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*MuseLetter #228 / May 2011 by Richard Heinberg*

*This month's Museletter comprises two pieces. The lead article is the first release of a new section from Chapter 5 of my upcoming book [The End of Growth](#) which will be published in September 2011 by [New Society Publishers](#). The second is the transcript of a speech I gave on Saturday at Worcester Polytechnic Institute. This speech was an alternative commencement address to one given by Rex Tillerson of Exxon Mobil, and was given by invitation from members of Students for a Just and Stable Future.*

## **Shrinking Pie: Competition and Relative Growth in a Finite World**

. . . [C]ommerce is but a means to an end, the diffusion of civilization and wealth. To allow commerce to proceed until the source of civilization is weakened and overturned is like killing the goose to get the golden egg. Is the immediate creation of material wealth to be our only object? Have we not hereditary possessions in our just laws, our free and nobly developed constitution, our rich literature and philosophy, incomparably above material wealth, and which we are beyond all things bound to maintain, improve, and hand down in safety? And do we accomplish this duty in encouraging a growth of industry which must prove unstable, and perhaps involve all things in its fall?

—*William Stanley Jevons (economist, 1865)*

Is the central assertion of this book—that world economic growth is over—already disproved? How else to explain China's continued exuberant expansion, or signs of recovery in the U.S. in 2010?

As stated in the Introduction, I am asserting that *real, aggregate, averaged* growth is essentially finished, though we may still see an occasional quarter or year of GDP growth relative to the previous quarter or year, and will still see residual growth in some nations or regions. The point can be summarized in a single sentence, but it bears reiterating and unpacking because there are several kinds of relative growth, and the competitive pursuit of advantage within a global economy that, overall, is shrinking rather than growing will powerfully shape political, geopolitical, and social developments for the next few decades.

In this chapter we will explore the growth prospects of the Asian economies. We will also examine the dynamics of currency wars. And we will see how rich and poor countries, and demographic sectors within those countries, are likely to fare in post-growth economy, and how increasing competition for depleting resources may drive nations toward conflict.

The best place to start this survey of prospects for short-to-medium-term relative growth is with China, which not only exemplifies rapid residual economic growth, but also points the way to how currency and resource rivalries, as well as old/young, rich/poor, urban/rural divisions might play out as the global economy contracts.

## **The China Bubble**

If one were looking for a single arguing point against the idea that world economic growth is ending, China would almost certainly be the best choice. New Chinese cities are springing up in mere months. A stop-motion video posted on the Internet last year showed a 15-story hotel being built in six days.[1] A new coal power plant opens, on average, every four days. Twenty million Chinese move from the countryside to cities each year. Because city dwellers contribute 20 times as much per capita to GDP, urbanization alone accounts for half or more of China's 10 percent annual GDP growth. China is building highways faster than any other nation, and its motorists are now buying around 13 million automobiles per year, versus 11 million annually in the U.S.—which had been the world's largest market for cars since the days of the Model T. It's all happening blindingly fast. Indeed, in both its scale and speed, the expansion of the Chinese economy is unprecedented in world history.

But how long can this go on? Will China escape the economic fate of older industrial nations, or is it poised for its own encounter with growth limits? There are four reasons for thinking current trends cannot be sustained.

### *1. Resource Depletion and Resource Competition: The Story of China's Coal*

China's appetite for resources and raw materials is driving up worldwide prices of a wide range of commodities including oil, iron, copper, cotton, cement, and soybeans. But for the Chinese economy, perhaps the single most important resource is coal. Indeed, it may not be an oversimplification to say that the fate of China's economy rests on its ability to maintain growth in coal supplies.

China relies on coal for 80 percent of its electricity and 70 percent of its total energy; coal also supports China's steel industry, the world's largest. Altogether, China is one of the most coal-dependent nations in the world. In order to become the world's second-largest economy, it has had to more than double its coal consumption over the past decade, so that it is now using nearly half of all coal consumed globally, and over three times as much as is consumed in the next nation in line, the U.S. (which prides itself on being "the Saudi Arabia of coal").

As China energy expert David Fridley and I argued in a recent op-ed in *Nature*, while China claims it has enough coal to fuel continued

economic growth, that claim is questionable.[2]

The nation has recently updated its proven coal reserves to 187 billion metric tons, putting it second in line after the U.S. in terms of supplies. That would be about 62 years' worth of coal at 2009 rates of consumption (over three billion tons per year). But this simple "lifetime" calculation is highly misleading.

