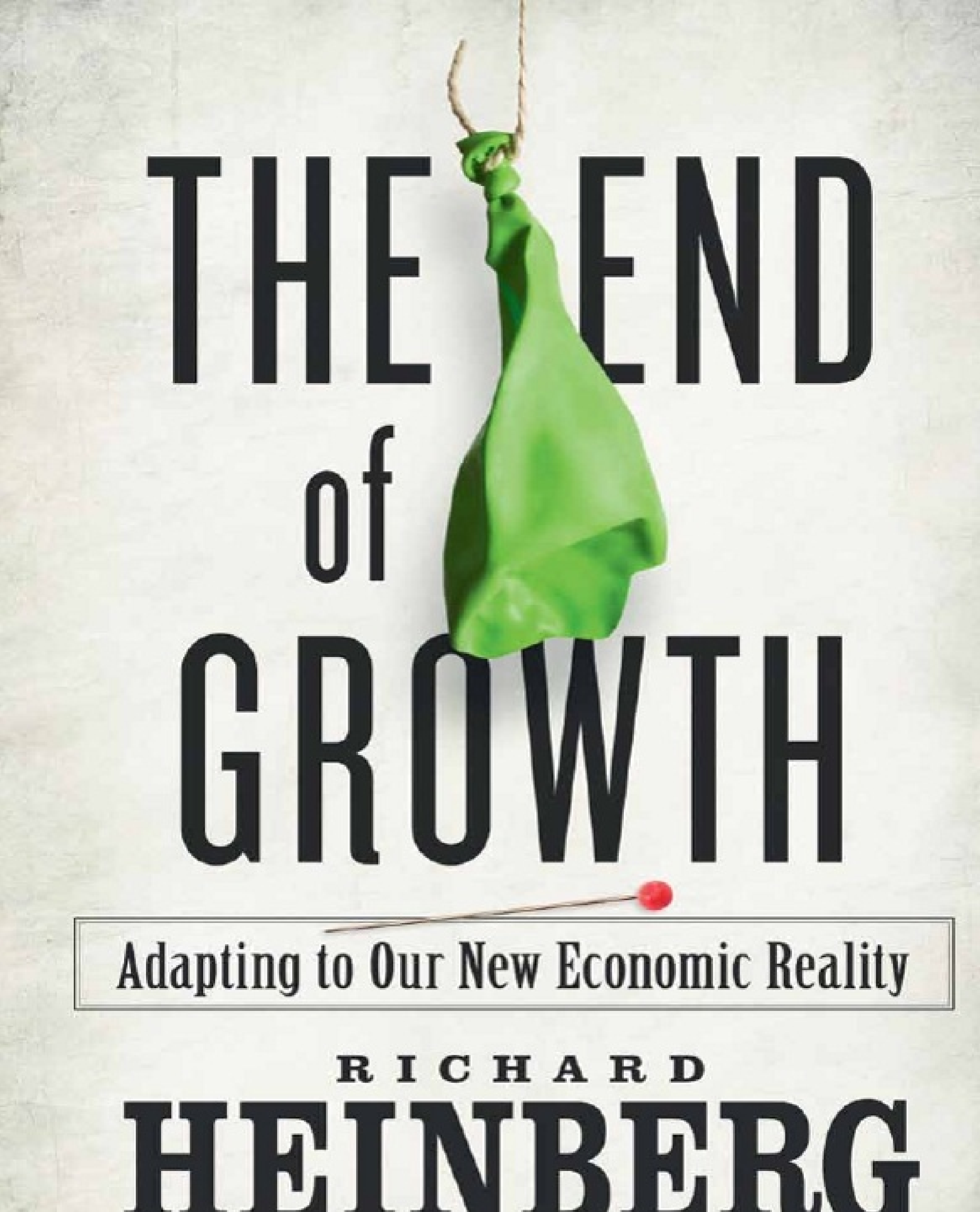
THE END
of
GROWTH
Adapting to Our New Economic Reality
RICHARD
HEINBERG

Heinberg draws in the big three drivers of inevitable crisis—resource constraints, environment impacts, and financial system overload—and explains why they are not individual challenges but o integrated systemic problem. By time you finish this book, you will have come to two conclusion First, we are not facing a recession—this is the end of economic growth. Second, this is not o children's problem—it is ours. It's time to get ready, and reading this book is the place to start.

— PAUL GILDING, author, *The Great Disruptio*
Former head of Greenpeace Internation

Richard has rung the bell on the limits to growth. This is real. The consequences for economic finance, and our way of life in the decades ahead will be greater than the consequences of t industrial revolution were for our recent ancestors. Our coming shift from quantity of consumption quality of life is the great challenge of our generation—frightening at times, but ultimately freeing.

— JOHN FULLERTON, President and Founder, Capital Institu

Why have mainstream economists ignored environmental limits for so long? If Heinberg is right, th will have a lot of explaining to do. The end of conventional economic growth would be a shatteri turn of events—but the book makes a persuasive case that this is indeed what we are seeing.

— LESTER BROWN, Founder, Earth Policy Institu
and author, *World on the Ed*

Heinberg shows how peak oil, peak water, peak food, etc. lead not only to the end of growth, and als to the beginning of a new era of progress without growth.

— HERMAN E. DALY, Professor Emeritu
School of Public Policy, University of Marylar

The End of Growth offers a comprehensive, timely and persuasive analysis of the reality of ecologic limits as they relate to economic growth. Filled with facts and figures and very readable, the boo makes a rational case while paying attention to nuance and counterarguments. A must-read for anyo who depends upon economic growth, which means all of us.

— LESLIE E. CHRISTIAN, CFA, President and CEO Portfolio 21 Investmen

Heinberg has masterfully summarized and updated the case against economics, and its fraudule scorecard—GDP. He explains why conventional economic growth is ending now, and why growth o human populations and material consumption will follow suit. Yet we all can still grow in wisdom an continue expanding the knowledge of our universe, while growing greener technologies capturing t sun's daily free photon flow as we transition to the Solar Age.

— HAZEL HENDERSON, author, *The Politics of the Solar Age* (198
and other books, President of Ethical Markets Media (USA and Brazil) and i
Green Transition Scoreboard

Dig into this book! It is crammed full of ideas, information and perspective on where our trouble world is headed—a Baedeker for the perplexed, and that's most of us.

— James Gustave Speth, author of *The Bridge at the Edge of the Worl Capitalism, the Environment and Crossing from Crisis to Sustainabili*

Read this book and have the light switched on.

