to completely address our global requirements for the indefinite future.

They further contend that future episodes of epidemic global NNR scarcity could be averted or at least greatly mitigated through the implementation of public and private initiatives that:

- Eliminate structural and institutional impediments to mining industry productivity, such as restrictive E&P regulations, compliance requirements, and access limitations; excessive permitting and licensing delays; onerous tariffs, quotas, and duties; excessive taxes and royalties; disruptive resource nationalism and asset confiscation; and corrupt governments;
- Encourage innovation in NNR exploitation technologies, processes, and infrastructure; and
- Incentivize investments in both E&P human resources and infrastructure, such as educating mining talent, educating the general public, investing in natural and manmade infrastructure upgrades and build outs, financing greenfield (new deposit) exploration projects, financing high risk exploration projects in remote areas and politically unstable areas, financing "junior" mining company exploration projects, and upgrading outdated E&P processes, equipment, and technologies.

In sum, while our current episode of global NNR scarcity is certainly unprecedented, global commodity markets, if allowed to operate freely, will bring about sufficient economically viable NNR supplies to completely address our global requirements for the indefinite future, thereby enabling us to achieve universal global prosperity.

We Should Know by 2020

If our current episode of global NNR scarcity proves to be a short-term cyclical phenomenon, it will be resolved between now and the year 2015, and we will experience sustained 5+% annual global economic (GDP) growth and significantly improving global material living standards from 2015 onward.

Or, if our current episode of global NNR scarcity is part of a longer term commodity super cycle, it will be resolved by the year 2020, and we will experience improving global economic (GDP) growth on the order of 3%-4% per annum between 2013 and 2020 and 5+% annual global GDP growth from 2020 onward.

If, on the other hand, our current episode of global NNR scarcity proves to be a permanent structural phenomenon, we will experience generally deteriorating global prosperity from this point forward, which will foster increasingly severe economic hardship, political instability, and social unrest.

Problems with the Optimistic Perspective

Even if the optimists are correct in their assertion that our current episode of global NNR scarcity is temporary, and even if their suggested initiatives are fully implemented, increasingly-prevalent, geologically-induced, permanent global NNR scarcity is inevitable. At best, our current episode of global NNR scarcity is a harbinger of increasing global NNR scarcity to come.

Going forward, the global mining industry is faced with the physically impossible task of reconciling our insatiable global NNR requirements with continuously diminishing returns on investments in the exploitation of finite and non-replenishing NNRs.

That is, in order to perpetuate our industrial lifestyle paradigm as is – much less to enable universal global prosperity through global industrialization – the global mining industry must:

- Continuously supply, through ever-improving technology and innovation,
- Ever-increasing quantities of NNRs, which are of continuously decreasing quality,
- At sufficiently low costs/prices to enable the continuously increasing levels of global NNR demand necessary to completely address our enormous and ever-increasing global NNR requirements –
- Forever!

Going forward, the global mining industry will undoubtedly continue to pull out all the stops in its effort to accomplish this objective, which will certainly buy us time. But a stay of execution is not the same as a pardon.

The "Squeeze" is On

Picture a vise tightening around the collective skulls of humanity in a relentless, remorseless "squeeze". The handle of the vise turns at only 1/1000th of a revolution per day, which causes incremental pain that is almost imperceptible on a day-to-day basis.

Over a period of 10 years, however, the vise handle makes 3+ complete revolutions; over 20 years, 7+ revolutions; and over 30 years, 10+ revolutions. While nobody can predict the timing with certainty, somewhere along the way humanity will crack…

The sad irony is that through our unsustainable natural resource utilization behavior – i.e., our continuous utilization of enormous quantities of finite, non-replenishing, and increasingly scarce NNRs – it is we ourselves who are turning the handle!

The saddest irony is that we have no choice – in order to perpetuate our industrialized existence, we must persist in our unsustainable natural resource utilization behavior, thereby continuing to turn the handle!!