Reserves lifetime figures are calculated on the basis of flat demand and lose meaning if demand grows over time. China's coal consumption is accelerating rapidly, so that the expected "62 years' worth" must be adjusted downward. Demand forecasts from China's Energy Research Institute would reduce the reserves lifetime to about 33 years; but if coal demand were to grow in step with projected Chinese economic growth, the reserves lifetime would drop to just 19 years.

Yet this still doesn't capture the situation. Production will peak and decline long before China's coal completely runs out. Further, as with oil production, coal mining proceeds on the basis of the "best-first" or "low-hanging fruit" principle, so we must assume that China is extracting its highest-quality, easiest-accessed coal now, leaving the lower-quality and more expensively mined coal for later. Unlike the U.S., China does not have vast deposits of surface-minable coal; over 90 percent of China's coal comes from underground mines up to 1,000 meters in depth, and those mines face increasing engineering challenges.

Hubbert analysis, which has been used to forecast oil production peaks, can also be applied to forecasting future coal supplies. In 2007, Chinese academics Tao and Li forecast that China's coal production will peak and start to decline perhaps as early as 2025.[3] Other forecasts are more pessimistic. A 2007 analysis by the Energy Watch Group of Germany forecast a peak of production in 2015 with a rapid production decline commencing in 2020.[4] And a 2010 study by Patzek and Croft forecast the peak of *world* coal production for this year (2011); they see China's coal peak also occurring essentially now.[5]

China has few options for reducing its reliance on coal, since the fuel is used in so many ways. In addition to powering the electricity and steel sectors, coal provides winter heat to hundreds of millions of northern Chinese; it is also used in the cement, non-ferrous metals, and chemicals industries. While China is rapidly expanding its supply of natural gas, to replace just the coal used for heating would double total gas consumption.

China is quickly developing alternative energy sources. But can these be brought on line fast enough to make a difference? Let's do some numbers. China aims to have 100 gigawatts (GW) of wind power capacity by 2020, and the nation's leaders plan to expand installed solar capacity to 20 GW during the same period. These are truly astonishing goals, and, if China even comes close to accomplishing them, it will become the world's renewable energy leader. But there is a problem. Total Chinese electricity generation capacity is 900 GW currently; with seven percent growth, that means the nation's electricity demand in 2020 will be something like 1800 GW. Wind and

solar together would supply less than seven percent of that. The only thing likely to boost that percentage much would be a dramatic reduction in growth of energy demand to, say, two percent annually.

The situation with nuclear power is similar: China has 11 atomic power plants now and is in the process of building 20 more, with a target of 60 GW of generating capacity, or possibly more, by 2020. But this will supply only between three and five percent of total electricity demand, depending on energy demand growth rates. In late 2010, energy policy makers in Beijing evidently began to take notice of the looming electricity supply problem, and rumors circulated of new efforts to construct up to 245 new nuclear plants over the next two decades (the U.S. has only 104 in total). If this new target is real, and if the Chinese succeed in achieving it, a large fraction of new electricity demand for the coming years could be met through sources other than coal—but China would still have an enormous (though more slowly growing) coal dependence to feed. Meanwhile, China's soaring demand for uranium would push up global prices for this energy mineral.[6]

In 2009 China was a substantial net importer of coal, having been a net exporter every year through 2008.[7] China could import more coal to enable further growth, but the biggest exporters of coal—Australia, Indonesia, and South Africa—have much smaller reserves and production rates. The entire seaborne trade in steam coal (mainly used by power plants) currently amounts to only 630 million tons per year, and China could absorb this much with only three years of continued growth in coal demand. That's not going to happen, though: Other nations need that export coal, too—including India, also a major coal-based economy, and also a country needing to import increasing amounts of fuel.

The conclusion is unsettling but inescapable: China's reliance on coal cannot be significantly reduced as long as its demand for electrical power continues to grow at anything like current rates. And even if energy demand growth tapers off and alternative energy sources come on line quickly, the country's ability to supply enough coal domestically will still be challenged. This will drive up coal prices worldwide, while choking off economic growth at home. China's energy economy is unsustainable and will cease growing in the foreseeable future, impacting many other nations as it does so.

