Shifting the Peak Oil "Debate" to Strategic Management

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March 2007

It's time to initiate a real public discourse on the Peak Oil "debate" from a management perspective. On the one side, there are the "Peak Oilers", urgently warning that world oil production will soon hit its maximum, if it hasn't already. Many predict dire ramifications for the economy and our current way of life. They are a disparate band, but include some prominent businessmen, members of Congress and the Intelligence community. On the other side, a number of government agencies, oil company CEOs, energy consultants and economists are publicly assuring us there is plenty of oil. They say production will not peak until at least 2030, maybe later…assuming we get access to politically and environmentally extreme areas and invest enough. Each side fires predictable volleys from well-entrenched positions. One side clearly has more corporate clout and better access to the mainstream media. The other uses the internet with the tenacity of resistance fighters. But bottom line, everyone is speculating. There's a conspicuous lack of verifiable data about how much oil is really out there and who has the capacity to produce more. How can ordinary people and businesses decide whom to believe, much less whether to act, in the face of such polarized viewpoints?

Out here in daily life, managers – and by that I mean anyone who makes conscious resource allocation decisions for themselves or others – frequently must take action in the face of incomplete and contradictory information. So, instead of arguing about who has correctly predicted the exact date for peak oil, how about shifting the debate? Let's examine the spectrum of possibilities, the assumptions underlying them, and their probability, uncertainty and risk. Using strategic management tools like probabilistic risk assessment, gaming, modeling and scenario planning, we can simulate potential courses of action without suffering real-life consequences. Then we'll be better able to answer the critical management questions: "What if?" and "So what?"

This paper uses elementary decision management and game theory to establish a conceptual framework within which we can examine different tactics and strategies that might be employed to navigate the Peak Oil transition.[1] It presents a matrix of speculative, but plausible societal outcomes, depending on whether the transition is abrupt or gradual, and whether we prepare for it or not. There are many actions (tactics) that markets, governments, the private sector, and/or social groups might select to balance demand with reduced oil supply. Different strategic approaches will employ different tactics. For this exercise, I considered four possible strategic approaches, using the decision management framework to evaluate probable outcomes and the opportunity loss risks of selecting one strategy over another.

Three Camps: Peak Oilers, Official Agencies, Technology Optimists

The debate surrounding Peak Oil is about "when" rather than "if". It entails a range of opinions concerning how much oil remains to be discovered and extracted and how soon we face a gap between consumption demand and the oil production rate.

We don't know whether the world oil production curve will end up a peak, a bell, or a plateau. But based on historical production curves for oil fields and regions, it is safe to assume that after the first half the

[1] The discussion presented here is largely excerpted from my MBA thesis: "Strategic Choices for Managing the Transition from Peak Oil to a Reduced Petroleum Economy" (Odland, 2006). Available at www.ldeo.columbia.edu/~odland/. Production data from the BP Statistical Review of World Energy 2005 were not updated for this paper, as the new numbers do not significantly alter the decision management approach.

ultimately recoverable oil reserves (URR) have been consumed, the world will be at or near its maximum oil production.[2] Expressed as a simple ratio, Peak Oil will occur approximately when

$$\frac{\text{cumulative production}}{\text{ultimately recoverable reserves}} = \frac{1}{2}$$

At the end of 2006, cumulative world oil production was slightly over 1 trillion barrels. All sides agree on the numerator. The contention is over the value of the denominator. Three camps have emerged:

1) The Peak Oilers: URR = approximately 2 Trillion bbl[3]
   Peak is now or within 10-15 years. It is urgent to start preparing.

2) Government and Industry Officials: URR = approximately 3-4 Trillion bbl[4]
   Peak is several decades off. There is plenty of time to prepare.

3) Technology Optimists: URR = at least 7-8 Trillion bbl oil equivalent[5]
   Peak is so far away as to not be a concern.

A big piece of the peak oil debate hinges on how each group defines resources versus reserves and what they are willing to consider as producible oil for the purposes of the discussion.

The Peak Oilers

The Peak Oilers often work in earth and environmental sciences, the oil industry, agriculture, logistics, or information technology. They think that official reserves are likely overstated for political and financial reasons, especially those of OPEC and Russia. They believe that up to 90% of the world's accessible oil has already been discovered and that additional reserves will become much harder to find and produce and much more expensive. They don't agree on the exact date that Peak Oil will occur or the shape of the peak, but most place the date between 2005 and 2020. Many believe that production could increase, then plateau for a period of 5 to 10 years due to increased deepwater production before starting to taper off. Others believe the peak is imminent and the decline will be precipitous. Although they agree that

[2] In individual fields, the documented peak has sometimes occurred sooner than the volumetric midpoint, in which case the decline may be gentle. Other fields have reported peak production well past the midpoint, followed by much steeper decline. Aggregate production curves (regional or country level) tend to approximate bell curves.

[3] The Oil Depletion Analysis Center (ODAC at www.odac-info.org) notes: "Assessments of the world's ultimately recoverable oil reserves vary, but 65 published studies by oil companies, geologists, government analysts and consultants over the past 50 years have produced remarkably consistent estimates. The overwhelming majority of these put the world's original endowment of recoverable oil at no more than about 2,400 billion barrels; the average estimate is 2,000 billion barrels." Note that this estimate fits with the cumulative production + the reserves reported in BP's annual statistical review.

[4] This estimate, which is the basis of the International Energy Agency projections, originates with the U.S. Geological Survey's World Petroleum Assessment 2000 (Digital Data Series - DDS-60. Available at http://pubs.usgs.gov/dds/dds-060/). At least one of the report's authors, Les Magoon, who directed the assessment of North American Reserves, has published a dissenting report, agreeing with the Peak Oilers (*Are We Running Out of Oil?* U.S. Geologic Survey Open File Report 00-320, 2000.)

[5] In addition to conventional oil reserves, Technology Optimists count alternative supplies on an oil-equivalent basis. These include 4 trillion barrel of oil equivalent (BOE) of oil sands and 3 trillion BOE of oil shale. Some people also include 3-4 trillion BOE of methane hydrate.

alternative fuels could slow the decline, Peak Oilers often do not count alternative oil sources in reserves. They don't believe the alternatives can provide the same amount of energy as oil, nor be produced at a meaningful rate. Critics call them "doomers" and practitioners of "junk economics" who fail to account for reserve growth, the impacts of technological innovation, or the effects of pricing on curbing demand and introducing new supply.

Official Agencies and Industry Spokesmen

The oil supply numbers published by the highly respected International Energy Agency are quoted as gospel by government and policy people throughout the world. According to IEA projections issued between 2000 and 2005, world oil supply will grow until at least 2035, or even 2050.[6] The IEA quotes their source of data as the U.S. Geologic Survey, World Petroleum Assessment 2000.[7] Private companies like Cambridge Energy Research Associates (CERA) and ExxonMobil also cite the USGS reserve estimates when they publicly predict peak oil dates at 2030 and beyond. However, the 3.3 trillion barrel URR estimate from the USGS study is regarded as unrealistically high by many geologists and analysts.[8] The 2000 Assessment reported 44% more oil than the 1998 USGS assessment of 2.3 trillion bbl URR. In addition to assuming very high reserve growth, the 2000 survey assumed a five-fold increase in the oil discovery rate, which has not occurred. Hence, many critics regard the USGS and IEA reserve estimates as political numbers.