— Caroline Lucas, Member of Parliament (U

Richard Heinberg is not one to shy away from difficult topics and The *End of Growth* is no exceptio Heinberg explains today's environmental and economic realities—which are scary to face. But believ me, not facing them is a whole lot scarier. And as Heinberg explains, the sooner we have this criticall needed conversation about how to live in a healthy, fair, and meaningful way on this one planet w have, the better it will be for all of us.

—Annie Leonard, author, *The Story of Stu*

A vitally important book—it helps clear away many of the mistaken assumptions that clutter ou heads when we think about 'obvious' and 'natural' facts of our economic life. You really need to rea it if you want to understand the next few crucial years.

— Bill Mckibben, author of *Deep Economy* and *Eaar*

From all my research, I'm come to appreciate how much the expectation of unending grow dominates public policy — and how ephemeral that goal is likely to prove. Until now, however, n one has had the foresight to address this critical topic. Congratulations to Richard Heinberg f providing such a lucid account of the natural limits to growth and the urgent need for a new econom model.

— Michael Klare, author, *Rising Powers, Shrinking Plan*

THE END
of
GROWTH

post carbon institute

The End of Growth is a "living book."

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GROWTH

Adapting to Our New Economic Reality

RICHARD
HEINBERG

NEW SOCIETY PUBLISHERS

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DEDICATION

To P. J., whose generosity makes my work possible —
and who keeps going even with the knowledge
that time and means work against us.

Contents

Acknowledgments

This book has benefited from the contributions of many people whose help deserves recognition.

I will start with the staff of Post Carbon Institute, the organization for which I am happy and prou to work. Asher Miller, Daniel Lerch, Ken White, and Tod Brilliant read the manuscript in variou stages and offered key editorial suggestions. This team has also collaborated with me on relate projects — including short YouTube videos such as the award-winning“300 Years of Fossil Fuels i 300 Seconds” and “Who Killed Growth?” Crystal Santorineos transcribed interviews and Simo Osborne published excerpts from the book on PostCarbon.org and EnergyBulletin.net (readers of tho excerpts in turn sent in valuable suggestions for the manuscript).

New Society Publishers also deserve thanks — especially Ingrid Witvoet, who edited t manuscript; Chris and Judith Plant, who responded enthusiastically to *The End of Growth* when it w no more than an idea; Sue Custance who helped shepherd the project along; and E. J. Hurst, w masterminded promotional efforts.

Jared Finnegan put his recent studies at the London School of Economics to use in offeri informed editorial suggestions for the manuscript, and also in preparing the graphs and their captio — a task that involved gathering dozens of data sets from a variety of sources. Jared’s editorial inp was especially crucial to the section “The End of ‘Development’” in Chapter 5.

Suzanne Doyle contributed many hours to compiling the Notes, finding sources and keeping tra of hundreds of references.

My research for *The End of Growth* entailed interviews and conversations with many brillia thinkers, each of whom deserves an introduction as well as my great thanks.

A conversation with Gus Speth — one of the giants of the environmental movement, who taught f many years at Yale (and now at Vermont Law School), and author of *A Bridge at the Edge of t World: Capitalism, the Environment, and Crossing from Crisis to Sustainability* — brought me up speed with recent developments in the world of alternative economics. Another conversation, this o with John Fullerton, formerly Managing Director of JPMorgan and more recently the founder of t Capital Institute, helped me understand the culture of Wall Street and how it evolved during the pa quarter century. These days John is working on steering the investment world toward a ju sustainable, and resilient economy and is pioneering several promising efforts in that direction.

Herman Daly, pioneer ecological economist, former World Bank economist, and author of *T Growth Illusion*, generously agreed to read and comment on Chapter 6.

Nate Hagens, hedge fund manager-turned-ecological economist, read most of the manuscript a contributed many important suggestions; his expert knowledge of the workings of financial mark informed Chapter 2.

Josh Farley, Fellow of the Gund Institute for Ecological Economics and a Professor in t Community Development and Applied Economics faculty at the University of Vermont (and co-auth with Herman Daly of the textbook *Ecological Economics*), read most of the manuscript and provid crucial guidance in several areas. A few of the explanatory Notes are lifted nearly verbatim from h comments in the margins of the manuscript. Hazel Henderson, futurist and author of *Ethical Market* ~~*Growing the Green Economy*, has been critiquing conventional economic theory for decades~~ whi offering alternative ways of making money work for people (rather than the other way arounc Interviewing her helped open my thinking to possibilities I hadn't considered, and I tried to captu these in Chapters 6 and 7.

Chris Martenson, creator of "The Crash Course" and veteran of ten years in corporate finance ar strategic consulting, writes an ongoing series of commentaries about the world financial situatio Because Chris's worldview is shaped by his awareness of resource limits and by systems thinking, find his analysis particularly credible and useful. His insights are reflected in Chapter 2 and 3.

Nicole Foss is co-editor of TheAutomaticEarth.com, where she writes under the name Stoneleig she also runs the Agri-Energy Producers' Association of Ontario, Canada, where she focuses on farm based bio-gas projects and grid connections for renewable energy. While living in the UK, Nicole wa a Research Fellow at the Oxford Institute for Energy Studies, where she specialized in nuclear safe in Eastern Europe and the former Soviet Union. I've benefited from reading many of h commentaries on the world financial scene, and Chapter 2 incorporates a number of important insigh she conveyed during a long conversation in December 2010.

Charles Hall, Professor of Systems Ecology at State University of New York College c Environmental Science and Forestry in Syracuse, is the world's principal authority on the subject c net energy, discussed in Chapter 4.While I owe a general, long-standing debt to Charlie's researc (whose importance is still unrecognized by many energy analysts), his most recent peer-reviewe publications provide crucial support to some of the core arguments in this book.

David Murphy, one of Charlie Hall's former students and now an important researcher in his ow right, is the author and co-author of key peer-reviewed papers on net energy cited in Chapter 4. Dav read that chapter and made important suggestions.

Michael Klare, Professor of Peace Studies at Hampshire College and author of *Rising Power* *Shrinking Planet*, is the world's foremost authority on linkages between resource depletion ar geopolitics. A conversation with him in late 2010 was the basis for the section "Post-Grow Geopolitics" in Chapter 5.

Bill Ryerson, founder and President of Population Media Center and President of the Populatic Institute, is the wisest, best informed, and most effective advocate for population issues I know. O conversation laid the groundwork for the section "Population Stress: Old vs. Young on a Full Plane in Chapter 5.