## *2. Export-Led Development Model*

The fundamental economic model that China has depended on for the past couple of decades was borrowed from Japan, and consists of producing low-cost export goods to fund investment at home. Essentially the same model is being pursued by Thailand, Vietnam, Taiwan, Malaysia, Singapore, the Philippines, and Indonesia. The story of what happened to Japan as a result of following this strategy should be a cautionary tale for its neighbors, and for Beijing in particular.[8]

The post-war Japanese export boom resulted in spectacular growth for four decades, but the undervalued yen eventually caused a deflationary contraction of Japan's economy, which is smaller today than it was in the late 1990s. There are good reasons to think the

same policies will achieve the same results in China. However, China is much larger than Japan, and the world economy is today far more fragile than it was in the late 1980s when the Japanese bubble burst, so the global consequences of a Chinese crash would be far greater.

After World War II, Japan kept its yen weak, making exports relatively cheap to foreign buyers. Japan also benefited from a high savings rate, which enabled massive investment in infrastructure and manufacturing capacity. The country's GDP ballooned by 600 percent from 1950 to 1970, pulling more people out of poverty more quickly than had ever been done anywhere previously.

Export- and investment-driven growth typically discourages consumption, as domestic prices are kept high and salaries low (to help fuel exports). In the case of Japan, yields on savings were suppressed so that available capital would flow to corporations and the government.

All of this resulted in a lopsided economy. In most modern market economies, consumption accounts for around 65 percent of GDP (in the U.S., the proportion is 70 percent), while investment in fixed assets such as infrastructure and manufacturing capacity makes up 15 percent. In 1970, Japan's domestic consumption contributed 48 percent of the economy and fixed investment 40 percent. As Ethan Devine put it in his article "The Japan Syndrome" in *Foreign Policy*, "In plain English, the Japanese were consuming relatively little while investing heavily in steel plants and skyscrapers, which didn't leave much for fish or tourism. Belatedly, Tokyo realized that a balanced economy must also have consumption and that coating the country with factories and infrastructure wouldn't do the trick." [9]

Throughout the 1970s and early 1980s, Japan gradually strengthened the yen so as to support the development of a consumer culture, and consumption rose to more than half of GDP. In 1985, Tokyo let its currency appreciate more rapidly. But the result was simply a spectacular inflation of real estate and stock prices. The bubble's collapse lasted more than a decade, with stock prices scraping bottom in 2003 (before plummeting even further after the commencement of the current global crisis in 2008). Export-oriented industries could not adapt to a domestically led economy because there was insufficient consumer demand. And so rapid growth turned to stagnation, which has persisted up to the present.

Japan still runs on exports, but now government spending is an essential prop for the economy. Twenty years of fiscal stimulus have done little more than stave off even more serious economic contraction, while government debt has grown to nearly 200 percent of GDP. [10]

Fast forward to China, 2011. Like Japan, China subsists largely on exports while investing heavily in infrastructure, paying for the latter with private savings that come from tamping down consumption. Beijing adopted the Japanese growth model in the 1990s, when its deregulation and opening up of the country's economy was widely praised. While these policies created tens of millions of jobs, as well as thousands of new roads and millions of new buildings, they have also generated imbalances reminiscent of Japan in the 1980s—except

that in many ways China has gone even further out on a limb.

Devine recites the startling numbers:

“China is far more dependent on exports and investment than Japan ever was, and the numbers are still moving in the wrong direction. Investment accounts for half of China’s economy while consumption is only 36 percent of GDP—the lowest in the world, drastically lower than even other emerging economies such as India and Brazil. But as the Japan example illustrates, low consumption leads to high savings, and China’s thrifty citizens, coupled with booming net exports, have bestowed upon the country the world’s largest current account surplus, triple that of Japan’s in 1985.”[11]

China’s legendary trade surpluses cause problems for its trading partners while stoking price inflation at home. And inflation, the usual result of an undervalued currency, is dangerous in a country where hundreds of millions of people still have trouble affording basic essentials.

To outsiders, China has looked like a shining example of what growth can accomplish, yet it has achieved its success by strangling personal consumption (which was the engine of growth in the U.S. and Europe) and sidelining small-scale entrepreneurs in favor of state-owned businesses and selected multinational corporations. Only a small percentage of its population has shared in the bounty.

China’s leaders are aware of the pitfalls of pursuing the Japanese development model, and have issued a comprehensive slate of reforms to foster consumption and curb excessive capital investment. But these efforts will only work if the U.S. and the rest of the world return to a path of growing consumption. If not, China’s choices may be limited. An export-driven economy can only succeed if others can afford to import.