Technology Optimists

Sometimes called Cornucopians, this group tends to consist of economists, technophiles, and others who believe strongly in the power of the market and human ingenuity. They profess faith that things will work themselves out once price sends its signal. The optimist camp does not limit itself to accessible reserves. It considers all the lower-grade hydrocarbon resources to be potential candidates for replacing oil as soon as price is high enough to make their extraction and conversion profitable. Critics say that they confuse resources with viable oil reserves that can be produced economically at a useful rate and that they are relying on faith in hypothetical technological innovations that are not yet even in the R&D stage.

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[6] IEA estimates traditionally show supply growing to meet demand, which is based on projected annual world GDP growth of 2-3%. They have explicitly assumed that any shortfall in supply could be met by increasing OPEC production, especially in Saudi Arabia. Since the Fall of 2005, however, the IEA has been revising its monthly demand growth projects downwards to align better with a smaller supply.

[7] Based on 1995 data, this study presented a probabilistic analysis of the oil potential in all the oil-favorable basins in the world. Teams of geologists estimated proved reserve (P-95) numbers (meaning it is 95% probable that the amount of oil is present). They also estimated very high possible reserve (P-5) numbers to allow for speculative oil discovery. They then performed Monte Carlo analysis to come up with the P-50 numbers used by the IEA. The study predicted significant reserve growth, modeled on US historical reserve growth rates.

Critics protest the USGS' application of a US reserve growth factor to the rest of the world. They argue that initial reserves in the U.S. were under-reported, resulting in a large growth factor. They believe that in OPEC and Russia, however, reported reserves have been significantly overstated. Application of the optimistic US growth factor to already inflated reserve numbers in other countries would result in unrealistically high estimates.

[8] See, for example, Jean Laherrere, *Is the USGS 2000 Assessment Reliable,* May 2, 2000. Published on the cyberconference of the WEC on May 19, 2000. http://energyresource2000.com

Liars' Poker: Bracketing the Range of Possible OPEC Reserves

While U.S. reserves are under-reported due to SEC requirements, nationally held reserves in other countries may be overstated for political reasons. A country with declining reserves may fear losing its international clout if it reports reduced reserves. The biggest system shocks will arise if the largest reported reserves, those of the OPEC countries bordering the Arabian Gulf, have been overstated. Many believe that indeed has happened. This in fact, is the essence of Matthew Simmon's 2005 analysis of Saudi oil field studies and reserve estimates in *Twilight in the Desert*.

Many industry analysts believe that OPEC's reserves are probably significantly lower than reported. No verifiable data has been released since the countries nationalized their reserves. In the mid-1980s, reported reserves in many OPEC countries jumped inexplicably[9] yet there were no reported new discoveries or advances in technology. Over 300 billion barrels of oil were added to the official supply.

A simple spreadsheet analysis (Figure 1) using published reserve data for Saudi Arabia illustrates the 160 billion barrel supply shock that is possible, for Saudi oil alone, between the best and worst case scenarios.

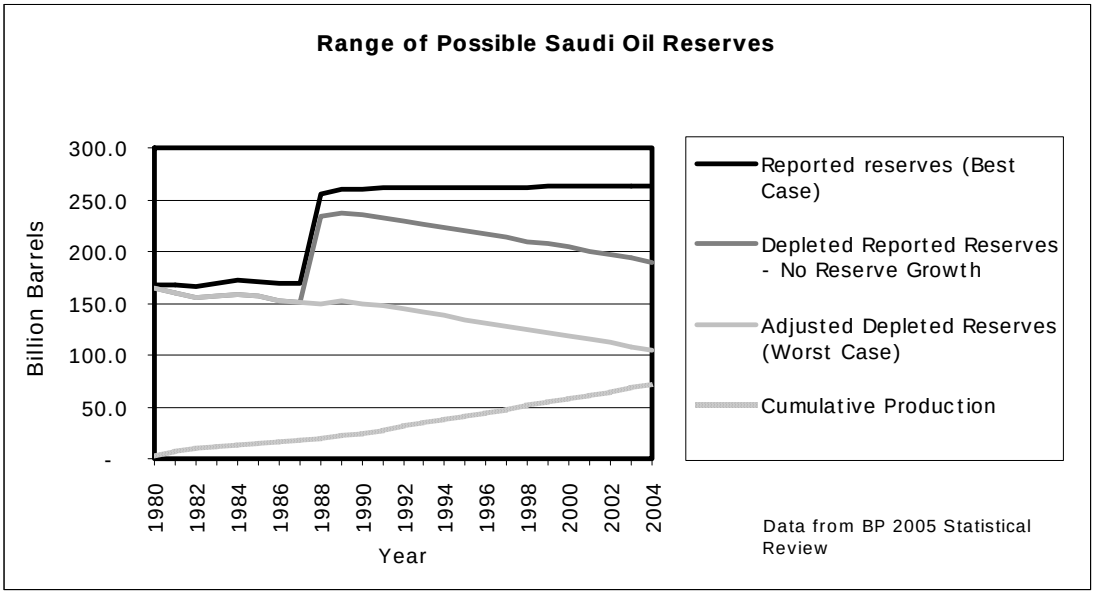


Figure 1. Best case: Approximately 260 billion barrels of officially reported reserves remain to be pumped. Annual additions to reserves = annual consumption. Worst case: reserves added in 1988 and cumulative production since 1980 are both subtracted from reported reserves. In that case, only 100 billion barrels or so remain to be pumped.

The best case assumes the 1980s reported reserve increases are real, and that every year the oil that is pumped is replaced by new reserves. If so, then Saudi Arabia still has about 260 billion barrels of oil remaining. The worst case assumes the 1980s additions were only "paper reserves", or an accounting

[9] In the face of an oil glut, brought on by the opening of the North Sea and Alaska's North Slope oil fields coincident with reduced demand after the 1970s oil price spikes, OPEC initiated a production quota system to maintain pricing control. Each member's allowable production was based on their share of total OPEC reserves. In 1985, tiny Kuwait suddenly reported 30 billion barrels of additional reserves. Within a few years the reported reserves of Iraq, Iran, Venezuela and United Arab Emirates jumped. In 1989, the Saudis booked an additional 90 billion barrels.

switch to reporting estimated total recoverable oil. It further discounts reported reserves by subtracting annual production, assuming no reserve replacement. Under the worst case, remaining Saudi Arabian supplies could be as low as 100 billion barrels.[10] If the same exercise is conducted for all of the OPEC countries, about 350 billion barrels of oil supply disappear under a worst-case scenario. Suddenly, the world's oil future looks potentially a lot bleaker. Without transparent reserve data reporting, there is no way to know how much oil can realistically be expected to come from OPEC in the future. While the truth probably lies somewhere between the best and worst case scenarios, it is not safe to assume that OPEC will be able to increase both reserves and production rate in the future to meet growing demand. Yet that is exactly what the USGS, the IEA and the entire western world are gambling on.