We are the hapless perpetrators of our own demise…

From "Resources and the American Dream" by Samuel H. Ordway, Jr. in 1953[37] -

"As particular resources become scarcer, the products made from them become dearer. At some point of scarceness and dearness, mass production will become unprofitable. The time is not predictable when the limit of expansion will be reached; but that a limit of expansion will be reached is a more plausible belief than that the resources of the earth are inexhaustible, regardless of a limitless, expanding consumption." (p. 30)

"But when that limit is reached, if we are not philosophically and spiritually prepared for a major transition in our way of life, thought, and economic faith, the consequences will create a spiritual as well as an economic upheaval that may well produce stagnation and decay." (p. 31)

"I would express the Theory of the Limit of Growth as follows:

Premises: Levels of human living are constantly rising with mounting use of natural resources. Despite technological progress, we are spending each year more resource capital than is created.

Theory: If this cycle continues long enough, basic resources will come into such short supply that rising costs will make their use in additional production unprofitable, industrial expansion will cease, and we shall have reached the limit of growth. If this limit is reached *unexpectedly*, irreparable injury will have been done to the social order." (p. 31)

"The price of failure to recognize the probabilities and to revise our faith, in time, could lead to the end of a culture." (p. 32)

Appendix A: Evidence of Diminishing Returns

Global investments in NNR exploitation – i.e., NNR exploration and production (E&P) – are increasing every year in real dollar terms, yet returns on these investments are diminishing.

- With respect to NNR exploration, the global mining industry is making fewer, far fewer in many cases, NNR discoveries, in terms of both quantity and quality.
- With respect to NNR production, the global mining industry is extracting "more" in almost all cases, but not "enough" in the vast majority of cases.

Within the context of persistently robust NNR requirements, the law of diminishing returns on investments in NNR exploitation takes effect when the disadvantageous factors attributable to continuously decreasing NNR quality overtake the advantageous factors derived from human innovation and advances in NNR exploitation technology.

Appendix A contains evidence of diminishing returns on global investments in NNR exploitation. Specifically, it cites comments from mining industry experts who have access to proprietary databases and industry information pertaining to global NNR E&P activity during the 20th and 21st centuries. Links to the referenced studies and papers are provided where available.

From "Fifty-year Trends in Minerals Discovery – Commodity and Ore-type Targets", Exploration and Mining Geology, 2000, Chris Blain - http://emg.geoscienceworld.org/content/9/1/1.abstract (abstract).

"The overall [metals] discovery rate rose throughout the 1950s and 1960s, peaked in the late 1970s, and evidently fell during the 1980s and 1990s. During this time, there were a series of discovery booms by commodity and ore-type model. Base metal discovery rates peaked in the 1960s and 1970s; gold peaked in the 1980s." (p. 10)

From “The Declining Discovery Trend: People, Science or Scarcity?” Society of Economic Geologists Newsletter, Ross Beaty, April 2010 - https://www.segweb.org/pdf/views/2010/04/SEG-Newsletter-Views-Ross-Beaty.pdf.

“Much of the earth has been pounded by prospectors and geologists. The entire world is readily accessible today by remote sensing and most of it by physical means. Much of the world has been surveyed by satellite imaging, airborne magnetometry and radiometry; surface geochemical surveys and regional-scale geological mapping have been carried out over large portions of the earth.

Many areas have seen very intensive exploration. Until the early 1990s, the diminishing returns of exploration efforts relative to funds expended was largely confined to the most heavily explored regions of the world—southern Africa, North America, and Australia—although most of the world’s greatest orebodies had been discovered decades earlier, no matter where they were located.

Beginning in about 1993, exploration became a truly global effort as the Soviet Union collapsed and opened up to new exploration, as Africa and Latin America became much more easily accessible, and as global sources of exploration capital became available to thousands of junior exploration companies that spread their mineral search all over the world.

This global search temporarily increased the success rate of global exploration efforts as new lands opened up in the 1990s, but in recent years exploration seems to have become increasingly unsuccessful again. Specifically, the massive increase in exploration budgets during the commodities boom from 2003 to 2008 was not mirrored by a massive increase in metals discovery during this period.

Quite the opposite.” (p. 2)

“Some will argue that new exploration techniques for penetrating the enormous covered areas of the earth will enable new discoveries, and new techniques for exploring deeper in the crust will open up massive unexplored regions for future discovery. I disagree—not with the potential for actual discovery but with the potential for economic extraction in these frontier exploration regions.” (p. 2)

“It should be no surprise to anyone, though, that current declining mineral discovery trends will likely continue, that ever-growing mineral commodity consumption will become harder to sustain, and that mineral and metal prices will increase.” (p. 3)

From “Global Discovery Trends 1950-2009: What, Where, and Who Found Them”, MinEx Consulting, Richard Schodde, Managing Director, 2010 PDAC Presentation - http://www.minexconsulting.com/publications/Global%20Discovery%20Trends%201950-2009%20PDAC%20March%202010.pdf.