Mats Larsson, a management consultant and author of several books including *The Limits* *Business Development and Economic Growth*, was an important source for Chapter 4, which he als read and commented on.

Jason Bradford, a former research biologist at Washington University and Missouri Botanic Garden, who currently leads the farmland management program for Farmland LP, read ar commented upon much of the manuscript and drafted a sidebar for Chapter 7.

Warren Karlenzig, one of the world's top experts on urban sustainability strategy and metrics, ar author of *How Green is Your City? The SustainLane U.S. City Rankings*, is a frequent traveler China, where he consults with local authorities on planning issues. His insight into that nation predicament and prospects is reflected in the section "The China Bubble" in Chapter 5.

David Fridley, staff scientist at the Energy Analysis Program at Lawrence Berkeley Nation

Laboratory and expert on China's energy policy, also offered important input to "The China Bubble."

Doug Tompkins, who enjoyed notable success in business and went on to become one of the world leading conservationists, read the manuscript and made helpful suggestions, while the Foundation f Deep Ecology provided material assistance for the promotion of this book.

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These expert readers and sources kept me from making many mistakes that would otherwise hav compromised the core message of *The End of Growth*. Any errors that remain are my so responsibility.

I am also deeply indebted to the work of Dennis Meadows and Jorgen Randers — the survivi members of the original Limits to Growth research group. If the world had listened, today we wou all have much less to worry about.

Finally, I would like once again to thank my wife Janet Barocco for her tireless support a encouragement, and for helping make our home a place of artistry, good humor, and natural beauty.

Introduction: The New Normal

Leading active members of today's economics profession...have formed themselves into a kind of Politburo for correct economic thinking. As a general rule — as one might generally expect from a gentleman's club — this has placed them on the wrong side of every important policy issue, and not just recently but for decades. They predict disaster where none occurs. They deny the possibility of events that then happen.... They oppose the most basic, decent and sensible reforms, while offering placebos instead. They are always surprised when something untoward (like a recession) actually occurs. And when finally they sense that some position cannot be sustained, they do not reexamine their ideas. They do not consider the possibility of a flaw in logic or theory. Rather, they simply change the subject.No one loses face, in this club, for having been wrong. No one is dis-invited from presenting papers at later annual meetings.And still less is anyone from the outside invited in.

— James K. Galbraith (economis

The central assertion of this book is both simple and startling: *Economic growth as we have known is over and done with*.

The "growth" we are talking about consists of the expansion of the overall size of the econom (with more people being served and more money changing hands) and of the quantities of energy ar material goods flowing through it.

The economic crisis that began in 2007–2008 was both foreseeable and inevitable, and it marks *permanent*, *fundamental* break from past decades — a period during which most economists adopte the unrealistic view that perpetual economic growth is necessary and also possible to achieve. The are now fundamental barriers to ongoing economic expansion, and the world is colliding with tho barriers.

This is not to say the US or the world as a whole will never see another quarter or year of grow relative to the previous quarter or year. However, when the bumps are averaged out, the gener trend-line of the economy (measured in terms of production and consumption of real goods) will l level or downward rather than upward from now on.

Nor will it be impossible for any region, nation, or business to continue growing for a while. Son will. In the final analysis, however, this growth will have been achieved at the expense of oth regions, nations, or businesses. From now on, only *relative growth* is possible: the global economy playing a zero-sum game, with an ever-shrinking pot to be divided among the winners.

Why Is Growth Ending?

Many financial pundits have cited serious troubles in the US economy — including overwhelmin un-repayable levels of public and private debt, and the bursting of the real estate bubble — immediate threats to economic growth. The assumption generally is that eventually, once thes problems are dealt with, growth can and will resume at "normal" rates. But the pundits generally mi factors ~~*external* to the financial system that make a resumption of conventional economic growth~~ near-impossibility. *This is not a temporary condition; it is essentially permanent*.

Altogether, as we will see in the following chapters, there are three primary factors that star firmly in the way of further economic growth:

- The *depletion* of important resources including fossil fuels and minerals;
- The proliferation of *negative environmental impacts* arising from both the extraction and use of resources (including the burning of fossil fuels) — leading to snowballing costs from both these impacts themselves and from efforts to avert them; and
- *Financial disruptions* due to the inability of our existing monetary, banking, and investment systems to adjust to both resource scarcity and soaring environmental costs — and their inabilit (in the context of a shrinking economy) to service the enormous piles of government and privat debt that have been generated over the past couple of decades.

Despite the tendency of financial commentators to ignore environmental limits to growth, it possible to point to literally thousands of events in recent years that illustrate how all three of th above factors are interacting, and are hitting home with ever more force.

Consider just one: the Deepwater Horizon oil catastrophe of 2010 in the US Gulf of Mexico.

The fact that BP was drilling for oil in deep water in the Gulf of Mexico illustrates a global tren while the world is not in danger of *running out* of oil anytime soon, there is very little new oil to b found in onshore areas where drilling is cheap. Those areas have already been explored and their ric pools of hydrocarbons are being depleted. According to the International Energy Agency, by 202 almost 40 percent of world oil production will come from offshore. So even though it's har dangerous, and expensive to operate a drilling rig in a mile or two of ocean water, that's what the o industry must do if it is to continue supplying its product. That means more expensive oil.

Obviously, the environmental costs of the Deepwater Horizon blowout and spill were ruinou Neither the US nor the oil industry can afford another accident of that magnitude. So, in 2010 th Obama administration instituted a deepwater drilling moratorium in the Gulf of Mexico whi preparing new drilling regulations. Other nations began revising their own deepwater oil exploratio guidelines. These will no doubt make future blowout disasters less likely, but they add to the cost o doing business and therefore to the already high cost of oil.

The Deepwater Horizon incident also illustrates to some degree the knock-on effects of depletio and environmental damage upon financial institutions. Insurance companies have been forced to rai premiums on deepwater drilling operations, and impacts to regional fisheries have hit the Gulf Coa economy hard. While economic costs to the Gulf region were partly made up for by payments fro BP, those payments forced the company to reorganize and resulted in lower stock values and returns investors. BP's financial woes in turn impacted British pension funds that were invested in th company.