### *3. Demographics: Old/Young, Rich/Poor, Urban/Rural*

Beijing’s one-child policy, introduced in 1979, was largely effective—though it had the abhorrent side effect of encouraging a disdain for female infants, a prejudice that has led to abortion, neglect, abandonment, and even infanticide. Applying mainly to urban couples of Han descent, the policy reduced population growth in the country of 1.3 billion by as much as 300 million people. This meant that by the 1980s and ‘90s, young workers had fewer dependents to support—and China’s manufacturing boom drew strength from young people moving from country to city to work in factories. For the nation as a whole, having a few hundred million fewer mouths to feed has acted as a social safety valve so far, and will reduce misery in the decades ahead as world resources deplete and human carrying capacity disappears.

However, there is a demographic price to pay. Beginning in 2015, China will see a growing number of older citizens relying on a shrinking pool of young workers.

Most of the nation’s factories are located in its coastal cities, of which some, like Shenzhen, were built from scratch as industrial centers.

Shenzen hosts the Foxconn Technology Group, an electronics manufacturer that makes components for Dell, Hewlett-Packard, and Apple; nearly all its workers are under 25.

China's older workers have largely been left behind in rural villages, or pushed from their urban homes into apartment blocks on cities' outskirts to make way for new apartments and office buildings occupied by younger urbanites and the companies hiring them. Age discrimination is a fact of life.

All of this will gradually change as China's work force ages. Within a generation, the average age of a Chinese worker will be higher than that of an American worker.[12] One of China's leaders' biggest fears, expressed repeatedly in public pronouncements, is that the nation will grow old before it grows rich (Japan, in contrast, got rich before it grew old).

To avoid this fate, China is trying to grow its economy as fast as possible now, while it still can.

One way it does this is to offer paltry pensions and poor-quality health care to older citizens. This makes China an attractive place for foreign corporations to do business. In the U.S., health care costs for older workers are often double the costs for workers in their 20s, 30s and 40s. By keeping its workforce young and denying them benefits, China's leaders keep costs down. American or European companies that move production to China or buy Chinese goods gain leverage to rewrite terms of employment with their older workers at home—or they can simply shut down domestic factories.

China's youthful labor force attracts foreign investment. But as the country's work force ages, its competitive advantage may evaporate. Moreover, the lack of adequate pensions and health care for Chinese workers will eventually result in worsening social stresses and strains.

It is the financial sacrifices of its people that have given China the opportunity to attract capital investment to its industries, and that generate subsequent profits that are then loaned back to the United States and other industrialized nations.

To understand the significance of those sacrifices, one must understand a little of the country's recent history. At the end of the Communist revolution in 1949, China was impoverished and war-ravaged; the overwhelming majority of its people were rural peasants. Communist Party chairman Mao Zedong set a goal of bringing prosperity to the populous, resource-rich nation. A period of economic growth and infrastructure development ensued, lasting until the mid-1960s. At this point, Mao appears to have had second thoughts: concerned that further industrialization would create or deepen class divisions, he unleashed the Cultural Revolution, lasting from 1966 to the mid-1970s, when industrial and agricultural output fell. As Mao's health declined, a vicious power struggle ensued, leading to the reforms of Deng Xiaoping. Economic growth became a higher priority than ever before, and it followed in spectacular fashion from widespread privatization and the application of market principles. "To get rich is glorious," Communist officials now proclaimed.

During the 1950s, '60s, and '70s, the Chinese people had worked hard and endured grinding poverty for the good of the nation. But in the 1990s a small segment of the populace—mostly in the coastal cities—began to enjoy a middle-class existence. Some Chinese were indeed becoming gloriously rich, while most remained mired in extreme poverty. The resulting wealth disparity is only bearable as long as the middle class continues to expand in numbers, offering the promise of economic opportunity to hundreds of millions of destitute peasants in the rural interior.

China's central government has unleashed a firestorm of entrepreneurial, profit-driven economic activity that is both unsustainable and difficult to control. Meanwhile, as we have seen, the uncontrollably dynamic economy is export-dependent and ill suited to meeting domestic needs.

China has encouraged rapid export-led, coal-fired economic growth, perhaps as a way of putting off dealing with its internal political, demographic, and social problems. If that is indeed Beijing's strategy, it has worked spectacularly well for a short while. But it is built on contradictions and false hopes. Over the course of the current decade, the Chinese demographic-economic strategy will likely begin to unravel. What happens next is anybody's guess.[13]

#### *4. Oh No—Not Another Real Estate Bubble!*

There is one more similarity between Japan and China that is worth mentioning. During the 1980s, real estate prices in Tokyo were jaw-dropping. In the Ginza district in 1989, choice properties fetched over 100 million yen (approximately \$1 million U.S. dollars) per square meter, or \$93,000 per square foot. Prices were only slightly lower in other major business districts in the city. By 2004, values of top properties in Tokyo's financial districts had plummeted by 99 percent, and residential homes were selling for less than a tenth their peak prices. Tens of trillions of dollars in value were wiped out with the combined collapse of the Tokyo stock and real estate markets during the intervening years.