“In spite of record exploration expenditures, the rate of discovery has declined over the last decade.” (p. 30)

From “World Exploration Trends 2008”, Metals Economics Group, 2009 - http://www.metalseconomics.com/sites/default/files/uploads/PDFs/pdac2008.pdf.

“Nevertheless, although it is beyond the scope of this study to quantify, we can be certain that in most parts of the world, today’s exploration dollar does not go as far as it did a decade ago.

Increased demand for services such as drilling and assaying, and rising input costs on everything from fuel to geoscientists, have significantly increased the costs of exploration; as a consequence, the substantial increase in exploration budgets over the past few years has not resulted in a proportionate rise in actual activity on the ground." (p. 4)

From "Trends in Exploration", Atlas Copco (Anders Gustafsson), 2009 - http://www.atlascopcoexploration.com/1.0.1.0/354/TS1.pdf.

"This means that the actual activity on the ground has not increased in direct proportion to the expenditure, despite continuously increasing exploration costs." … "In addition, ore grades are continuously declining, making discoveries more difficult than when ore bodies outcropped or were at shallow depths." (p. 4)

"The cost of exploration has increased, and in order to find future volumes and qualities of minerals, exploration has to be in remote areas and, in some cases, high-risk areas with higher costs." (p. 6)

From Tracking the trends 2011, Deloitte - http://www.deloitte.com/view/en_AL/al/industries/energyresources/mining/d13892602649d210VgnVCM2000001b56f00aRCRD.htm.

"As emerging economies around the globe continue their rapid industrialization, demand for commodities has sky-rocketed. This has served to keep commodity prices at least steady or rising on everything from coal, copper, and iron ore to gold, silver and rare earth metals." (p. 4)

From "Tracking the trends 2012", Deloitte – http://www.deloitte.com/assets/Dcom-SouthAfrica/Local%20Assets/Documents/Industries/Mining/Tracking%20the%20trends%202012.pdf –

"Massive industrialisation is sucking up critical resources around the world, threatening to drive capital costs to unsustainable levels if improperly managed." – Tony Zoghby, South African Mining Leader (Deloitte) (p. 5)

"Demand in China, India and even across Africa has been rising at break-neck speed and long-term forecasts seem to point to rising demand for decades to come." (p. 6)

"In the next few years, escalating costs, talent shortages and competing infrastructure builds will make it very difficult for mining companies to complete their capital projects on time and on budget." – David Quinlin, European Mining Lead (Deloitte) (p.19)

"Dwindling access to deposits, deteriorating grades, spiking global demand and lofty commodity prices have all conspired to heighten mining company appetite for geographic and economic risk. As a result, mining companies are straying from established mining nations like South Africa, Australia and Chile to increasingly remote locales, including Eritrea, Papua New Guinea, the Democratic Republic of Congo, Liberia, Afghanistan, Mongolia and Kazakhstan." (p. 22)

From "World Exploration Trends 2012", Metals Economics Group, 2012 - http://www.metalseconomics.com/sites/default/files/uploads/PDFs/wet2012english.pdf.

"Despite concerns about the global economy and projections of lackluster growth for most countries, China and other resource-hungry emerging and developing economies are still expected to lead global GDP growth and demand for metals over the next few years." (p. 6)

"On the supply side, the industry still faces many of the limitations that existed prior to the 2008 economic downturn that effectively set back the clock on many developments. While periods of weakness and volatility will likely continue in the near term, most metals prices are expected to remain above their long-term trends…" (p. 6)

From "China – The Engine of a Commodities Super Cycle" Citigroup (Smith Barney), Heap, 2005 - http://www.fallstreet.com/Commodities_China_Engine0331.pdf.