The Growing Gap: So Much Depletion, So Few New Megafields

Another simple spreadsheet analysis illustrates the potential supply/demand gap that could develop over the next 10 years. In Figure 2, I've extrapolated demand at growth rates of 1.5% and 3%. Then I've plotted projected new deepwater production based on Chris Skrebowski's megafield tracking in Petroleum Review and used it to offset current world production decline rates of 2% to 5%.[11] In reality, the world decline rate will start out small, then increase as more fields and regions tip into decline.

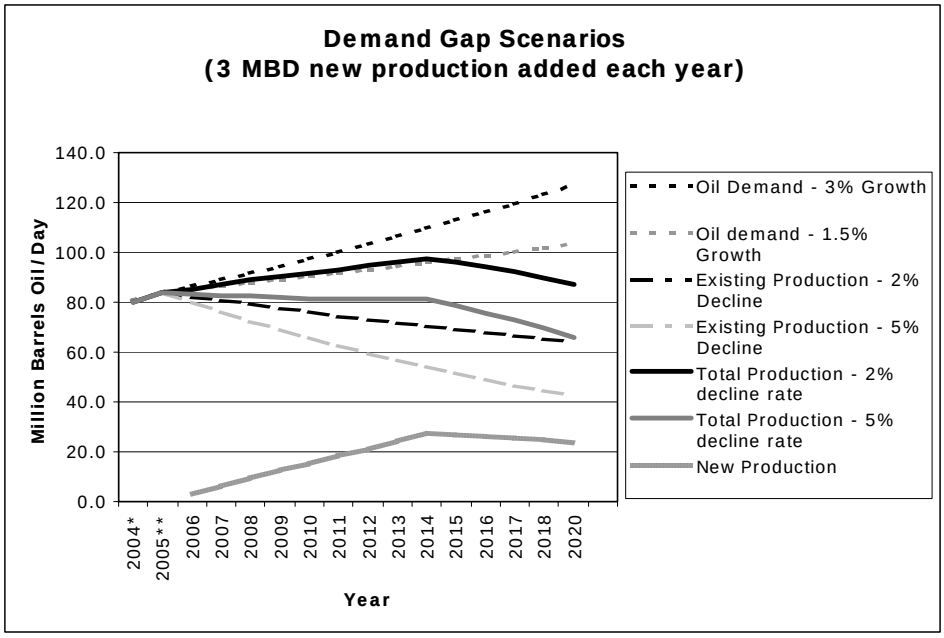


Figure 2. Projected gap between oil demand and supply at 1.5% and 3% demand growth, assuming 2% to 5% annual decline in existing production. Annual additions to production of 3mbd are projected, with new fields beginning to decline after 10 years.

[10] Matthew Simmons' 2005 book *Twilight in the Desert* cast considerable doubt on officially reported Saudi oil reserve numbers and pumping capacity based on his evaluation of numerous oil field engineering reports.

[11] This plot is a variation of the "oil-a-gator" graphs that Skrebowski showed at the November 2005 ASPO conference in Denver, Colorado. The estimate of new production is based on his tracking of reported megafields ("*Prices Set Firm Despite Massive New Capacity" (Megaprojects Update)*, Petroleum Review, October 2005, pp. 36-40, and "*Oil Fields Mega Projects 2004*", Petroleum Review, January 2004, pp. 18-20). Note that Skrebowski uses a world decline rate (Type III depletion) of about 1.6% for his models.

The potential shortfall is obvious. If the new field numbers prove accurate, the current rate of production might be sustained, or even grow, until 2015. But it could prove very difficult to meet any significant growth in demand. Figure 3 illustrates the supply/demand deficit. As Figures 2 and 3 make clear, a demand/supply gap could arise before peak oil production is reached. Once demand exceeds the supply rate, the world will tip from a buyers' to a sellers' market for petroleum. The incipient demand gap will be recognized by price increases, price volatility, and market uncertainty. Production could still increase from year to year, but it won't fill the gap. The economic impacts will have begun. System weaknesses will become manifest. Physical shortages could occur in places. The "Big Rollover" as USGS Geologist Les Magoon calls it, will be very disruptive to business as usual.

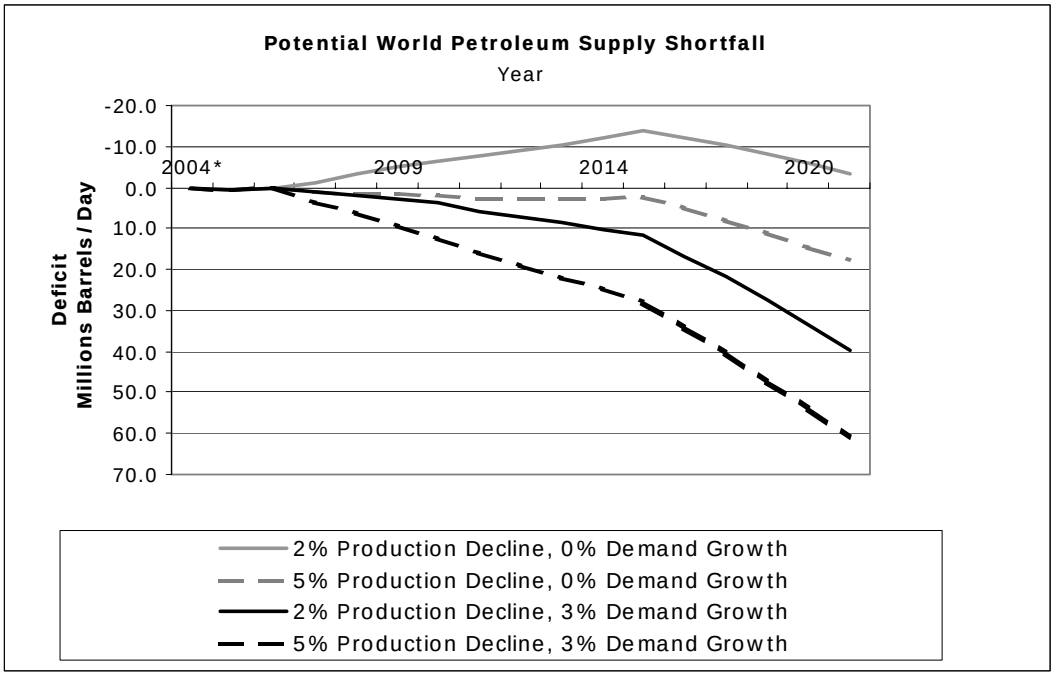


Figure 3. Projected oil supply deficit at demand growth rates of 0% and 3%, given current production decline rates of 2% to 5%. New production estimated at 3 mbd per year, with new fields entering decline after 10 years.

This inventory delivery data should set off alarm bells for any competent business manager. The inescapable conclusion: just-in-time delivery of future oil supplies is not a prudent operating assumption. Even if a new supergiant field were discovered this year (and the odds of finding another king-sized field like Saudi Arabia's Ghawar are exceedingly small), there would still be a major world production gap for several years while the new discovery came on line. [12]

[12] Note also that although the giant Alaskan North Slope fields did significantly slow the decline of US oil production, they did not return the US to peak production rates.

Transition Endgame: Gambling for our Energy Future

This section sets out the oil transition as a decision management game and compares four strategic approaches.