This is just one event — admittedly a spectacular one. If it were an isolated problem, the econom could recover and move on. But we are, and will be, seeing a cavalcade of environmental a economic disasters, not obviously related to one another, that will stymie economic growth in mo and more ways. These will include but are not limited to:

- Climate change leading to regional droughts, floods, and even famines;

- Shortages of energy, water, and minerals; and
- Waves of bank failures, company bankruptcies, and house foreclosures.

Each will be typically treated as a special case, a problem to be solved so that we can get "back normal." But in the final analysis, they are all related, in that they are consequences of a growi human population striving for higher per-capita consumption of limited resources (including no renewable, climate-altering fossil fuels), all on a finite and fragile planet.

Meanwhile, the unwinding of decades of buildup in debt has created the conditions for a once-in-century financial crash — which is unfolding around us, and which on its own has the potential generate substantial political unrest and human misery.

The result: we are seeing a perfect storm of converging crises that together represent a watersh moment in the history of our species. We are witnesses to, and participants in, the transition fro decades of economic growth to decades of economic contraction.

The End of Growth Should Come As No Surprise

The idea that growth will stall out at some point this century is hardly new. In 1972, a book title *Limits to Growth* made headlines and went on to become the best-selling environmental book of a time.[1]

That book, which reported on the first attempts to use computers to model the likely interactio between trends in resources, consumption, and population, was also the first major scientific study question the assumption that economic growth can and will continue more or less uninterrupted in the foreseeable future.

State of the World

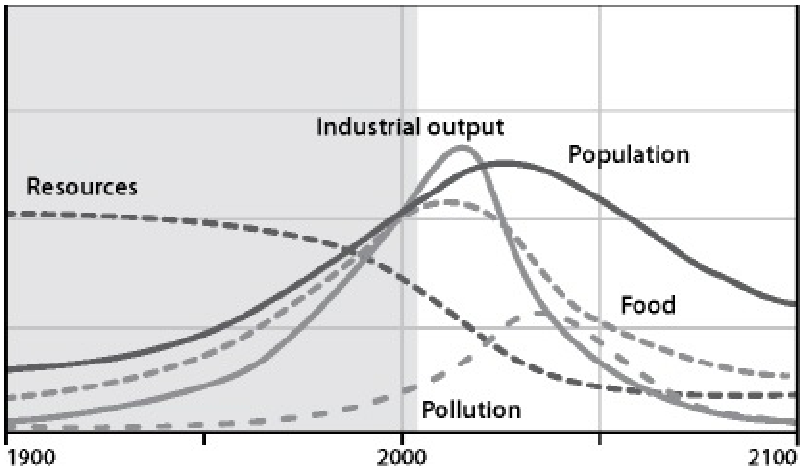

FIGURE 1. Limits to Growth Scenario. Source: The Limits to Growth: The 30-Year Update (2004), p. 169.

The idea was heretical at the time — and still is. The notion that growth *cannot* and *will n* continue beyond a certain point proved profoundly upsetting in some quarters, and soon *Limits Growth* was prominently "debunked" by pro-growth business interests. In reality, this "debunkin merely amounted to taking a few numbers in the book completely out of context, citing them "predictions" (which they explicitly were not), and then claiming that these predictions had faile

The ruse was quickly exposed, but rebuttals often don't gain nearly as much publicity as accusation and ~~so today millions of people mistakenly believe that the book was long ago discredited.~~ In fact, th original *Limits to Growth* scenarios have held up quite well. (A recent study by Australia Commonwealth Scientific and Industrial Research Organization (CSIRO) concluded, "[Our] analys shows that 30 years of historical data compares favorably with key features of [the *Limits to Growt* business-as-usual scenario...."')[3]

The authors fed in data for world population growth, consumption trends, and the abundance various important resources, ran their computer program, and concluded that the end of growth wou probably arrive between 2010 and 2050. Industrial output and food production would then fall, leadi to a decline in population.

The *Limits to Growth* scenario study has been re-run repeatedly in the years since the origin publication, using more sophisticated software and updated input data. The results have been simil each time.[4]

Why Is Growth So Important?

During the last couple of centuries, economic growth became virtually the sole index of national wel being. When an economy grew, jobs appeared and investments yielded high returns. When th economy stopped growing temporarily, as it did during the Great Depression, financial bloodlettin ensued.

Throughout this period, world population increased — from fewer than two billion humans o planet Earth in 1900 to over seven billion today; we are adding about 70 million new "consumer each year. That makes further economic growth even more crucial: if the economy stagnates, the will be fewer goods and services *per capita* to go around.

We have relied on economic growth for the "development" of the world's poorest economie without growth, we must seriously entertain the possibility that hundreds of millions — perha billions — of people will never achieve the consumer lifestyle enjoyed by people in the world industrialized nations. From now on, efforts to improve quality of life in these nations will have focus much more on factors such as cultural expression, political freedoms, and civil rights, and muc less on an increase in GDP.

Moreover, we have created monetary and financial systems that *require* growth. As long as th economy is growing, that means more money and credit are available, expectations are high, peop buy more goods, businesses take out more loans, and interest on existing loans can be repaid.[5] But the economy is not growing, new money *isn't* entering the system, and the interest on existing loa cannot be paid; as a result, defaults snowball, jobs are lost, incomes fall, and consumer spendin contracts — which leads businesses to take out fewer loans, causing still less new money to enter th economy. This is a self-reinforcing destructive feedback loop that is very difficult to stop once it ge going.

In other words, the existing market economy has no "stable" or "neutral" setting: there is on growth or contraction. And "contraction" can be just a nicer name for recession or depression — long period of cascading job losses, foreclosures, defaults, and bankruptcies.

We have become so accustomed to growth that it's hard to remember that it is actually is a fairl recent phenomenon.

Over the past few millennia, as empires rose and fell, local economies advanced and retreated – ~~while world economic activity overall expanded only slowly, and with periodic reversals. Howeve~~ with the fossil fuel revolution of the past century and a half, we have seen economic growth at a spee and scale unprecedented in all of human history.[6] We harnessed the energies of coal, oil, and natur gas to build and operate cars, trucks, highways, airports, airplanes, and electric grids — all th essential features of modern industrial society. Through the one-time-only process of extracting ar burning hundreds of millions of years' worth of chemically stored sunlight, we built what appeare (for a brief, shining moment) to be a perpetual-growth machine. We learned to take what was in fa an extraordinary situation for granted. It became *normal*.

But as the era of cheap, abundant fossil fuels comes to an end, our assumptions about continue expansion are being shaken to their core. The end of growth is a very big deal indeed. It means the er of an era, and of our current ways of organizing economies, politics, and daily life.

