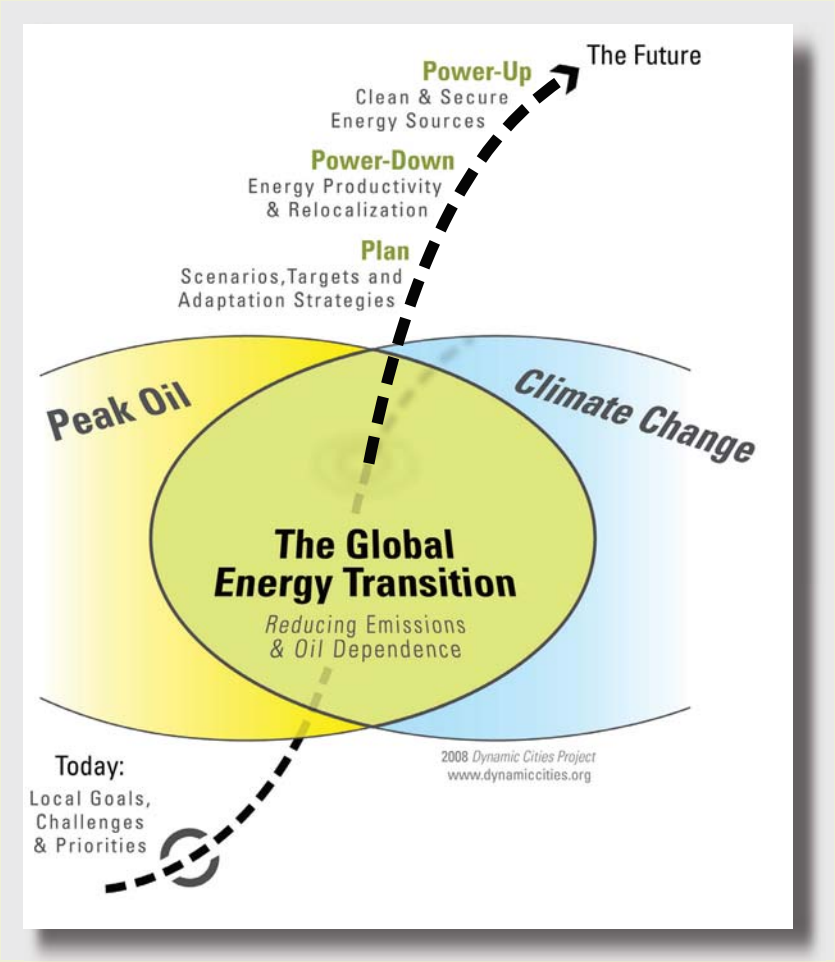
Peak Oil and Climate Change: Scenarios and Implications

Bryn Davidson

Municipal and regional planning in the context of the global energy transition



Peak oil and climate change are unprecedented global challenges that will bring about fundamental changes to both our cities and regions, and the global economy. In combination, these two forces will drive a decades-long transition away from the cheap, but carbon intensive, fossil fuels that have become the backbone of our modern society.

In response to these two forces, we need to focus on strategies which reduce *both* emissions *and* oil dependence. These high-priority actions will include improving the energy productivity of our local economies, improving the food and shelter security of our most vulnerable populations, and making large investments in cleaner and more secure sources of energy.

Before we can start this, however, we need a new way to plan.

We need to break away from the current practice of extrapolating past trends, while at the same time accounting for the potentially massive impacts, and equally large uncertainty, surrounding both peak oil and climate change.

One potentially powerful way to move forward is through scenario-based planning.

Scenarios allow us to bundle together sets of assumptions about the impacts of peak oil and climate change and can help bridge differences of

scientific or political opinion. Scenarios can help us prepare for energy, economic, and climate shocks while helping define a positive path towards a post-carbon future.

Through scenario-based planning we can test the potential value of our long term investments – in infrastructure, land use plans, or policy – in different futures defined by energy and emissions constraints. By placing these plausible futures side-by-side, and asking the key question, "which investments and actions best retain their value across *all* potential futures?" we can create more resilient cities, while avoiding investments in 'stranded assets'.

What follows is an outline of scenarios incorporating both peak oil and climate change into a broader vision of the 'global energy transition', and an example of using scenarios to plan for truck traffic and road capacity in Southern California and beyond.

Energy Transition = Peak Oil + Climate Change

In 2005-06 with the one-two punch of Hurricane Katrina and Al Gore's *An Inconvenient Truth* having heightened public focus on climate change, there was an attentive global audience listening when the Intergovernmental Panel on Climate Change (IPCC) released their 2007 assessment that climate change was, in fact, real and human activity was responsible for it.

Independent of any ensuing controversy over the technical aspects of climate change, the years since 2005 have seen a broad change in the level of global interest in climate policy, and it now seems that climate concerns have earned an indelible place in our planning strategies.

Enter peak oil.