The Players: Oil Haves, Heavy Users and Have-Nots

The geopolitical distribution of the remaining oil differs markedly from the distribution of its heaviest users (Table 1). Therein lies the motivation for much of the foreign policy and war that has characterized the last century. More than half of the countries that are heavy oil users are also net importers. The U.S., an Oil-Have that is the heaviest user of all, imports more than 60% of its daily needs. Therefore, it will increasingly play the game from the perspective of a Have-Not. Clearly, China will be playing the transition endgame as a Have-Not, too.

Table 1

OIL ENDGAME - THE MAJOR PLAYERS

THE HAVES Top 15 Oil Reserve Countries				THE HEAVY USERS Top 15 Oil Consumers*			
2004 Data	Reserves Billion bbl	% Total			Daily MBD	Annual Billion bb	% Total
Saudi Arabia	262.7	22.1%		USA	20.5	7.5	25.4%
Iran	132.5	11.1%		China	6.7	2.4	8.3%
Iraq	115.0	9.7%		Germany	2.6	1.0	3.3%
Kuwait	99.0	8.3%		Russian Federation	2.6	0.9	3.2%
United Arab Emirates	97.8	8.2%		India	2.6	0.9	3.2%
Venezuela	77.2	6.5%		South Korea	2.3	0.8	2.8%
Russian Federation	72.3	6.1%		Canada	2.2	0.8	2.7%
Kazakhstan	39.6	3.3%		France	2.0	0.7	2.4%
USA	29.4	2.5%		Mexico	1.9	0.7	2.3%
Canada	16.8	1.4%		Italy	1.9	0.7	2.3%
Qatar	15.2	1.3%		Brazil	1.8	0.7	2.3%
Mexico	14.8	1.2%		United Kingdom	1.8	0.6	2.2%
Brazil	11.2	0.9%		Saudi Arabia	1.7	0.6	2.1%
Norway	9.7	0.8%		Spain	1.6	0.6	2.0%
United Kingdom	4.5	0.4%		Iran	1.6	0.6	1.9%
Total Rest of World	190.9	16.1%		Total Rest of World	27.1	9.9	33.6%
TOTAL WORLD	**1188.6**	100.0%		**TOTAL WORLD**	80.8	29.5	100.0%

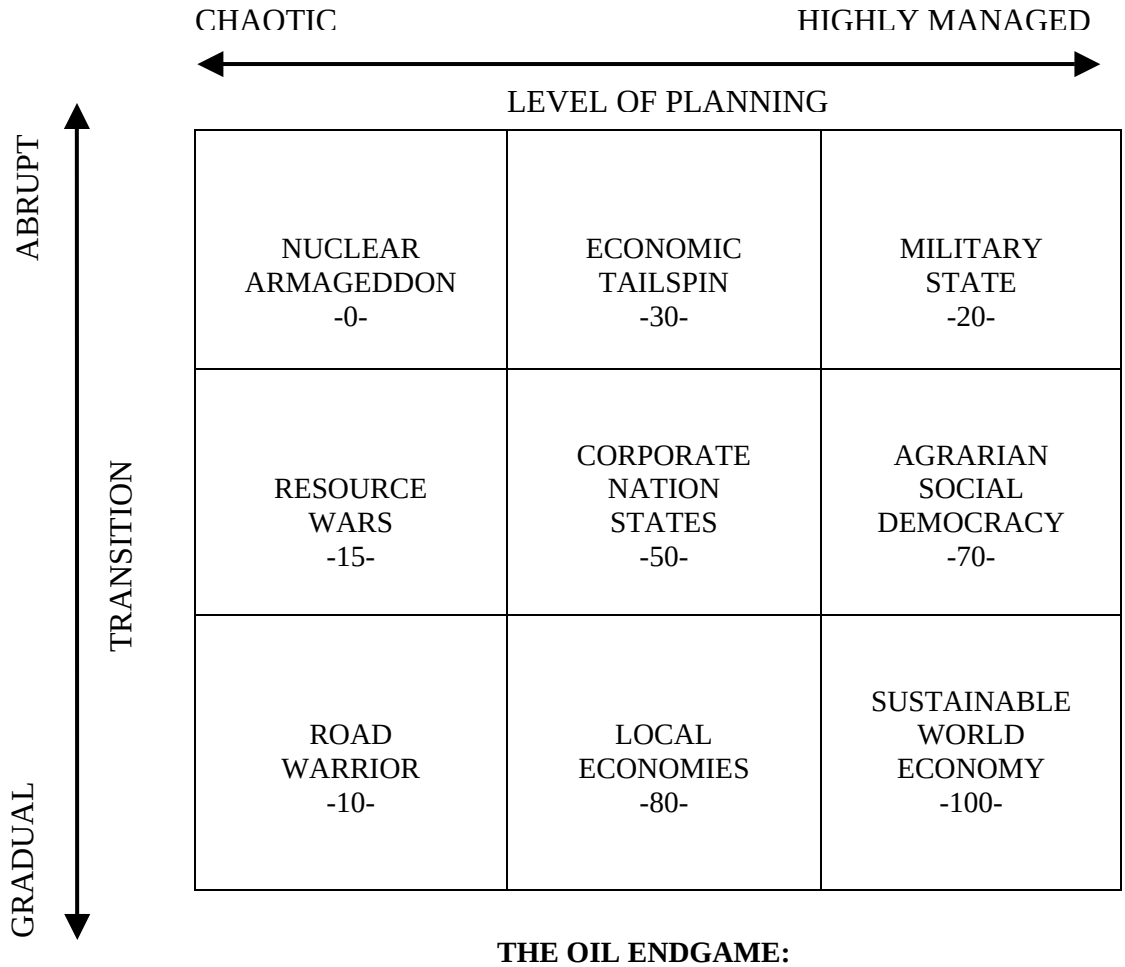
*Heavy Users may be Oil-Haves (Shaded) or Have-Nots

All Data from BP Statistical Review 2005
OPEC reserves not discounted

The Oil Endgame pits Oil-Haves against Heavy Users. Shaded countries have significant reserves, but also heavy consumption. They must balance the revenue benefit of exports with the need to provide oil for their own populations. Heavy Users that are net importers, like the U.S., will play the game as oil Have-Nots. Note that OPEC countries contain 75% of the reported reserves.

The Stakes: A Matrix of Plausible Outcomes

Figure 4 presents an array of speculative outcomes to the Peak Oil endgame. The envisioned outcomes are intentionally extreme to make the contrasts between them starker. But all have analogs in history or have been played out in speculative fiction.



THE OIL ENDGAME:
A MATRIX OF PLAUSIBLE OUTCOMES

Figure 4. Oil Endgame Matrix of Outcomes. The outcomes are scored on a subjective scale of relative desirability from 0 (low) to 100 (high).

Outcomes are sorted on the x-axis based on the degree of transition planning, which could range from zero (chaos/collapse) to a highly managed transition into a reduced petroleum economy. The Y-axis portrays the transition time allotted to prepare for life on the downward side of Peak Oil, which ranges from abrupt (little to no warning) to gradual (20-30 years preparation time, whether wisely used or not).