Once again, China is following in Japan's footsteps. Massive real estate projects—houses, shopping malls, factories, and skyscrapers—have been proliferating in China for years, attracting both private and corporate buyers. As prices have soared, investors have turned into speculators, intent on buying brand-new properties with the intention of flipping them.

Building is being driven by artificially inflated demand—the very definition of a bubble. And this is resulting in oversupply. In city after city, acres of commercial space sit vacant. Indeed, whole cities intended for millions of inhabitants have been built in the Chinese interior and now stand all but empty.[14] Some might argue that the Chinese are investing in infrastructure now in anticipation of many millions more citizens moving into urban centers over the coming decades—however, this presupposes continuing rapid economic growth, which is exactly what is in question. If growth sputters, this infrastructure overbuild will be a dead weight on the Chinese economy.

Though Beijing initiated an effort to cool the real estate and stock markets in 2008, the global financial crisis forced officials to relent in favor of lavish stimulus spending on shovel-ready infrastructure projects. The Chinese funneled 4 trillion yuan (about \$590 billion) into what in many cases turned out to be yet more empty new shopping malls, empty new cities, and empty new factories.

For Chinese citizens, investment in the stock market hardly makes sense, given dramatic episodes of turbulence in recent years. Instead, a condominium or a house is seen as the most sensible and profitable investment. But this results in a bidding up of prices to the point where, in major cities like Beijing and Shanghai, a condo can cost 20 times a worker's annual salary. A worker in Tokyo might expect to pay only eight times her annual wages for a similar property.

What are the chances of putting off a property price meltdown? According to a November, 2010 article by Wieland Wagner in the German magazine *Der Spiegel*,

“Cao Jianhai of the Chinese Academy of Social Sciences in Beijing likens the Chinese economy to “a volcano before an eruption.” Nevertheless, he doesn't believe that the government of Hu Jintao, the Communist Party leader and president, and Prime Minister Wen will allow a crash to occur before its term in office ends in 2012—local governments are too dependent on the real estate boom. According to Cao, Beijing will go to “any expense” to pump money into the financial system and spur a renewed surge of rapid economic growth.”[15]

Once Hu and Wen are gone, however, it will be up to their successors to deal with the fallout from a housing crash.[16]

#### *Economic Growth's Last Stand?*

China is no more able to sustain perpetual growth than any other nation. The only questions, really, are when its growth will stall, and by what pace and to what degree its economy will contract.

The property bubble is likely to be China's biggest short-term problem, and it could have knock-on effects on the nation's banking system. The bubble could start to deflate as soon as next year, or the year after. Beijing will do what it can to prop up growth and tamp down social strain, and this could buy another couple of years—though there is no guarantee that the effort will succeed.

Over the longer haul (the next 2-10 years), China's greatest vulnerabilities are in the areas of energy, demographics, and the environment (water, climate, and agriculture). By the period 2016 to 2020, problems in these areas will accumulate and become mutually exacerbating, and it will eventually be impossible for China's leaders to plug all the leaks in the dike.

Already, China's social structure is stressed, as can be seen from the many regional rebellions that take place each year (but that go mostly unreported in world media). This is the main reason the central government is ruthless with respect to press and Internet freedoms and other civil liberties.

Talk to a businessperson from China and you may hear how the continued expansion of the Chinese economy is inevitable and unstoppable. But peer beneath the surface and you will see roiling, boiling ferment.

We have discussed China at some length, not only because it has become the world's second-largest national economy and is the world's foremost energy user, but because it is emblematic. India, Thailand, Indonesia, Malaysia, and Vietnam are each pursuing somewhat different paths toward the same grail of rapid economic growth, but their strategies and vulnerabilities are sufficiently similar that an understanding of China's predicament provides useful context for gauging these other countries' prospects.

China is likely the site of world economic growth's last stand. This nation, together with the other Asian "tigers," comprises the main engine of expansion that remains after the faltering of the older, more established economies in North America and Europe. When China sputters, the quickening slide of the global economy will be clear and obvious to everyone.