Like climate change, there have been groups of professionals talking about 'peak oil' – the peaking and permanent decline of global oil production[1] – for decades, but with turbulent gas prices, and global oil supplies entering an apparent plateau, the abstract idea has suddenly become very real.

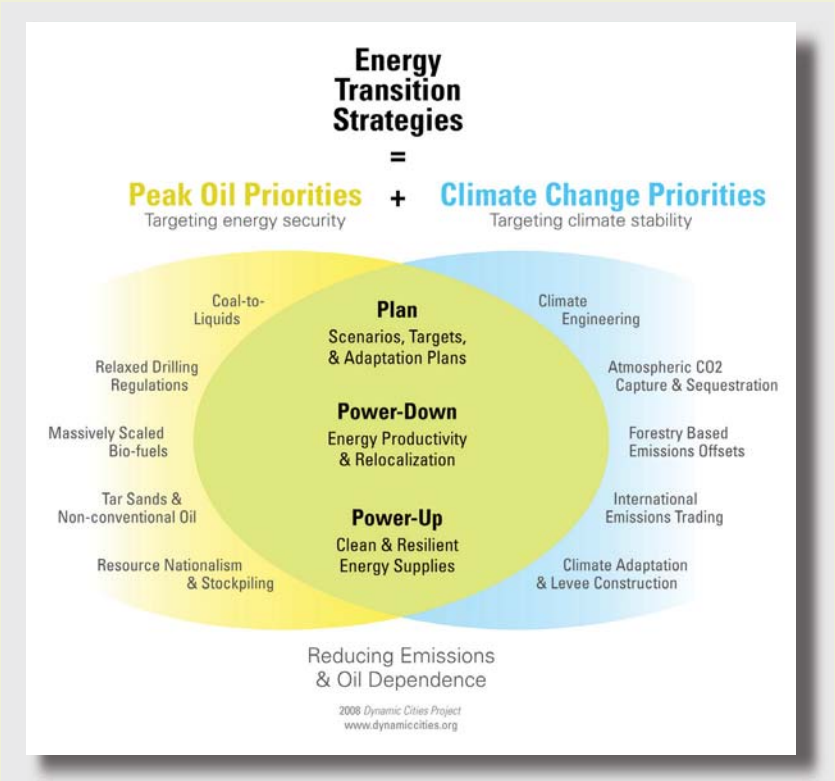
Peak Oil vs. Climate Change

What has emerged, then, is a situation where the market's responses to rising energy prices (and by extension, peak oil) have been both good and bad in terms of climate change.

On one hand, the recent dramatic rise in gas prices led to a dramatic shift in the sale of fuel efficient cars and even reversed the nearly 30 year growth trend in highway travel. Likewise, the rising tide of energy prices has spurred a dramatic surge of investment in alternative fuels and renewable energy.

On the other hand, if you are concerned about climate change or environmental protection, many potential responses to peak oil can be seen as serious threats.

Rising energy prices are bound to brush away political opposition to drilling offshore and in protected areas.[2] Non-conventional fuels from tar sands, shale, and coal will attract billions in investment while significantly increasing the carbon intensity of our fuel supply.[3] In many places food will become fuel, and rainforests will continue to be ploughed under for fuel crops.



Because of these threats, many climate activists see peak oil as a distraction at best, and at worst, an industry agenda aimed at removing all barriers to extraction.

To ignore or marginalize peak oil, however, is to ignore the potentially massive impact that rising energy prices and shortages could have on our economy, on our food and housing supply, and on global stability. As witnessed by the powerful impact of rising gas prices, the economic force of peak oil has the potential to dwarf the near term local impacts of climate change and self-imposed climate legislation.

When looking at climate policy from a peak oil context, many climate mitigation strategies such as forestry-based offsets, atmospheric carbon capture, and emissions trading are of relatively little value because they do nothing to reduce the oil dependence of our local economies and cities.

If, collectively, we focus all of our climate mitigation dollars on tree planting offsets (or are hoping that depleting natural gas supplies will replace coal or oil) then we are leaving our economies, cities, food systems, and homes vulnerable to the impacts of peak oil and peak natural gas.

Peak Oil + Climate Change: Finding Common Ground

In the end, climate change may be a much larger multi-generational threat, but in the near term the immediate and tangible impact of peak oil will likely demand a much sharper focus on transportation and oil-dependence than a climate-only approach would suggest.

In terms of priorities, we will need to focus on the oil dependence of the regional economy and workforce, and the oil dependence of core community services such as medical, police, and fire services as well as food and shelter security for the most vulnerable populations.

For this reason, we must prioritize those actions which find common ground between peak oil and climate change; strategies which reduce *both* emissions *and* oil dependence.

This is not to say that emissions trading will not be a necessary tool or that we will not need some unconventional oil or natural gas, but rather that we

need to find common ground and aggressively prioritize those strategies which address *both* peak oil *and* climate change.