The stakes are high. Extreme negative outcomes are possible, including nuclear obliteration, or collapse of civilization and a return to a pre-industrialized standard of living. Less severe, even positive, outcomes

are also possible. At the positive extreme, the transition from fossil fuels is consciously managed to achieve a sustainably high standard of living for a majority of the world's people.[13]

Chaotic/Collapse Outcomes

- **Nuclear Armageddon**: Also known as "Last Man Standing" or "If I can't have it, you can't either", one of the have-not superpowers (e.g. U.S. or China) or a "rogue state" (e.g. Pakistan or Korea) exercises the nuclear option to prevent others from access to oil resources. This brings the game to an abrupt end.

- **Resource Wars:** Code-named "War that will not end in our lifetime"[14], increased competition for remaining petroleum supplies leads to a perpetual state of proxy wars, direct military intervention/occupation, and escalating terrorism until recoverable supplies are exhausted, or simply no longer worth fighting for.

- **Road Warrior[15]:** As petroleum supplies become increasingly scarce, civil society breaks down into tribal units scrambling to stay alive and defend their hoarded resources from marauders.

Semi-Chaotic to Quasi-Managed Outcomes

- **Economic Tailspin/Global Recession:** The sudden and unforeseen onset of oil supply shortages undermines the economy, leading to price spikes, fuel delivery disruptions, reduced GDP, spiraling petroleum import deficits and a dollar crisis. Periods of inflation/hyperinflation alternate with recession/depression. A global recession ensues.

- **Corporate Nation-States:** Under this variation of Return to Feudalism, arable land and resource ownership ends up concentrated in a small group of elites or companies. Everyone else works for them as tenant farmers, indentured laborers, or soldiers, in return for income or basic necessities and protection.

- **Local Economies/Community Solutions:** Intentional communities develop around local agriculture, supporting local businesses and reaching decentralized agreements on resource usage and group governance. They concentrate on energy efficiencies and micropower to maintain a decent standard of living in a supportive social network. Interaction with the outside world is via telecommuting and mass transit.

Highly Managed Transition Outcomes

- **Military State:** Due to oil shocks and supply disruptions, the government declares a state of emergency, imposes rationing and curfews and severely restricts movement of the population. Military police (or contract security) quell periodic civil uprisings. Picture New Orleans in the aftermath of Hurricane Katrina, but without the flooding.

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[13] Determining a hypothetical set of conditions under which this would be possible has been the goal of the World3 computer modeling scenarios run by the MIT scientists and modelers (Meadows et al, *Limits to Growth: 30-year update*).

[14]This phrase was introduced into public lexicon as a nominal "war on terror" by Vice President Dick Cheney in 2001, and has been reinforced by wide repetition since.

[15] In honor of the Mad Max and Road Warrior movies, starring Mel Gibson.

- Agrarian Social Democracy: A centralized planning decision directs a society-wide effort and national resources towards feeding the population. A significant portion of the population becomes farmers. Land ownership and farm operations are scaled to a low-energy, community level with significant participation of individuals in local decisions and governance (e.g., post-Soviet Cuba[16] rather than the failed Soviet socialist model of huge collective, high-energy-input farms).

- Sustainable World Economy: A full-scale, international cooperative effort is implemented to dramatically reduce energy consumption, enhance technological efficiencies and develop renewable energy sources and alternatives. The mitigation actions are initiated early enough to prevent severe energy disruptions and hardship. The world population stabilizes at a high level of sustainable human welfare.[17]

Preferred Outcomes

These are not the only possible outcomes and the reader is invited to substitute different visions.[18] The point is that some of the outcomes (e.g., Nuclear Armageddon, Military State, Resource Wars and Road Warrior) are highly undesirable and, in my opinion, should be avoided at all costs. However, these destructive outcomes are quite possible under either abrupt or unplanned (chaotic) transitions. The abrupt outcomes (Armageddon, Economic Tailspin, and Military State) are inherently unstable and would eventually devolve to other outcomes. Quasi-managed options (Economic Tailspin and Corporate Nation State) involve significant hardship and financial insecurity and portend the end of the Middle Class. The most satisfactory outcomes (Sustainable World Economy, Local Economies, and Agrarian Social Democracy) are achievable options only with sufficient transition time and focused preparation.

Asymmetric Risks

Due to the high stakes, and the limited number of acceptable outcomes, the risks of the game are highly asymmetric. On the one hand, taking radical action now might leave some accessible oil in the ground (money on the table). On the other hand, the risk of not acting is to significantly increase the probability of catastrophic outcomes. Transition time is of the essence. The number of potentially satisfactory outcomes is reduced if action is not initiated significantly before the peak. As Robert Hirsch notes in his white paper to DOE on Peak Oil mitigation:

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[16] When the Soviet Union collapsed, Cuba abruptly lost its major supplier of imported petroleum. Fortunately, emergency plans to mitigate a potential U.S.-led oil blockade had already been prepared. Using these, the Cubans implemented a crash program to switch to decentralized, low-energy intensity agriculture. A painful transition - the "Special Period" – followed, where the average Cuban lost 30 pounds, but thousands of small bio-intensive farms now successfully feed the population. The status of farmers was elevated to that of doctors. (Faith Morgan and Megan Quinn, *The Power of Community: How Cuba Survived Peak Oil*, 53-minute DVD produced by Community Service, Inc., copyright 2006).

[17] This is the ideal outcome that is achieved by mid-century under MIT's World3 modeling scenario 9, when inputs are set at: families limited to 2 children; industrial output per capita is fixed; and improved technologies abate pollution, conserve resources, increase land yield, and protect agricultural land. (Meadows, et al, *Limits to Growth:30-Year Update*, 244).

[18] It is easy to envision other negative outcomes, such as Four Horseman of the Apocalypse (war, famine, pestilence, and death ride out to reduce the population to a sustainable level), or Asian Revenge, in which Americans end up as day laborers for wealthy Chinese who now own their houses and all their assets. Additional positive outcomes are harder to imagine.

> The world has never faced a problem like this. Without massive mitigation more than a decade before the fact, the problem will be pervasive and will not be temporary. Previous energy transitions (wood to coal and coal to oil) were gradual and evolutionary; oil peaking will be abrupt and revolutionary. [19]

The Goal

Given an unknowable state of nature, i.e. the true amount of remaining oil, its peak production date, and the quantity of production that can realistically be replaced by alternative sources, the player(s) must select a course of action(s) to avert a potentially catastrophic outcome. Advanced players may try to optimize their outcome from among the several satisfactory ones. Expert players will try to manage the transition with as little social pain, economic hardship and dislocation as possible.

The Rules

There are no rules of etiquette. Alliances of any sort are allowed. Treaties may be broken. Military intervention, trade agreements, tariffs, and terrorism are all allowed. Players may only employ resources and technologies that exist today, or that may reasonably be expected to become available within the next 10 to 20 years. Divine or alien interventions are ruled out as strategies, as are any proposed technologies that defy the second law of thermodynamics.[20]

A Palette of Strategic Actions (Tactics)

Tactics are specific actions, or tools, which players have at their disposal to implement their strategic approaches to a problem. Table 2 lists the most obvious types of tactics that might be employed within different sectors to advance diverse objectives in the oil endgame and to reduce sector exposure to peak oil impacts during the transition to a reduced petroleum economy. The range of tactics available are encompassed by:

1) **the free market** - passive action;
2) **government action** - centralized decisions to intervene through military action, policy, or spending;
3) **private sector action** - decentralized investment decisions and voluntary behavior changes by businesses and individuals taken to benefit the entity; and
4) **collective action** – community or societal actions taken to benefit the members of the group and ensure its survival.