It is essential that we *recognize and understand the significance of this historic moment*: if we hav in fact reached the end of the era of fossil.fueled economic expansion, then efforts by policy makers continue pursuing elusive growth really amount to a flight from reality. World leaders, if they ar deluded about our actual situation, are likely to delay putting in place the support services that ca make life in a non-growing economy tolerable, and they will almost certainly fail to make neede fundamental changes to monetary, financial, food, and transport systems.

As a result, what could be a painful but endurable process of adaptation could instead becon history's greatest tragedy. We can survive the end of growth, and perhaps thrive beyond it, but only we recognize it for what it is and act accordingly.

BOX I.1 But Isn't the US Economy Recovering?

From July 2009 through the end of 2010, the US economy posted GDP gains — i.e., signs of growth. Nominal GDP surpassed pre-recession levels in mid-2010, while inflation-adjusted GDP nearly returned to its pre-recession level.[7] This followed GDP contraction in the months December 2007 through June 2009.[8]

But, as we will see in Chapter 6, GDP is a poor gauge of overall economic health. Even if GDP has returned to former levels, the economy of the United States is fundamentally changed: unemploymer levels are much higher and tax revenues for state and local governments are severely reduced. Some economists may define this technically as a recovering and growing economy, but it certainly is not a healthy one.

Moreover, much of this apparent growth has come about because of enormous injections of stimulus and bailout money from the Federal government. Subtract those, and the GDP growth of the past year or so almost disappears.

On the basis of historical analysis of previous financial crises, economists Carmen Reinhart and Kenneth Rogoff conclude that the economic crisis of 2008 will have

". . .deep and lasting effects on asset prices, output and employment. Unemployment rises and housing price declines extend out for five and six years, respectively. On the encouraging side, outpu declines last only two years on average. Even recessions sparked by financial crises do eventually en albeit almost invariably accompanied by massive increases in government debt.... The global nature of the [current] crisis will make it far more difficult for many countries to grow their way out throug higher exports, or to smooth the consumption effects through foreign borrowing. In such circumstances, the recent lull in sovereign defaults is likely to come to an end."[9]

But this analysis considers only the financial aspects of the crisis and ignores the deeper issues of energy, resources, and environment. The "recovery" that began in 2009 occurred in the context of energy prices that had fallen substantially from their peak in mid-2008; but as consumer demand showed tepid signs of revival in late 2010, oil prices lofted upward again. If this "recovery" continue energy prices will rise even further and contraction will resume.

In short: while the US economy may have posted growth (as technically defined) in 2009–2010, it is operating in a fundamentally different mode than before: it is led to a greater extent than before by government spending (as opposed to consumer activity), and it is hostage to energy prices.

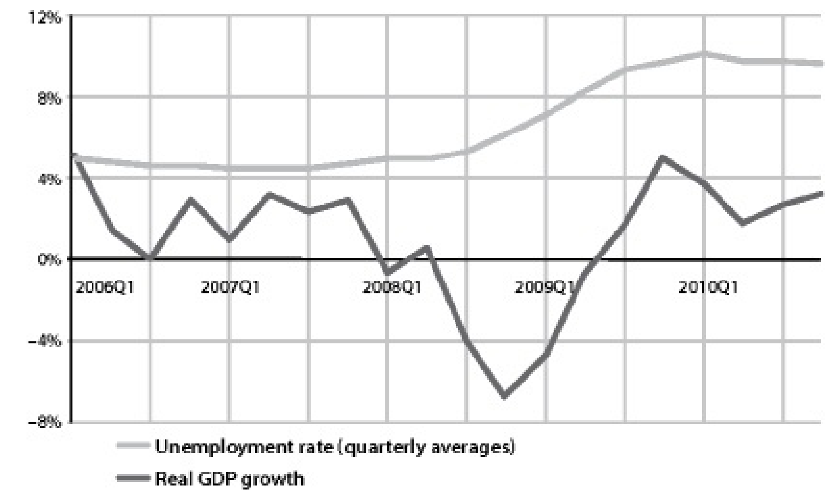

FIGURE 2. Economic Growth and Unemployment, 2006–2010. As the US economy contracted from the financial crisis in 2008, economic growth went negative and the unemployment rate shot up. Source: US Bureau of Labor Statistics, US Bureau of Economic Analysis.

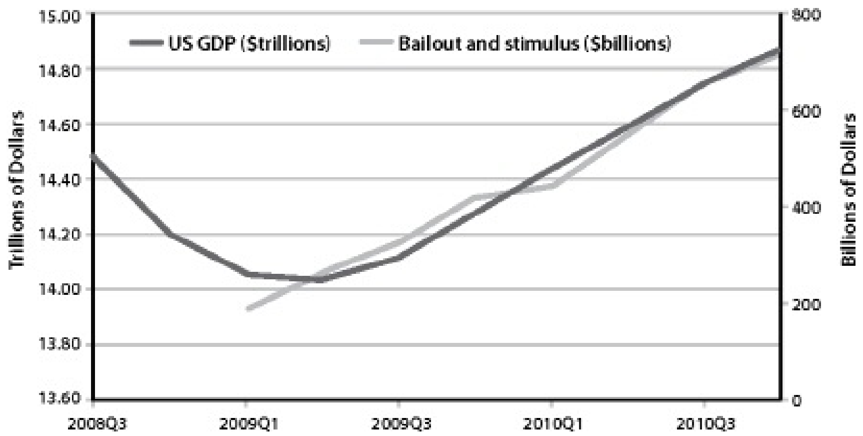

FIGURE 3. Economic Growth, Stimulus, and Bailouts. "Bailout and Stimulus" refers to the Troubled Asset Relief Program (TARP) and the American Recovery and Reinvestment Act of 2009. As this graph shows, these federal government expenditures appear to have been the primary source of economic growth since the financial crisis in 2008. What happens when the federal government can no longer bail out the banks and stimulate the economy? Source: US Bureau of Economic Analysis, The Committee for a Responsible

Federal Budget.

But Isn't Growth Normal?

Economies are systems, and as such they follow rules analogous (to a certain extent) to those th govern biological systems. Plants and animals tend to grow quickly when they are young, but the they reach a more or less stable mature size. In organisms, growth rates are largely controlled b genes, but also by availability of food.

In economies, growth seems tied to the availability of resources, chiefly energy ("food" for th industrial system), and credit ("oxygen" for the economy) — as well as to economic planning.