Taken in the context of the global energy transition, aggressive action on climate change is no longer an economic burden, but rather the core of a strategy that will make both the nation's and region's economy more competitive in a future defined by peak oil and carbon constraints.

Peak Oil: What We Know

While climate change has garnered much attention in both public and government forums, peak oil has, thus far, been largely relegated to online communities and niche professional discussion by organizations like the Association for the Study of Peak Oil and Gas (ASPO).

This dearth of public discussion has occurred even while the topic was being actively studied by mainstream institutions like the U.S. Department of Energy,[4] the U.S. Government Accountability Office[5] and several branches of the U.S. military.[6]

What follows then, is a brief recap of some of the key salient points in the peak oil dialogue – an attempt to separate 'what we know' from 'what we believe' and to create a foundation from which scenarios integrating peak oil and climate change can be built.

Peak Oil: Aging Giant Fields

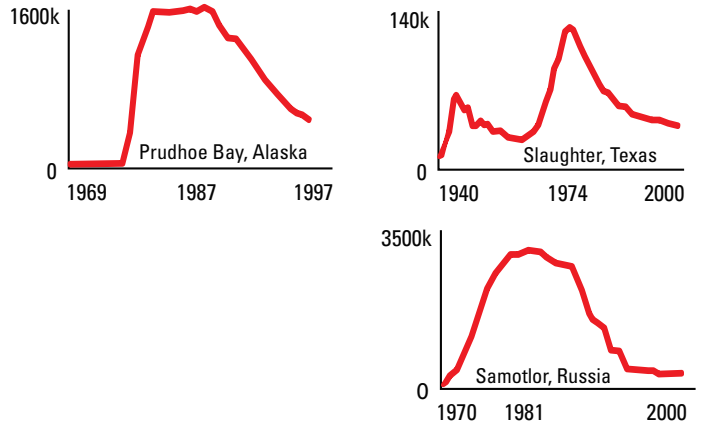
While it has been clearly observed that nearly all oil fields go through a cycle of growth, peaking, and then decline (see Figure 1 for three examples), and that a majority of oil producing nations have already gone through the same peaking experience, there has been significant debate over the timing and potential impact of global peak oil.

Before getting into the contentious points, however, it is helpful to capture some of the key issues around which there is a broader consensus. Chief among these is the fact that the major 'super-giant' oil fields – the backbone of an energy system that has been supplying us for generations – are now very old, strained, and many of the largest fields in the system have started into what is likely to be a permanent and potentially rapid decline.[7]

Figure 1

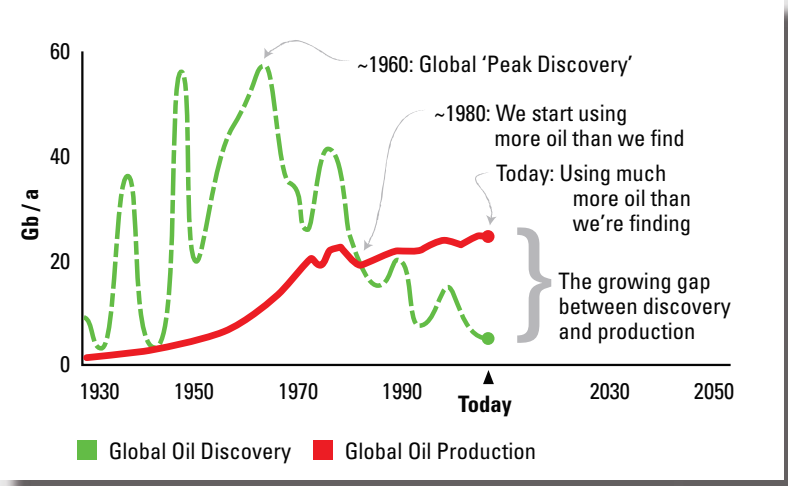
What peaking looks like

Oil production profiles for three super-giant oil fields



Production curves adapted from a presentation by investment banker, and author of "Twilight in the Desert", Matt Simmons

Figure 2



Source: Association for the Study of Peak Oil and Gas (ASPO)

Peak Oil: Peak Discovery

At the same time, while our consumption of oil has been growing, we have been discovering fewer and fewer giant oil fields.

Globally 'peak discovery' (the heyday of global oil drilling) occurred in the 1960s with the discovery of Saudi Arabia's super giant fields. Since this point of peak discovery, the rate at which we have been finding new oil has been declining steadily.

Today, after nearly fifty years of declining discoveries, we would need to find several new fields the size of Saudi Arabia's to even have a chance of reversing this trend. While it is likely that there will be a number of new discoveries forthcoming (in the arctic, in ultra deep water, or somewhere else) it is highly unlikely that any amount of investment or drilling will result in sufficiently enormous finds to reverse the fifty year trend.[8]

Non-Conventional Oil

While no new conventional super-giant oil fields have been discovered in recent decades, there has been great discussion about 'Saudi sized' oil reserves in North America in the form of non-conventional oils, specifically in Canada's tar sands[9] and oil shales in the U.S.