Four distinct strategic approaches, comprised of various combinations of tactics, are then developed to compare different ways that the Peak Oil transition endgame might be played.

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[19] Hirsch, Robert L. (SAIC), Roger Bezdek (MISI), and Robert Wendling (MISI), *Peaking of World Oil Production: Impacts, Mitigation, and Risk Management.* White Paper prepared as an account of work for the U. S. Department of Energy, February 2005. p. 64.

[20] e.g., no perpetual motion machines.

Table 2
Potential Strategic Actions (Endgame Tactics)
Available to the Different Sectors

MAR-KET	M-1	Let Market Pricing Equilibrate Supply and Demand
GOVERNMENT	G-1	Governments Secure the Oil - Nationalization - Trade and Development Agreements - Military Threat or Intervention
	G-2	Market Interventions - Price Caps - Rationing - Fuel Consumption Taxes - Subsidies and Incentives - Fiscal Policy
	G-3	Spending on Research & Development and Infrastructure
	G-4	Policy and Law - National Energy Policy - International Cooperation Policies
PRIVATE SECTOR	P-1	Protect Self Against Short-Term Price and Supply Shock
	P-2	Shift Values Towards Sufficiency & Long-Term Sustainability - Conservation/Reuse - Best Use of Finite Resources - Shift Investment Dollars - Renewable Energy, Education
SOCIAL GROUP	S-1	Reinforce Community Values by Exerting “Norming” Pressure
	S-2	Leverage Resources

Four Possible Approaches to Transition to the Reduced Petroleum Economy

1) The American Way of Life is Non-Negotiable[21]: Hanging onto Lifestyle

This is Plan A, the publicly stated US policy position. It involves securing access to the world's oil at all costs, militarily if necessary. This course of action, which has defined America's foreign policy since before the fall of the Soviet Union, is based on the premise that America's security and economic well-being depend on its global hegemony as the sole superpower. [22] The attitude also reflects a political reluctance at the highest levels to ask Americans to reduce their oil consumption in the face of emerging supply tightness. Using this strategy, there is no preparation for a peak oil crisis, other than market signaling and the continuing efforts of the US government to secure access to oil through military threats and interventions.

2) To the Victors Go the Spoils: Privatization of the World's Energy

This approach is closely related to Approach #1, but transcends national boundaries and involves active investment by certain private sector groups to protect themselves and profit from the upcoming crisis. In this case, the global elite (transnational corporations and wealthy families) attempt to gain control of the remaining oil supplies, principally through privatization of nationally held resources. Their investments are protected by private security forces or government-provided armies. Public utilities are also privatized, thus transferring control of energy distribution and mass transportation to the private sector. The government may act at behest of the elites to ration some oil to the populace, while keeping less restricted supplies for themselves.

3) What Color is Your Parachute? Full-scale Preparation Effort

This approach assumes that people become aware of the pending crisis and its magnitude early enough to try to prepare. The government institutes a full-scale, multi-faceted effort to meet the challenge, using every viable tactic in its arsenal. It puts the country on a "war footing" through a massive education campaign and begins extensive conservation and R&D efforts, as well as investment in energy and transportation infrastructure. It intervenes to achieve immediate oil demand reduction via fuel taxes, gasoline rationing, and incentives for more efficient travel. Finally, the government enacts a sustainable national energy policy and pursues international cooperative agreements on production and allocation of a depleting world oil supply. The private sector, after employing short-term tactics to protect themselves from oil supply shock, starts shifting values, intellectual effort and investment dollars towards long-term energy sustainability. They cut oil consumption while making aggressive investment in renewable energy sources, efficiencies, mass transportation and local agriculture. Societal groups reinforce the value shift towards conservation, efficiencies and sustainable technologies and pool resources to leverage their impacts.

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[21] President George Bush, Sr., speech at Earth Summit on the Environment, Rio de Janeiro, 1992. However, the quote is usually attributed to Vice-President Dick Cheney.

[22] Most influentially articulated by Zbigniew Brzezinski, *The Grand Chessboard: American Primacy and its Geostrategic Imperatives* (New York: Basic Books, Perseus Books Group, 1997) and Donald Kagan, Gary Schmidt, and Thomas Donnelly, *Rebuilding America's Defenses: Strategy, Forces and Resources for a New Century*, A report of The Project for the New American Century (2000).

4) Small is Beautiful: Power Down to Sustainable Communities[23]

Under this approach, people begin a conscious move away from centralized government and towards self-sufficient, intentional communities and regional alliances, in the belief that they can scale back consumption significantly while still maintaining a comfortable standard of living and actually enhancing quality of life. Personal, business, and social tactics focus on efficient technologies, conservation, local renewable energy sources, reduced transportation use of oil, regional food sources and local livelihood.[24] This approach is independent of, and may end up at odds with, Government tactics that are simultaneously employed.

Speculated Playouts under the Four Approaches

Possible endgame outcomes for each of the four strategic approaches in Table 3. Each scenario is considered under five possible states of nature, which represent the range of the underlying, but unknowable amount of the world's remaining recoverable oil reserves.[25] The consequences of selecting each approach are summarized and compared in Table 4 and discussed below.

1) Non-Negotiable American Way of Life

This approach has the effect of driving full speed ahead with the breaks removed. Following it, Americans become even more insular in attitude and militaristic abroad. Resource wars are conducted full-time, through direct intervention and surrogates. The trade deficit for oil and the national debt spiral out of control, and the country has trouble financing its 20+ million barrel/day petroleum habit, but does not cut back consumption. Within the Muslim world, hatred of Americans kindles increased terrorism and sabotage of oil infrastructure. China and the U.S. risk war over access to the remaining oil supplies.

Without any warning or preparation, the transition to post-peak oil production - no matter if now or in 20 years - hits the public abruptly. The resulting decline in oil availability can only be solved through brutal demand destruction through pricing and supply disruptions. Economic hardship and dislocation is extreme. Probable outcomes are increasingly violent and militaristic in the short term, and chaotic in the long term, resulting in the breakdown of government and society. In the short term, Continuity of Government (COG) plans are enacted, resulting in a U.S. military state until the populace rebels. Final outcomes potentially include Nuclear Armageddon under an abrupt transition scenario or Road Warrior under a gradual transition scenario.

[23] After E.F. Schumacher's seminal book, *Small is Beautiful: A study of economics as if people mattered*, Abacus edition, London: Sphere Books, Ltd., 1974, and Richard Heinberg's *Power Down*. BC Canada: New Society Publishers, 2004.

[24] These tactics epitomize the values of participants at the annual Community Solutions to Peak Oil Conference, held in Yellow Springs, Ohio in 2004-2006.