During the past 150 years, expanding access to cheap and abundant fossil fuels enabled rap economic expansion at an average rate of about three percent per year; economic planners began take this situation for granted. Financial systems internalized the expectation of growth as a promi of returns on investments.

Most organisms cease growing once they reach adulthood; if curtailment of growth weren genetically programmed, plants and animals would outgrow a range of practical constraints: imagin for example, the survival challenges faced by a two-pound hummingbird. If the analogy holds, the economies must eventually stop growing too. Even if planners (society's equivalent of regulator DNA) dictate more growth, at some point increasing amounts of "food" and "oxygen" will cease to b available. It is also possible for wastes to accumulate to the point that the biological systems th underpin economic activity (such as forests, crops, and human bodies) are smothered and poisoned.

But many economists don't see things this way. That's probably because current economic theori were formulated during the anomalous historical period of sustained growth that is now endin Economists are merely generalizing from their experience: they can point to decades of steady grow in the recent past, and they simply project that experience into the future.[10] Moreover, they hav theories to explain why modern market economies are immune to the kinds of limits that constra natural systems: the two main ones have to do with *substitution* and *efficiency*.

If a useful resource becomes scarce, its price will rise, and this creates an incentive for users of th resource to find a substitute. For example, if oil gets expensive enough, energy companies might sta making liquid fuels from coal. Or they might develop other energy sources undreamed of today. Man economists theorize that this process of substitution can go on forever. It's part of the magic of th free market.

Boosting efficiency means doing more with less. In the US, the number of dollars generated in th economy for every unit of energy consumed has increased steadily over recent decades.[11] Part of th increasing efficiency is a result of outsourcing manufacturing to other nations — which must the burn the coal, oil, or natural gas to make our goods. (If we were making our own running shoes an LCD TVs, we'd be burning that fuel domestically.)[12] Economists also point to another, related form efficiency that has less to do with energy (in a direct way, at least): the process of identifying th cheapest sources of materials, and the places where workers will be most productive or work for th lowest wages. As we increase efficiency, we use less — of energy, resources, labor, or money — to d more. That enables more economic growth.

Finding substitute resources and upping efficiency are undeniably effective adaptive strategies market economies. Nevertheless, the question remains as to how long these strategies can continue work in the real world — which is governed less by economic theories than by the laws of physics. the real world, some things don't have substitutes, or the substitutes are too expensive, or don't wo as well, or can't be produced fast enough. And efficiency follows a law of diminishing returns: th first gains in efficiency are usually cheap, but every further incremental gain tends to cost more, unt further gains become prohibitively expensive.

In the end, we can't outsource more than 100 percent of manufacturing, we can't transport goo with zero energy, and we can't enlist the efforts of workers and count on their buying our produc while paying them nothing. Unlike most economists, most physical scientists recognize that grow within any functioning, bounded system has to stop sometime.

BOX I.2 Cooking the Books on Growth

Are government economic statistics accurate and credible? Not according to consulting economist John Williams of shadowstats.com. After a "lengthy process of exploring the history and nature of economic reporting and interviewing key people involved in the process from the early days of government reporting through the present," Williams began compiling his own data and publishing them on his website. In some cases, as with unemployment statistics, he simply highlights the discrepancy between current definitions and reporting practices and former ones: if unemployment numbers were reported today the way they were in the 1970s, the current figure would be in the range of 16–18 percent rather than the officially reported 9–10 percent (for example, people who have give up looking for jobs are no longer categorized as "unemployed").

"Shadow stats" for inflation are consistently higher than the government's reported figures, and GDP growth rates consistently lower.

Regarding Figure 4, Williams notes, "The SGS-Alternate GDP reflects the inflation-adjusted, or real, year-to-year GDP change, adjusted for distortions in government inflation usage and methodological changes that have resulted in a built-in upside bias to official reporting."

All of which raises the question: How much of the economic "recovery" is actually only smoke an mirrors?

The Simple Math of Compounded Growth

In principle, the argument for an eventual end to growth is a slam-dunk. If any quantity grows steadi by a certain fixed percentage per year, this implies that it will double in size every so-many years; th higher the percentage growth rate, the quicker the doubling. A rough method of figuring doublin times is known as the rule of 70: dividing the percentage growth rate into 70 gives the approxima time required for the initial quantity to double. If a quantity is growing at 1 percent per year, it wi double in 70 years; at 2 percent per year growth, it will double in 35 years; at 5 percent growth, it wi double in only 14 years, and so on. If you want to be more precise, you can use the Y^x button on scientific calculator, but the rule of 70 works fine for most purposes.

Here's a real-world example: Over the past two centuries, human population has grown at rat ranging from less than one percent to more than two percent per year. In 1800, world population stoo at about one billion; by 1930 it had doubled to two billion. Only 30 years later (in 1960) it had double again to four billion; currently we are on track to achieve a third doubling, to eight billion human around 2025. No one seriously expects human population to continue growing for centuries into th future. But imagine if it did — at just 1.3 percent per year (its growth rate in the year 2000). By th year 2780 there would be 148 trillion humans on Earth — one person for each square meter of land o the planet's surface.

It won't happen, of course.

In nature, growth always slams up against non-negotiable constraints sooner or later. If a speci finds that its food source has expanded, its numbers will increase to take advantage of those surplu calories — but then its food source will become depleted as more mouths consume it, and i predators will likewise become more numerous (more tasty meals for them!). Population "blooms" (periods of rapid growth) are nearly always followed by crashes and die-offs.[13]

Here's another real-world example. In recent years China's economy has been growing at eig percent or more per year; that means it is more than doubling in size every ten years. Indeed, Chin now consumes more than twice as much coal as it did a decade ago — the same with iron ore and o The nation now has four times as many highways as it did, and almost five times as many cars. Ho many more doublings can occur before China has used up its key resources — or has simply decide that enough is enough and has stopped growing? The question is hard to answer with a specif number, but it is unlikely to be a large one.

This discussion has very real implications, because the economy is not just an abstract concept; it what determines whether we live in luxury or poverty, whether we eat or starve. If economic grow ends, everyone will be impacted, and it will take society years to adapt to this new conditio Therefore it is important to know whether that moment is close at hand or distant in time.