The difference between 'conventional' and 'non-conventional' oil is important, however, because non-conventional oil is much harder to get out of the ground and often requires the consumption of large amounts of either water, natural gas, or electricity to extract crude from either sand or stones.[10]

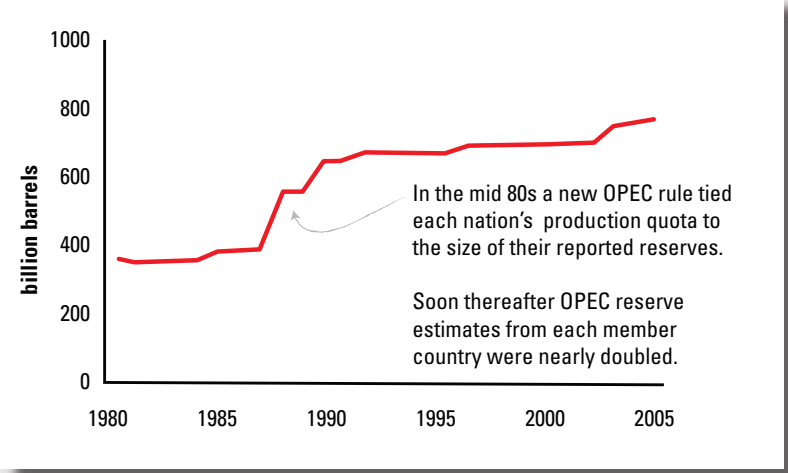
Because of these potential limits to the production of non-conventional oil, it is important to distinguish between the size of 'reserves' – which are often quoted in articles and editorials as being 'Saudi sized' – and the actual potential flows of oil which are significantly smaller than the giant reserve numbers might suggest.

Peak Oil: What We Know is Uncertain

The potential scope of a peak oil driven energy shock has been widely debated and opinions run the gamut from 'nothing to worry about' to 'we are facing the collapse of the globalized economy'.

Figure 3

Reported OPEC Oil Reserves: Paper Barrels?
World oil data is often of poor quality or susceptible to political manipulation



Source: US EIA. 2006 International Energy Outlook

Depending on what assumptions you make, and whose data you trust, you could potentially arrive at either conclusion, though, as is usually the case, the truth probably lies somewhere in the middle.

Much of the uncertainty surrounding peak oil stems from the fact that much of the data available is either of poor quality or has been deliberately manipulated. OPEC oil reserves, for instance, were almost instantly doubled in the 80s after a new rule was implemented that tied each country's quota to the size of their published reserves (see Figure 3).

Given the suspect nature of this reserves jump,[11] many early peak proponents believe that actual OPEC reserves might be substantially smaller than the numbers quoted by many mainstream energy groups and energy reporters.

In the realm of future projections, and dates for global peak oil, the opinions vary widely as well. On one hand there are early peak proponents – such as those from ASPO[12] – who are predicting a near term peak followed by a rapid decline. On the other hand there are those who believe peaking will happen later as part of a long sustained plateau.

An evolving consensus among the former group (a position reinforced by peer reviewed academic studies,[13] near term 'mega-projects' forecasts,[14 15] recent world events, and cautionary statements from the International Energy Agency[16]) is for a peak or plateau running from 2005 to around 2012, and followed by a later peak in global natural gas production.

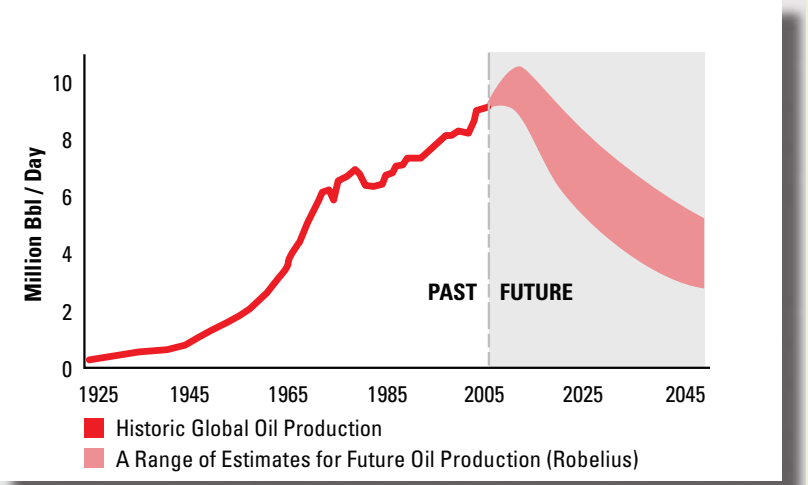
Figure 4 shows the results of a peer-reviewed analysis of the world's super giant oil fields.[17] From this study, the predicted date for peak oil ranges between ~ 2008 and ~ 2018, with rapid declines occurring post peak.