[25] The five possible states of nature considered are the ones characterized on the website www.oilscenarios.info and correspond closely to the camps described above. The "Pollyana" state represents the most extreme form of optimism. Under this view, future oil reserves are unlimited. Proponents of the abiotic oil theory fall into this camp.

Table 3

Possible Endgame Outcomes Under Different States of Nature

	States of Nature - Timing of Peak Oil				
	A	**B**	**C**	**D**	**E**
	Pollyana	**Optimist**	**Plateau**	**Pessimist**	**Head-for-Hills**
Years til Peak	40+	15-30	5-15	0-7	0-2
Probability of Occurrence	1%	10%	35%	40%	14%
Strategic Approach					
1) Non-negotiable American Lifestyle	Nuclear Armageddon Resource Wars	Nuclear Armageddon Resource Wars	Nuclear Armageddon Resource Wars Economic Tailspin	Nuclear Armageddon Road Warrior Resource Wars Economic Tailspin	Nuclear Armageddon Road Warrior Resource Wars Economic Tailspin
2) To the Victor go the Spoils - Privatize Resources	Resource Wars Corporate State	Resource Wars Corporate State	Resource Wars Military State Economic Tailspin Corporate State	Resource Wars Military State Economic Tailspin Corporate State	Military State Economic Tailspin
3) Parachute - Full-scale Preparation	Agrarian Democracy Local Economies Sustainable World	Agrarian Democracy Local Economies Sustainable World	Corporate State Agrarian Democracy Local Economies	Military State Economic Tailspin Corporate State	Military State Economic Tailspin
4) Small is Beautiful - Power Down/Re-localize	Nuclear Armageddon Economic Tailspin Military State Agrarian Democracy Local Economies	Nuclear Armageddon Military State Economic Tailspin Agrarian Democracy Local Economies	Nuclear Armageddon Military State Economic Tailspin Agrarian Democracy Local Economies	Nuclear Armageddon Military State Economic Tailspin	Nuclear Armageddon Military State Economic Tailspin

Available Outcomes	Years to Implement	Desirability Rating
Nuclear Armageddon	0-2	0
Road Warrior	5-30	10
Resource Wars	2-15	15
Military State	1-5	20
Economic Tailspin	0-5	30
Corporate Nation State	2-15	50
Agrarian Democracy	5-15	70
Local Economies	10-25	80
Sustainable World Economy	20-30	100

Note: Probabilities of occurrence for the states of nature and desirability ratings for the outcomes are the author's subjective assessment. It's a game. Players should determine their own probability weightings and outcome ratings.

Table 4

Comparison of Four Strategic Approaches to Managing the Transition From Peak Oil Production to a Reduced Petroleum Economy							
STRATEGIC APPROACH	**TACTICS EMPLOYED**	**LEVEL OF PREPARATION**	**TRANSITION TIME**	**POST PEAK DESCENT**	**AVAILABLE ENDGAME OUTCOMES**	**DESIRABIL -ITY SCORES**	**EXPECTED VALUE OF PAYOFF**
The American Way of Life is Non-Negotiable	M-1 G-1 (Military)	Govt. – Low Public - None	Abrupt 0-2 years	Very Steep, Bumpy, Hard Landing	Nuclear Armageddon Road Warrior Resource Wars Economic Tailspin	0 10 15 30	**14**
To the Victor go the Spoils (Privatization of the World's Energy)	M-1 G-1 (Military) G-2 (rationing) P-1	Govt. – Low to Moderate Corp./Elites – High Public - Low	Short to Moderate 2-15 years	Steep, but Controlled	Resource Wars Military State Economic Tailspin Corporate State	15 20 30 50	**29**
Parachute **(Full-Scale Preparation)**	M-1 G-1 (Trade&Aid) G-2 (rationing, fuel or carbon taxes, incentives) G-3, G-4 P-1, P-2 S-1, S-2	Govt. – High Public - High	Moderate to Long 15-30 years	Plateau to Gradual Less Bumpy Softer Landing	Military State Economic Tailspin Corporate State **Agrarian Democracy** **Local Economies** **Sustainable World**	20 30 50 **70** **80** **100**	**49**
Small Is Beautiful: **(Power Down/Re-localize**	M-1 P-1, P-2 S-1, S-2	Govt. - None Public - Mod. to High	Short to Moderate 2-15 years	Steep. locally moderate. Softer Landing	Nuclear Armageddon Military State Economic Tailspin **Agrarian Democracy** **Local Economies**	0 20 30 **70** **80**	**27**

Key: M-1: Market pricing; G-1: Government secures the oil; G-2: Market interventions; G-3: Government Research&Development; G-4: national and international policy; P-1: private actions to avert price/supply shock; P-2: investment shift to long-term sustainability; S-1: social norming: S-2: leveraged resources. **Preferred outcomes shown in bold.** The expected payoff values are calculated from the average desirability scores for the outcomes for each given strategy/state of nature, weighted by the probability of occurrence for the given state of nature.

2) To the Victors Go the Spoils

This scenario plays out similarly to the first with respect to ongoing resource wars and the exploding government trade and budget deficits. The wholesale transfer of public assets to the private sector creates dangerously imbalanced social equity and wealth. National boundaries and governments cease to have more than symbolic meaning. Those holding real assets, especially oil, wield great power (pun intended). But now, rightly mindful of barbarians at the gate, the elites must reside in walled compounds protected by armies. The middle class finds itself increasingly powerless, and unable to afford an independent and mobile lifestyle. In debt beyond their wildest imagination, they are forced to sign long-term, low-wage contracts to work for the elite businesses that can offer them debt relief, physical protection, and a chance to earn enough to buy the basic necessities. Although Economic Tailspin and Military State outcomes are both possible under an abrupt transition, the most stable outcome achievable under this approach is Corporate Nation States.[26]

Under this strategy, the American way of life is highly negotiable; the middle class' current access to cheap energy is transferred to the highest bidder. With corporations and wealthy elites holding all the assets and managing the post-peak transition, the decline is neither as steep nor as bumpy as under the non-negotiable American lifestyle approach. However, this approach creates significant resource allocation, security, and liberty issues for most of the US population.

3) Parachute: Full-scale Preparation Effort

Under this scenario, the unplanned outcomes on the matrix are avoided. However, the abrupt undesirable outcomes of Economic Tailspin and Military State are still possible if the onset of peak oil occurs before the preparation efforts are put into effect or have time to achieve results. With a short time horizon, the "hard landing" will not be averted. Demand destruction will occur through harsh price shocks and economic depression and/or militarily enforced reduction of oil consumption. But with sufficient preparation time for conservation to curb demand and investment to develop alternative and efficient technologies and mass transit, the slope of the oil decline curve would be less steep and bumpy than under any of the other scenarios. With full-scale preparation for a long enough period it might be possible to achieve the three most acceptable outcomes – Agrarian Social Democracy, Local Economies, and Sustainable World Economy.