"But, increasing production costs mean that higher capital expenditure is likely to translate into a relatively small expansion in production." (p. 15)

"However, we also believe production costs are likely to continue rising on a structural basis. The additional supply required to meet higher trend demand growth will be higher cost. Margins are expected to remain constant, and prices will be driven higher." (p. 17)

From "Mining Investment Trends and Implications for Minerals Availability", David Humphreys, Polinares (EU Policy on Natural Resources), 2012 - www.polinares.eu/docs/d2-1/polinares_wp2_chapter3.pdf.

"The second set of constraints on mineral development – referred to here as economic constraints – are a product of the fact that mineral resources deplete over time. That is to say, ores become lower in grade or more difficult to treat, whilst ore deposits are found at greater depth or in more remote locations.'

"To some degree, the upward pressure on industry costs which results from these trends can be offset by improvements in technology, and typically this has been the experience of the past 30 years. However, there is no law which says that this has to be the case and, for a number of mineral commodities, it would appear that the declining quality of reserves, combined with other factors like higher energy prices, are pushing up net production costs, notwithstanding continuing technological progress." (p. 9)

From "Global Mineral Exploration and Production – The Impact of Technology" – M.A. Doggett, 2000?; http://pubs.usgs.gov/circ/2007/1294/reports/paper10.pdf.

"Many of the largest, highest grade, closest to surface, closest to market mineral deposits have been depleted or currently are in production. Over the next half century, the competition for land use among diverse sectors of an ever-increasing population will intensify. Mining companies struggling to improve the traditional bottom line will be forced to support a triple bottom line incorporating the costs and benefits of environmental and social responsibilities." (p. 63)

"The results indicate that exploration expenditure levels have been increasing significantly in real terms over time. Exploration increased from $3.5 billion in the 1950s to $12 billion in the 1970s and to approximately $28 billion in the 1990s [1999 dollars]. Taken on its own, this trend suggests that discovery costs have been increasing over time." (p. 63)

Permanent global NNR scarcity is a question of "when", not "if";
and if not "now", then "soon"…

Endnotes

1. “200 Years of Commodity Prices”, Barry Bannister, 2010 - http://www.japaninc.com/files/images/mgz_72_commo-price-cycles.JPG.
2. “Scarcity – Humanity’s Final Chapter?” pages 51-70; Chris Clugston, 2012; www.nnrscarcity.com.
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 (Historic US NNR utilization information compiled by the Mineral Information Institute is available upon request from coclugston at Verizon dot net.) –www.mii.org.
5. Estimated total US mineral utilization in the year 1800: per capita US 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 US mineral utilization was 1500 lbs. times 5.3 million people, equals (3,975,000 tons) ~ 4 million tons.
6. Estimated US total mineral utilization in the year 2008: per capita US 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, equals ~6.5 billion tons total.
7. US year 1800 and year 2008 GDP data from Measuring Worth - http://www.measuringworth.com/.
8. “Crust”, Wikipedia, 2011 - http://en.wikipedia.org/wiki/Crust_(geology).
9. “Abundance of Elements in Earth’s Crust”, Wikipedia, 2010 - http://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth's_crust.
10. The mass of earth’s crust is approximately 1.913×10^{22} kg; or approximately 20 quintillion metric tonnes - http://wiki.answers.com/Q/What_is_the_mass_of_Earth's_crust
11. “Mineral Commodities Summary 2009”, page 191; USGS, 2009 - http://minerals.usgs.gov/minerals/pubs/mcs/2009/mcs2009.pdf.
12. “Mineral Commodities Summary 2009”, USGS, page 192.
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Chris Clugston Bio

Since 2006, I have conducted extensive independent research into the area of “sustainability”, with a focus on nonrenewable natural resource (NNR) scarcity. NNRs are the fossil fuels, metals, and nonmetallic minerals that enable our modern industrial existence.

I have sought to quantify from a combined ecological and economic perspective the extent to which America and humanity are living unsustainably beyond our means, and to articulate the causes, magnitude, implications, and consequences associated with our “predicament”. My research culminated in the publication of ***Scarcity – Humanity’s Final Chapter?*** (Please see www.nnrscarcity.com for additional information.)

My previous work experience includes thirty years in the high technology electronics industry, primarily with information technology sector companies. I held management level positions in marketing, sales, finance, and M&A, prior to becoming a corporate chief executive and later a management consultant.

I 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.