While there are still some economic and industry groups who dispute this type of near term projection, we are still in a position of needing to incorporate the potentially profound impacts of peak oil driven energy scarcity, and climate change driven policy, into the models used to plan our cities and regions.

To do this, in the most responsible way possible, we need to move beyond the linear planning approach that has guided past development, and instead talk about different scenarios for the future.

Figure 4

Peering Ahead: Global Peak Oil Scenarios
A Peer-Reviewed Analysis by Fredrik Robelius, University of Uppsala



Scenarios: Exploring Plausible Futures

Those cities which are affected by simultaneous energy and climate crises could plausibly experience a 'major shock transition' defined by several decades of severe economic turbulence, widespread migration and immigration, government rationing programs, and food and housing shocks which put vulnerable populations at risk.

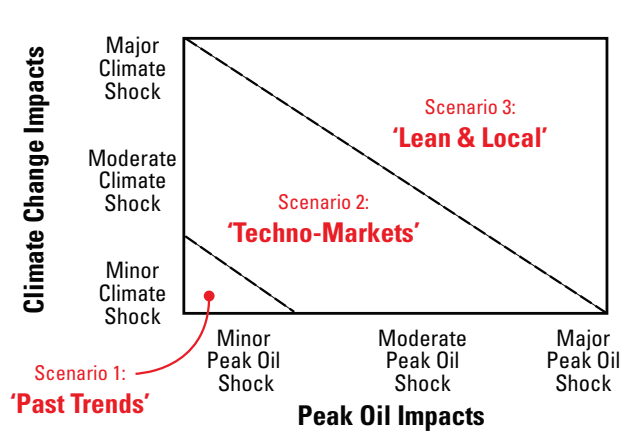
By contrast, if oil depletion and climate impacts are less severe, then a proactive region might undergo a largely market-driven, and relatively 'high tech' transition away from carbon intensive fuels.

These two scenarios, named 'Lean and Local' and 'Techno-Markets' respectively are contrasted with the 'Past Trends' scenario which embodies many of the assumptions still used by most planning agencies today.

Figure 5 shows a diagram which maps out these three scenarios as defined by the combined impacts of peak oil and climate change. Potential climate shocks range from minor (e.g. warmer weather) to major (e.g. massive sea level rise). Potential peak oil shocks range from minor (e.g. rising prices) to major (e.g. the collapse of globalized trade).

Figure 5

Peak Oil + Climate Change: Combined Impacts & Scenarios
Defining three plausible scenarios encompassing the individual and combined impacts of peak oil and climate change



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The key distinction between 'Techno-Markets' and 'Lean and Local' is the breakdown of the globalized economy (from peak oil, climate change, or other factors) which limits the uptake of new green technologies, and shifts the emphasis from global markets to government and local community action.

For a narrative outline of the 'Techno-Markets' and 'Lean and Local' scenarios (see Figure 6).

Scenarios: Gaming the Future

With these three narrative scenarios in place it becomes possible to create relatively transparent numerical models – using bundles of assumptions from each scenario – to 'game' future potential impacts on planning metrics like transportation demand.

In the past, planning agencies have predicted future demand for highways and other major infrastructure investments by extrapolating past growth trends into the future. While this "predict and provide" approach may have made sense in the past, it does a very poor job of accounting for a future defined by the unfolding impacts of both peak oil and climate change.

An alternative approach, then, is to do a supply-based projection which – in the case of transportation demand forecasts – looks at the future availability of fuels in a future defined by fuel scarcity and carbon constraints.

This type of modeling starts with an oil depletion scenario[18] (tailored to a specific location like the U.S. or Canada) and then layers in bundles of assumptions about how quickly we can scale up various mitigation strategies.

In the case of the 'Techno-Markets' scenario the wedges for technological mitigation and adaptation strategies are relatively large (assuming that global trade and credit markets continue to support the uptake of new technologies).

By contrast, the 'Lean and Local' scenario assumes that technological mitigation and adaptation strategies are impeded by economic difficulties and that community based solutions, government infrastructure spending, and government rationing programs play a larger role.

Modeling Future Transportation Demand

With a regionally specific depletion model[19] in hand we can begin to layer in the various mitigation strategies that will be implemented to address either peak oil or climate change.

The 'wedges' for these strategies (including alternative fuels, vehicle efficiency and electrification, among others) illustrate the speed with which each strategy or technology can be brought to market and scaled up.

The wedges are based on an amalgamation of various studies and forecasts, but are weighted by scenario. The wedge for vehicle efficiency, for instance, is much larger in the 'Techno Markets' scenario than in the 'Lean and Local', but both are based on an analysis of how quickly the fleet of vehicles can be turned over as newer, more efficient vehicles gradually replace older ones.