4) Small is Beautiful: Power Down/Re-localize

Under this approach, individuals and local groups that manage to scale down their energy requirements and switch to local jobs and food sources are able to insulate themselves to some degree from the price shocks and hardships that face the unprepared. Given sufficient time, these groups could establish viable Local Economies. With sufficient numbers, they could attain enough political clout to affect energy policies and resource allocation within their regions. Different regions would develop different survival strategies, depending on their unique geography and demographics as well as their natural resource endowment. Agrarian Social Democracy models might be selected in some areas. Many communities would undoubtedly fail. Hardship could be the norm. Successful communities would need to build defenses and alliances to protect themselves from hungry, migrating hoards.

As with the other three scenarios, an abrupt transition to post-peak oil would still result in undesirable outcomes. Because the Small-is-Beautiful approach cannot exert restraining influence at the national level, the Nuclear Armageddon outcome remains possible under this scenario.

<u>Selecting the Preferred Strategy</u>

[26] Apologies to Neal Stephenson, to whom I owe credit for the Corporate Nation State vision, which I have lifted, altered and diluted from his futuristic novels *Snow Crash* and *The Diamond Age*.

Before choosing one strategy over another, it is useful to bracket the range of possible payoffs and opportunity loss risk. The expected payoff values shown in Table 4 assumed that every outcome assigned to a strategy under a given state of nature had an equal chance of occurring. A realist would use this method to calculate the odds. An optimist, however, would consider the best possible outcomes and the maximum they might win through their gamble. And a pessimist would look at how much potential payoff they would leave on the table by making the wrong decision. Table 5 shows the best outcome available under each strategy for a given state-of-nature and the probability-weighted best payoff score. Not surprisingly, the highest payoffs obtainable under *any* state of nature occur when the Parachute – full-scale preparation approach is selected. As a direct consequence, the potential opportunity loss for the Parachute scenario is zero.

In contrast, Table 6 is an opportunity loss table. It compares the maximum scores attainable for each strategy under each state of nature, and calculates how much gain would potentially be foregone by not selecting the winning strategy for that state. It is an interesting exercise to change the probabilities of occurrence for the states of nature. Assigning a higher probability to the Pollyana and Optimist states of nature only increases the magnitude of loss if a business-as-usual approach is selected and the true state of nature turns out to be otherwise.

Conclusion

No matter which Peak Oil camp a person belongs to, a gaming exercise helps clarify the potential viability of any potential path of action before it is chosen. It also becomes apparent that some approaches yield preferable outcomes under any scenario and that the downside risks of not acting in time are much greater than the risks of initiating corrective action too early.

It is clear that the non-negotiable American way of life is not a viable solution. The US no longer has the domestic oil to pull it off; it is too import-dependent. This strategy does not adequately acknowledge the new geopolitical realities of China's rise to Super Power status or Russia's re-emergence as an Oil-Have and the king of natural gas. Entailing both abrupt transition and zero advance planning, the odds for this strategy favor the Nuclear Armageddon outcome. The downside risks for the non-negotiable approach are greater than for any other scenario. It should thus be ruled out.

With the additional time and planning employed under the To-The-Victor-Go-the-Spoils approach, the Nuclear Armageddon outcome might be averted. After all, annihilation of the world as we know it would spoil any victory. However, the outcomes that are available to the Victor involve significant military control and hardship for the vast majority of people, who may decide not to accept them without a fight.

The Small-Is-Beautiful approach has substantial merit. Two acceptable outcomes are possible and individuals and societal groups can start preparations immediately, without waiting for the government to take action. The downside risks of not selecting this approach are very low. But without government investment in infrastructure and international cooperation to allocate the oil between nations, this strategy cannot control the larger forces that could lead to Resource Wars, Nuclear Armageddon, or a Military State.

Therefore, assuming we don't belong to a group that actually desires Nuclear Armageddon or collapse, that we'd like some sort of free future for our children, and that the Cornucopians are probably (99% in my estimation) wrong, the rational thing is to choose the Parachute approach. That is, to start full-scale preparations immediately. Frankly, given the stakes, we should simultaneously employ the Small-is-Beautiful approach and any other strategies that have a chance of improving the outcome.

Table 5

Oil Endgame Payoffs
Best Possible Outcomes

	States of Nature - Timing of Peak Oil					
	A	**B**	**C**	**D**	**E**	**Probability-**
	Pollyana	**Optimist**	**Plateau**	**Pessimist**	**Head-for-Hills**	**Weighted**
Years til Peak	40+	15-30	5-15	0-7	0-2	**Best**
Probability of Occurrence	1%	10%	35%	40%	14%	**Outcome**
Strategic Approach						
1) Non-negotiable American Lifestyle						
Best possible outcome(s)	Resource Wars	Resource Wars	Economic Tailspin	Economic Tailspin	Economic Tailspin	
Best possible score	**15**	**15**	**30**	**30**	**30**	**28**
2) To the Victor go the Spoils						
Best possible outcome(s)	Corporate State	Corporate State	Corporate State	Corporate State	Economic Tailspin	
Best possible score	**50**	**50**	**50**	**50**	**30**	**47**
3) Parachute - Full-scale Preparation						
Best possible outcome(s)	Sustainable World	Sustainable World	Local Economies	Corporate State	Economic Tailspin	
Best possible score	**100**	**100**	**80**	**50**	**30**	**63**
4) Small is Beautiful - Power Down/Re-localize						
Best possible outcome(s)	Local Economies	Local Economies	Local Economies	Economic Tailspin	Economic Tailspin	
Best possible score	**80**	**80**	**80**	**30**	**30**	**53**

Note: Probabilities of occurrence for the states of nature and desirability ratings for the outcomes are the author's subjective assessment. It's a game. Players should determine their own probability weightings and outcome ratings.

Table 6

Opportunity Loss Risks to the Oil Endgame if Non-Optimal Strategy is Chosen

	States of Nature - Timing of Peak Oil					
	A Pollyana	**B Optimist**	**C Plateau**	**D Pessimist**	**E Head-for-Hills**	**Probability-Weighted Opportunity Loss**
Years til Peak	40+	15-30	5-15	0-5	0-2	
Probability of Occurrence	1%	10%	35%	40%	14%	
Strategic Approach						
1) Non-negotiable American Lifestyle						
Best Possible Outcome, Chosen Strategy, Given State	15	15	30	30	30	
Best Possible Outcome, Any Strategy, Given State	100	100	80	50	30	
Potential Opportunity Loss	**-85**	**-85**	**-50**	**-20**	**0**	**-35**
2) To the Victor go the Spoils - Privatize Resources						
Best Possible Outcome, Chosen Strategy, Given State	50	50	50	50	30	
Best Possible Outcome, Any Strategy, Given State	100	100	80	50	30	
Potential Opportunity Loss	**-50**	**-50**	**-30**	**0**	**0**	**-16**
3) Parachute - Full Scale Preparation						
Best Possible Outcome, Chosen Strategy, Given State	100	100	80	50	30	
Best Possible Outcome, Any Strategy, Given State	100	100	80	50	30	
Potential Opportunity Loss	**0**	**0**	**0**	**0**	**0**	**0**
4) Small is Beautiful - Power Down/Re-Localize						
Best Possible Outcome, Chosen Strategy, Given State	80	80	80	30	30	
Best Possible Outcome, Any Strategy, Given State	100	100	80	50	30	
Potential Opportunity Loss	**-20**	**-20**	**0**	**-20**	**0**	**-10**

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