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## Your Post-Petroleum Future

*Worcester Polytechnic Institute in Worcester, MA invited Rex Tillerson, CEO of ExxonMobil, to give the commencement speech at its 2011 graduation ceremonies on May 14. When students heard of this, many were surprised and upset. As Linnea Palmer Paton of Students for a Just and Stable Future put it in a letter to WPI President Berkey, "[W]e, as conscientious members of the WPI community and proud members of the Class of 2011, will not give [the Exxon CEO] the honor of imparting . . . his well-wishes . . . for our futures . . . when he is largely responsible for undermining them." The students then invited Richard Heinberg, Senior Fellow of Post Carbon Institute, to give an alternative commencement speech. After a few days of negotiations, the college administration agreed to give Heinberg the podium immediately after the main ceremony. Many students chose to walk out during Tillerson's address. This is what Richard Heinberg had to say.*

ExxonMobil is inviting you to take your place in a fossil-fueled twenty-first century. But I would argue that Exxon's vision of the future is actually just a forward projection from our collective rear-view mirror. Despite its high-tech gadgetry, the oil industry is a relic of the days of the Beverly Hillbillies. The fossil-fueled sitcom of a world that we all find ourselves still trapped within may on the surface appear to be characterized by smiley-faced happy motoring, but at its core it is monstrous and grotesque. It is a zombie energy economy.

Of course, we all use petroleum and natural gas in countless ways and on a daily basis. These are amazing substances—they are energy-dense and chemically useful, and they yield enormous economic benefit. America started out with vast reserves of oil and gas, and they helped make our nation the richest and most powerful in the world.

But oil and gas are finite resources, so it was clear from the start that, as we extracted and burned them, we were in effect stealing from the future. In the early days, the quantities of these fuels available seemed so enormous that depletion posed only a theoretical limit to consumption. We knew we would eventually empty the tanks of Earth's hydrocarbon reserves, but that was a problem for our great-great-grandkids to worry about. Yet U.S. oil production has

been declining since 1970, even with huge discoveries in Alaska and the Gulf of Mexico. Other countries are also seeing falling rates of discovery and extraction, and world crude oil production has been flat-lined for the past six years, even as oil prices have soared. According to the International Energy Agency, world crude oil production peaked in 2006 and will taper off from now on.

ExxonMobil says this is nothing we should worry about, as there are still vast untapped hydrocarbon reserves all over the world. That's true. But we have already harvested the low-hanging fruit of our oil and gas endowment. The resources that remain are of lower quality and are located in places that are harder to access than was the case for oil and gas in decades past. Oil and gas companies are increasingly operating in ultra-deep water, or in arctic regions, and need to use sophisticated technologies like hydrofracturing, horizontal drilling, and water or nitrogen injection. We have entered the era of extreme hydrocarbons. This means that production costs will continue to escalate year after year. Even if we get rid of oil market speculators, the price of oil will keep ratcheting up anyway. And we know from recent economic history that soaring energy prices cause the economy to wither: when consumers have to spend much more on gasoline, they have less to spend on everything else.

But if investment costs for oil and gas exploration and extraction are increasing rapidly, the environmental costs of these fuels are ballooning just as quickly. With the industry operating at the limits of its technical know-how, mistakes can and will happen. As we saw in the Gulf of Mexico in the summer of 2010, mistakes that occur under a mile or two of ocean water can have devastating consequences for an entire ecosystem, and for people who depend on ecosystem services. The citizens of the Gulf coast are showing a brave face to the world and understandably want to believe their seafood industry is safe and recovering, but biologists who work there tell us that oil from the Deepwater Horizon disaster is still working its way up the food chain.

Of course the biggest environmental cost from burning fossil fuels comes from our chemical alteration of the planetary atmosphere. Carbon dioxide from oil, gas, and coal combustion is changing Earth's climate and causing our oceans to acidify. The likely consequences are truly horrifying: rising seas, extreme weather, falling agricultural output, and collapsing oceanic food chains. Never mind starving polar bears—we're facing the prospect of starving people.

But wait: Is this even happening? A total of nearly half of all Americans tell pollsters they think either the planet isn't warming at all, or, if it is, it's not because of fossil fuels. After all, how can the world really be getting hotter when we're seeing record snowfalls in many places? And even if it *is* warming, how do we know that's not because of volcanoes, or natural climate variation, or cow farts, or because the Sun is getting hotter? Americans are understandably confused by questions like these, which they hear repeated again and again on radio and television.