Figure 6

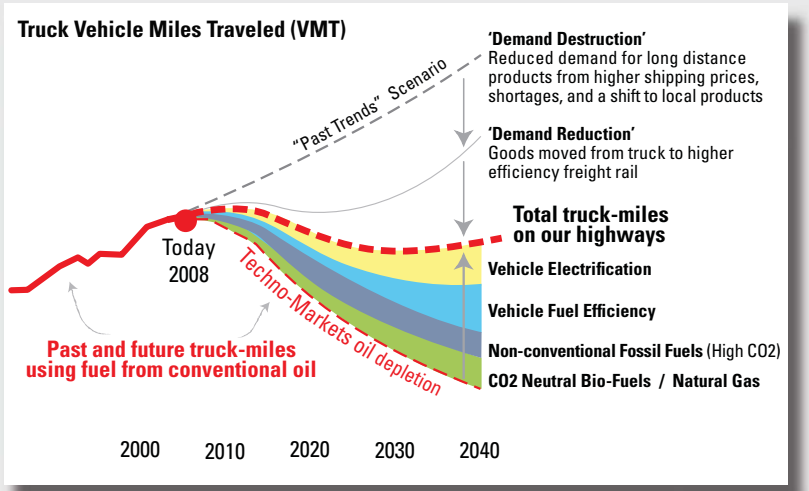
2 Scenarios for the Energy Transition (2000-2050)

	1 **"Techno-Markets"** A turbulent market driven transition	2 **"Lean and Local"** A transition driven by a combination of major shocks
Key Points	The market, after several years of turbulent transition, responds to energy shocks, carbon caps, and carbon pricing with new green technologies and jobs that scale up quickly.	Combined energy, economic, and climate shocks derail both the economy and local concern for climate change. Technological adaptation is limited by the stagnant global economy. Government rationing is common. Local and low tech community-based solutions predominate.
Narrative	Energy prices rise and fall, and rise again (like a roller coaster) leading to turbulent stock markets and inflation. Older industries are forced to shift to new 'green' models in response to higher prices and a growing market demand for energy efficient products and services. "Oil dependent" suburban real estate stagnates, while walkable communities with transit options see growing demand and appreciation. Highway and airport expansion projects are halted in favor of infrastructure repair projects and other capital projects that increase the 'energy productivity' of the regional economy. Green building standards are mandated for all new construction. Massive government and private sector programs assist with efficiency upgrades to older homes and buildings. Assistance programs help low income families and seniors to transition smoothly. Global markets quickly scale up new energy and environmental technologies. Cap and trade systems regulate large emitters of CO_2. Carbon taxes are widely enacted, but in the short term have a relatively small impact when compared to the price impact from peak oil. Communities that invested heavily in transit, density, and efficient buildings transition smoothly to an emerging post-carbon economy.	Cities with oil dependent economies lose business and population to regions with more resilient economies and reliable water supplies. Governments enact energy, food and housing rationing systems (which stay in place more than a decade). Populations fluctuate wildly as migrants and immigrants seek refuge from places made un-inhabitable by the changing climate, changing economy, and chronic energy shortages. Some communities and suburban housing tracts are abandoned while others re-form around new, primarily local, economies. Farming communities absorb migrant workers, while urban centres pack more people into their existing housing stock. For a decade, many North American cities see the re-emergence of shantytowns and other informal settlements. Low-tech and improvised solutions predominate over high tech ones. For several decades, local economic concerns trump global climate concerns, even with the disappearance of arctic sea ice and rising sea levels. After decades of turbulent transition, new land use patterns, transport systems, and low carbon energy systems re-emerge which support much lower energy and carbon use per capita. As a result, the global economy eventually stabilizes and returns to the task of adapting to the ever-changing climate.

Figure 7 illustrates a 'Techno-Markets' transition for freight trucking. In this case the depletion model is used to capture the future decline of available diesel fuel while the wedges show bio-fuels, non-conventional oil and natural gas, efficiency, and electrification all scaling up.

Figure 7

How many freight trucks will be driving in the future?
A scenario using the 'Techno-Markets' oil depletion model and technology 'wedges'



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1. Cars aren't the biggest challenge

Unlike trucks and planes, personal cars could easily see dramatic gains in fuel efficiency.

Our logistics chains and 'just in time' delivery systems, by contrast, have a much smaller potential for increased efficiency (a relatively small 'wedge').

2. Peak Roads

Under this scenario, truck VMT peaks around 2010 and declines until 2030, implying that there already exists, today, as much road capacity for freight as will be required for the next 30+ years.

3. Peak Local (~2025)

Given the lengthy time required to scale-up infrastructure responses like rail freight and electrification, under this scenario the period of 2015-2030 is defined by periodic shortages of globalized products and an increasing demand for local products.