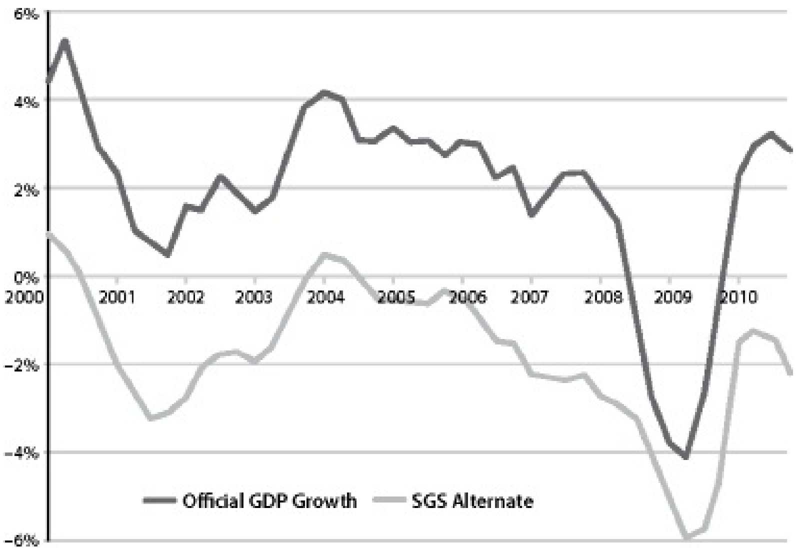

FIGURE 4. US GDP Growth, Official vs. Shadowstats, 2000–2010. Official GDP data comes from the Bureau of Economic Analysis. The SGS Alternate comes from Shadow Government Statistics. Both datasets are adjusted for inflation. Source: Shadow Government Statistics, American Business Analytics and Research LLC, shadowstats.com

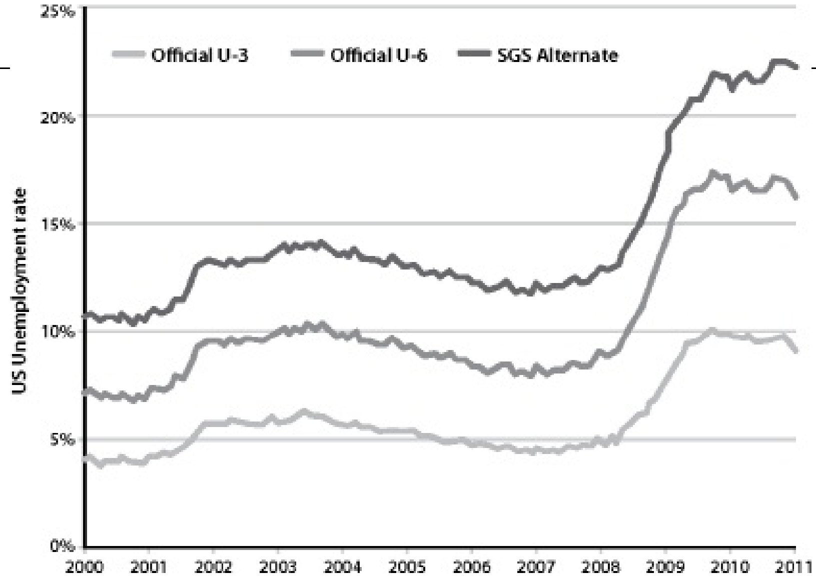

FIGURE 5. Civilian Unemployment, Official vs. Shadowstats, 2000–2010 (Seasonally Adjusted). The SGS-Alternate Unemployment Rate reflects current unemployment reporting methodology adjusted for the significant portion of “discouraged workers” no longer included after 1994. The Bureau of Labor Statistics U-6 rate includes both discouraged workers as currently defined (discouraged less than one year) and long-term discouraged workers (discouraged more than one year). Source: Shadow Government Statistics, American Business Analytics and Research LLC, shadowstats.com.

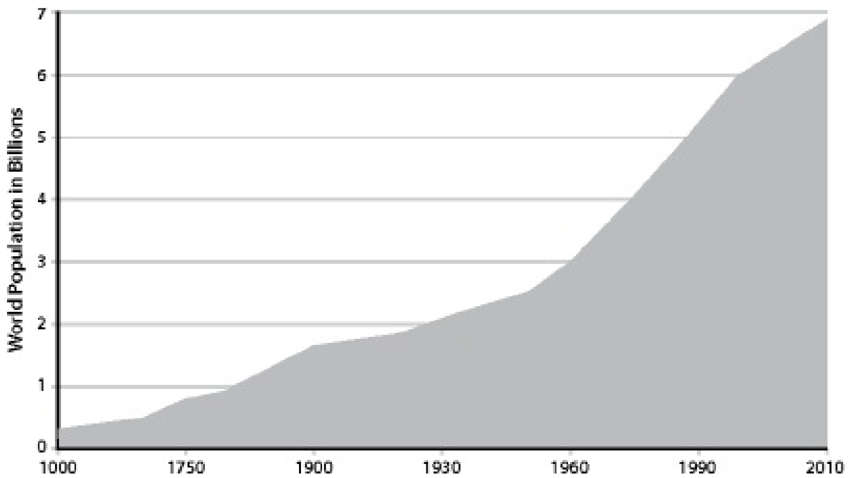

FIGURE 6. World Population Growth, 1000–2010. Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, “World Population Prospects: The 2008 Revision” (2009–10 population data based on 2008 projection).

The Peak Oil Scenario

As mentioned, this book will argue that global economic growth is over because of a convergence three factors — resource depletion, environmental impacts, and systemic financial and moneta failures. However, a single factor may be playing a key role in bringing the age of expansion to close. That factor is oil.

Petroleum has a pivotal place in the modern world — in transportation, agriculture, and t chemicals and materials industries. The Industrial Revolution was really the Fossil Fuel Revolutio and the entire phenomenon of continuous economic growth — including the development of th ~~financial institutions that facilitate growth, such as fractional reserve banking — is ultimately~~ base on ever-increasing supplies of cheap energy.

Growth requires more manufacturing, more trade, and more transport, and those all in turn requi more energy. This means that if energy supplies can't expand and energy therefore become significantly more expensive, economic growth will falter and financial systems built on expectatio of perpetual growth will fail.

As early as 2000, petroleum geologist Colin Campbell discussed a Peak Oil impact scenario th went like this.[14] Sometime around the year 2010, he theorized, stagnant or falling oil supplies wou lead to soaring and more volatile oil prices, which would precipitate a global economic crash. Th rapid economic contraction would in turn lead to sharply curtailed energy demand, so oil prices wou then fall; but as soon as the economy regained strength, demand for petroleum would recover, pric would again soar, and as a result of that the economy would relapse. This cycle would continue, wi each recovery phase being shorter and weaker, and each crash deeper and harder, until the econom was in ruins. Financial systems based on the assumption of continued growth would implode, causi more social havoc than the oil price spikes would themselves directly generate.