Now of course, if you apply the critical thinking skills that you've learned here at WPI to an examination of the relevant data, you'll probably come to the same conclusion as has been reached by the

overwhelming majority of scientists who have studied all of these questions in great depth. Indeed, the scientific community is nearly unanimous in assessing that the Earth *is* warming, and that the only credible explanation for this is rising levels of CO<sub>2</sub> from the burning of fossil fuels. That kind of consensus is hard to achieve among scientists except in situations where a conclusion is overwhelmingly supported by evidence.

I'm not out to demonize ExxonMobil, but some things have to be said. That company plays a pivotal role in shaping our national conversation about climate change. A 2007 report from the Union of Concerned Scientists described how ExxonMobil adopted the tobacco industry's disinformation tactics, and funded some of the same organizations that led campaigns against tobacco regulation in the 1980s—but this time to cloud public understanding of climate change science and delay action on the issue. According to the report, between 1998 and 2005 ExxonMobil funneled almost \$16 million to a network of 43 advocacy organizations that misrepresented peer-reviewed scientific findings about global warming science. Exxon raised doubts about even the most indisputable scientific evidence, attempted to portray its opposition to action as a positive quest for "sound science" rather than business self-interest, and used its access to the Bush administration to block federal policies and shape government communications on global warming. All of this is well-documented.

And it worked. Over the course of the past few years one of our nation's two main political parties has made climate change *denial* a litmus test for its candidates, which means that climate legislation is effectively unachievable in this country for the foreseeable future. This is a big victory for ExxonMobil. Its paltry \$16 million investment will likely translate to many times that amount in unregulated profits. But it is a disaster for democracy, for the Earth, and for your generation.

But here's the thing. Everyone knows that America and the world will have to transition off of fossil fuels during this century anyway. Mr. Tillerson knows it as well as anyone. Some people evidently want to delay that transition as long as possible, but it cannot be put off indefinitely. My colleagues at Post Carbon Institute and I believe that delaying this transition is extremely dangerous for a number of reasons. Obviously, it prolongs the environmental impacts from fossil fuel production and combustion. But also, the process of building a renewable energy economy will take decades and require a tremendous amount of investment. If we don't start soon enough, society will get caught in a trap of skyrocketing fuel prices and a collapsing economy, and won't be in a position to fund needed work on alternative energy development. In my darker moments I fear that we have already waited too long and that it is already too late. I hope I'm not right about that, and when I talk to young people like you I tend to feel that we *can* make this great transition, and that actions that have seemed politically impossible for the past forty years will become inevitable as circumstances change, and as a new hearts and minds comes to the table.

Even in the best case, though, the fact that we have waited so long to address our addiction to oil will still present us with tremendous

challenges. But this is not a problem for ExxonMobil, at least not anytime soon. When the price of oil goes up, we feel the pain while Exxon reaps the profits. Even though Exxon's actual oil production is falling due to the depletion of its oilfields, corporate revenues are flush: Exxon made almost \$11 billion in profits in just the past three months. This translates to jobs in the oil industry. But how about the renewable energy industry, which everyone agrees is the key to our future?

For the past forty years, every U.S. president without exception has said we must reduce our country's dependence on imported petroleum. Addiction to oil has become our nation's single greatest point of geopolitical, economic, and environmental vulnerability. Yet here we are in 2011, still driving a fleet of 200 million gasoline-guzzling cars, trucks, and SUVs. The inability of our elected officials to tackle such an obvious a problem is not simply the result of ineptitude. In addition to funding climate denial, fossil fuel companies like Exxon have contributed to politicians' election campaigns in order to gain perks for their industry and to put off higher efficiency standards and environmental protections. Denying looming fuel supply problems, discouraging a transition to renewable energy, distorting climate science—these are all understandable tactics from the standpoint of corporate self-interest. Exxon is just doing what corporations do. But once again, it is society as a whole that suffers, and the consequences will fall especially on your generation.

Mr. Tillerson may have informed you about his company's Global Climate and Energy Project at Stanford University. Exxon is now funding research into lowering the cost and increasing the efficiency of solar photovoltaic devices, increasing the efficiency of fuel cells, increasing the energy capacity of lithium-ion batteries for electric cars, designing higher-efficiency engines that produce lower emissions, making biodiesel fuel from bacteria, and improving carbon capture and storage. This is all admirable, if it is genuine and not just window-dressing. Here's a reality check in that regard: Exxon is investing about \$10 million a year in the Global Climate and Energy Project—an amount that almost exactly equals Mr. Tillerson's personal compensation in 2010. Ten million dollars also equals about three hours' worth of Exxon profits from last year. You tell me if you think that is a sensibly proportionate response to the problems of climate change and oil depletion from the world's largest energy company.