The model shown here is a snapshot of one bundle of assumptions. In the case of California, legislation such as AB 32 might limit the extent to which fuels from 'non-conventional' sources like coal, tar sands, or shale might be scaled up – while legislation such as Proposition 10 might weight the natural gas wedge relative to electrification or rail freight.

Using this type of modeling, the *Dynamic Cities Project*[20] has run scenarios for trucks, personal cars and airplanes. Unsurprisingly, air travel suffers serious declines across most scenarios, with per-capita air travel down ~30% by 2020 even in the 'Techno-Markets' context.

Truck travel sees similar declines, whereas, demand for personal cars in the 'Techno-Markets' scenario is potentially much more resilient. The significant difference between trucks and personal car travel arises because there is tremendous room for efficiency gains with cars (even using current technology) and the fleet of cars can turn over much more quickly than the truck or airplane fleet.

Scenarios: Comparing Plausible Futures

There is an adage that says 'when you realize you are in a hole, the first priority is to stop digging'. From a policy and planning point of view, we need to take the same approach and, as a first priority, look at the areas where we are investing millions into projects that might become stranded assets.

While the scenarios described here are layered with assumptions, and quickly become complex, they ultimately are used to answer two straight-forward questions:

1. "Is our investment [in new highway capacity] the best way to invest millions of dollars, or could that investment become a stranded asset?"

2. "Is there a better investment which would retain its value in every scenario? (While reducing both emissions and the oil dependence of the regional economy)"

In the case of truck vehicle-miles-traveled (VMT) we can look at three scenarios for the future road space required for trucks in 2020:

- Under a **'Past Trends'** scenario truck travel is predicted to rise by as much as 50% (a number suggested by extrapolating the growth from 1980-2005).
- By contrast, a **'Techno-Markets'** scenario, which accounts for peak oil and climate impacts coupled with a strong market and technology response, predicts a 10% decline in truck VMT by 2020.
- A **'Lean and Local'** scenario – resulting from combined energy, economic, and climate shocks – results in an even steeper 30% decline by 2020.

Scenarios: Are We Nearing 'Peak Roads'?

In the two scenarios which account for peak oil and climate impacts, truck VMT peaks in the near future, and then declines for several decades (as high cost diesel fuel, carbon caps, and a more local economy reverses the globalization trend of the past 30 years[21]).

In these scenarios, which contrast sharply with the 'Past Trends' predictions, we have as much road capacity today as we will ever need, or be able to use (i.e. 'peak roads'). This implies that there is a good chance that new highway (or airport) expansion projects risk becoming 'stranded assets.'[22]

By contrast, investments that increase the energy productivity of the workforce and economy could simultaneously address climate change and the economic strength of the region.

Energy Transition and the Post-Carbon Economy

Peak oil and climate change are driving an unprecedented global energy transition which will demand an unprecedented response from our cities and regions, and from the global economy.

Through the lens of peak oil, climate legislation can be seen not as an economic burden, but rather as a critical catalyst for making the Southern California economy more competitive, and the region's cities more healthy and prosperous. To do this, however, climate policy must have a stronger focus on strategies that reduce *both* emissions *and* oil dependence.

Likewise, oil depletion models need to become integral components of the region's infrastructure and economic development planning. Today's long term investments will serve us through the turbulent decades of the energy transition, and will serve our children in a post-oil future.

It is critical, then, that we begin to use scenarios as a tool for breaking away from 'extrapolated' planning, and as a way to bridge the uncertainty that defines both peak oil and climate change. We can use scenarios as a means to avoid sinking millions of dollars into potentially stranded assets, and to channel our efforts towards more resilient alternatives.

In most cases, these alternatives are fairly clear; an emphasis on passenger and freight rail, electrification of transport, transit and carpooling, local manufacturing and job creation, livable density in mixed use communities, preservation of high quality agricultural land, and new cleaner energy supplies.

These investments, which find the common ground between peak oil and climate change, will form the backbone of a new, post-carbon, economy that will create local jobs, protect the region's most vulnerable populations, and help us transition to a future we can be proud of.

About the Author

Bryn Davidson is a LEED accredited designer and sustainability consultant holding degrees in mechanical engineering (U.C. Berkeley) and architecture (U. British Columbia). He is the cofounder and executive director of the Dynamic Cities Project (DCP) and is a principal of Rao/Davidson Design and Planning (Rao/D Cityworks). Mr. Davidson has given numerous presentations on the global energy transition to public and professional groups, and recently presented a talk on scenario planning at the 2008 ASPO-USA world oil conference. In parallel with his research and outreach work through the DCP, Mr. Davidson designs low-energy green buildings, and works on projects that aim to have a "net positive" impact on their community's emissions and oil dependence.

Additional Information About the Dynamic Cities' Depletion Models

The Dynamic Cities Project (www.dynamiccities.org)

The Dynamic Cities Project was founded in 2005 as a non-profit think tank working to integrate the nexus of peak oil and climate change – "the global energy transition" – into the practice of urban and regional planning. Since then, the DCP's presentations and research have received enthusiastic reviews both locally and globally.