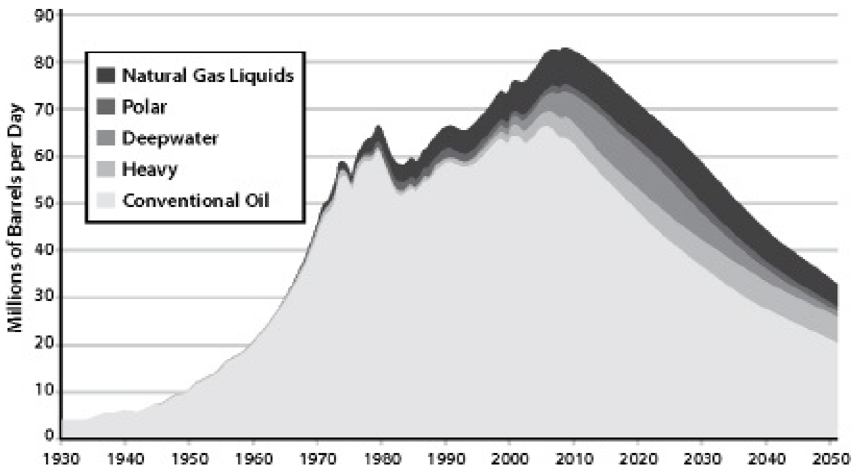

FIGURE 7. World Oil Production. Source: Colin Campbell, personal comunication.

Meanwhile, volatile oil prices would frustrate investments in energy alternatives: one year, o would be so expensive that almost any other energy source would look cheap by comparison; the ne year, the price of oil would have fallen far enough that energy users would be flocking back to it, wi investments in other energy sources looking foolish. But low oil prices would discourage exploratio for more petroleum, leading to even worse fuel shortages later on. Investment capital would be short supply in any case because the banks would be insolvent due to the crash, and governmen would be broke due to declining tax revenues. Meanwhile, international competition for dwindling o supplies might lead to wars between petroleum importing nations, between importers and exporte and between rival factions within exporting nations.

In the years following the turn of the millennium, many pundits claimed that new technologies f crude oil extraction would increase the amount of oil that can be obtained from each well drilled, a that enormous reserves of alternative hydrocarbon resources (principally tar sands and oil shal would be developed to seamlessly replace conventional oil, thus delaying the inevitable peak f decades. There were also those who said that Peak Oil wouldn't be much of a problem even if happened soon, because the market would find other energy sources or transport options as quickly needed — whether electric cars, hydrogen, or liquid fuel made from coal.

In succeeding years, events appeared to be supporting the Peak Oil thesis and undercutting th views of the oil optimists. Oil prices trended steeply upward — and for entirely foreseeable reason discoveries of new oilfields were continuing to dwindle, with most new fields being much mo difficult and expensive to develop than ones found in previous years. More oil-producing countri were seeing their extraction rates peaking and beginning to decline despite efforts to mainta production growth using high-tech, expensive extraction methods like injecting water, nitrogen, o carbon dioxide to force more oil out of the ground. Production decline rates in the world's old, supe giant oilfields, which are responsible for the lion's share of the global petroleum supply, wer accelerating. Production of liquid fuels from tar sands was expanding only slowly, while th development of oil shale remained a hollow promise for the distant future.[15]

From Scary Theory to Scarier Reality

Then in 2008, the Peak Oil scenario became all too real. Global oil production had been stagnant sinc 2005 and petroleum prices had been soaring upward. In July 2008, the per-barrel price shot up nearly $150 — half again higher (in inflation-adjusted terms) than the price spikes of the 1970s th had triggered the worst recession since World War II. By summer 2008, the auto industry, the truckin industry, international shipping, agriculture, and the airlines were all reeling.

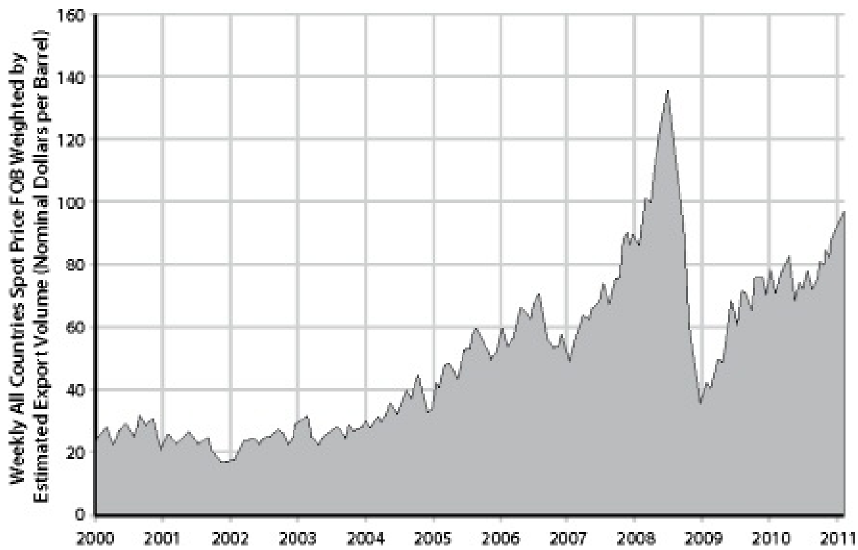

FIGURE 8. World Crude Oil Prices, 2000–2011. Source: US Energy Information Administration.

But what happened next riveted the world's attention to such a degree that the oil price spike was a but forgotten: in September 2008, the global financial system nearly collapsed. The most frequent discussed reasons for this sudden, gripping crisis had to do with housing bubbles, lack of prop regulation of the banking industry, and the over-use of bizarre financial products that almost nobod understood. However, the oil price spike had also played a critical (if largely overlooked) role initiating the economic meltdown.[16]

In the immediate aftermath of that global financial near-death experience, both the Peak Oil impa scenario proposed a decade earlier and the *Limits to Growth* standard-run scenario of 1972 seemed be confirmed with uncanny and frightening accuracy. Global trade was falling. The world's large auto companies were on life support. The US airline industry had shrunk by almost a quarter. Foo