Even if Exxon's investments in a sustainable energy future were of an appropriate scale, they come late in the game. We are still in a bind. That's because there is no magic-bullet energy source out there that will enable world energy supplies to continue to grow as fossil fuels dwindle. Renewable energy is viable and necessary, and we should be doing far more to develop it. But solar, wind, geothermal, tidal, and wave power each have limits and drawbacks that will keep them from supplying energy as cheaply and as abundantly as we would like. Our bind is that we have built our existing transport infrastructure and food systems around energy sources that are becoming more problematic with every passing year, and we have no Plan B in place. This means we will probably have less energy in the future, rather than more.

Again, I am addressing my words especially to you students. This will be the defining reality of your lives. Whatever field you go into—business, finance, engineering, transportation, agriculture, education, or entertainment—your experience will be shaped by the energy transition that is now under way. The better you understand this, the more effectively you will be able to contribute to society and make your way in the world.

We are at one of history's great turning points. During your lifetime you will see world changes more significant in scope than human beings have ever witnessed before. You will have the opportunity to participate in the redesign of the basic systems that support our society—our energy system, food system, transport system, and financial system. I say this with some confidence, because our existing energy, food, transport, and financial systems can't be maintained under the circumstances that are developing—circumstances of fossil fuel depletion and an unstable climate. As a result, what you choose to do in life could have far greater implications than you may currently realize.

Over the course of your lifetime society will need to solve some basic problems:

- How to grow food sustainably without fossil fuel inputs and without eroding topsoil or drawing down increasingly scarce supplies of fresh water;
- How to support 7 billion people without depleting natural resources—including forests and fish, as well as finite stocks of minerals and metals; and
- How to reorganize our financial system so that it can continue to perform its essential functions—reinvesting savings into socially beneficial projects—in the context of an economy that is stable or maybe even shrinking due to declining energy supplies, rather than continually growing.

Each of these core problems will take time, intelligence, and courage to solve. This is a challenge suitable for heroes and heroines, one that's big enough to keep even the greatest generation in history fully occupied. If every crisis is an opportunity, then this is the biggest opportunity humanity has ever seen.

Making the best of the circumstances that life sends our way is perhaps the most important attitude and skill that we can hope to develop. The circumstance that life is currently serving up is one of fundamentally changed economic conditions. As this decade and this century wear on, we Americans will have fewer material goods and we will be less mobile. In a few years we will look back on late 20<sup>th</sup> century America as time and place of advertising-stoked consumption that was completely out of proportion to what Nature can sustainably provide. I suspect we will think of those times—with a combination of longing and regret—as a lost golden age of abundance, but also a time of foolishness and greed that put the entire world at risk.

Making the best of our new circumstances will mean finding happiness in designing higher-quality products that can be re-used, repaired, and recycled almost endlessly; and finding fulfillment in human relationships and cultural activities rather than mindless

shopping. Fortunately, we know from recent cross-cultural psychological studies that there is little correlation between levels of consumption and **levels of** happiness. That tells us that life can in fact be better without fossil fuels.

So whether we view these as hard times or as times of great possibility is really a matter of perspective. I would emphasize the latter. This is a time of unprecedented opportunity for service to one's community. It's a time when it will be possible to truly change the world, because the world has to change anyway. It is a time when you can make a difference by helping to shape this needed and inevitable change.

As I travel, I meet young people in every part of this country who are taking up the challenge of building a post-petroleum future: a 25-year-old farmer in New Jersey who plows with horses and uses no chemicals; the operator of a biodiesel co-op in Northampton; a solar installer in Oakland, California. The energy transition will require new thinking in every field you can imagine, from fine arts to banking. Companies everywhere are hiring sustainability officers to help guide them through the challenges and opportunities. At the same time, many young people are joining energy and climate activist organizations like 350.org and Transition Initiatives.

So here is my message to you in a nutshell. Fossil fuels made it possible to build the world you have inhabited during your childhood and throughout your years in the education system. Now it's up to you to imagine and build the world after fossil fuels. This is the challenge and opportunity of your lifetimes. I wish you good cheer and good luck as you make the most of it.