Dynamic Cities' Depletion Models

The Dynamic Cities Project has created two models (Figure 8) which aim to capture a high and low case for the amount of oil available to consumers and businesses in the U.S. and Canada.

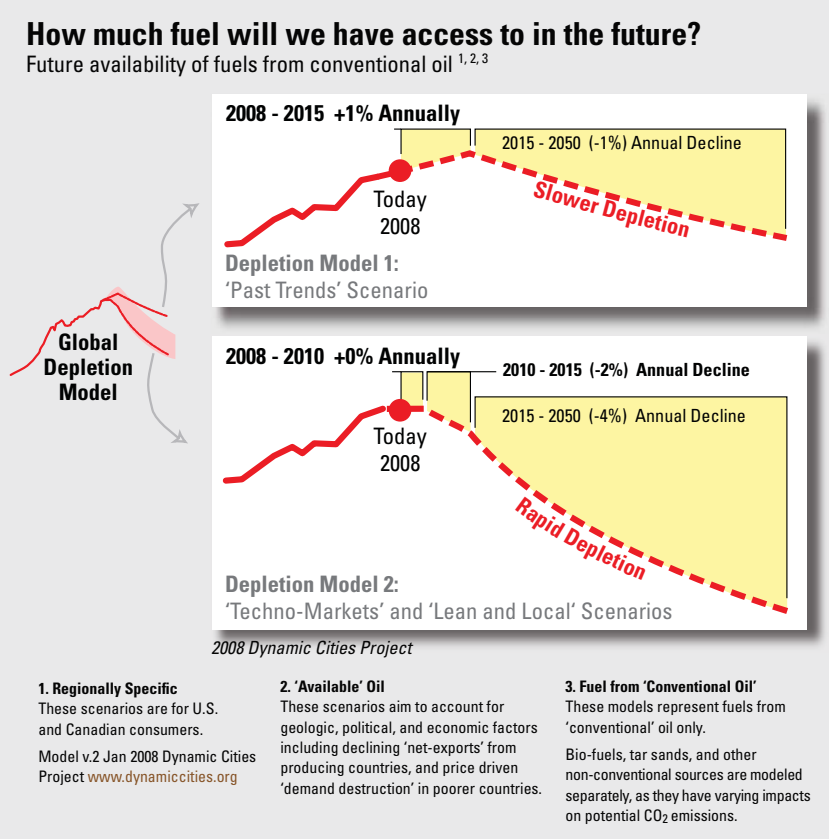
These models are derived in part from the peer reviewed global depletion study done by Fredrik Robelius at the University of Uppsala, but – like the narrative scenarios – they aim to incorporate the wide range of political, economic, and geological factors which will make the local experience of peak oil different from that of exporting countries (whose internal oil consumption is subsidized and will peak later) and poor countries (who cannot afford oil at today's prices).

Model #1 assumes that Saudi Arabia and other exporters have oil supplies on the higher end of the range of estimates, but that they (in particular the Saudis) limit their production so as to slow global depletion and preserve oil resources for their future generations.

Model #2 assumes that US imports of oil are flat to 2010, and then decline slowly to 2015 (as richer US consumers are able to out-purchase their competitors in poorer countries). Post 2015, with imports from Mexico and other countries in serious decline, the depletion rate accelerates to 4% a year.

Depletion model #1 is used as an input into the 'Past Trends' scenario as a test to see if any of today's current assumptions about future growth in transportation demand could still be true. Depletion model #2, by contrast, is used for both the 'Techno-Markets' and 'Lean & Local' scenarios.

Figure 8



Endnotes

1. For a graphical overview of peak oil, see the Dynamic Cities Project's presentation "Peak Oil: Navigating the Debate" http://dynamiccities.squarespace.com/peak-oil-navigating-the-debate/

2. "Last month...the Democratic-controlled Congress allowed the moratorium to lapse amid pressure from the White House, Republican lawmakers...who had come under attack for not doing more to bolster domestic energy supplies with gas prices topping $4 a gallon over the summer." Cynthia Dizikes, Los Angeles Times, November 13, 2008

3. "Canadian oil sands representatives have become regular visitors to [Sacramento]...The Alberta oilmen are there for damage control. Canadian producers are investing billions of dollars on new oil sands projects aimed at supplying oil primarily to the U.S. market, but which generate more greenhouse gases than other sources." Claudia Cattaneo, Financial Post, October 31, 2008

4. "Peaking of World Oil Production: Impacts, Mitigation, and Risk Management" Robert L. Hirsch, Roger Bezdek, Robert Wendling, Consultant study prepared for the U.S. Department of Energy, February 2005

5. "Crude Oil: Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production" GAO-07-283, February 28, 2007

6. "Pentagon and Peak Oil: A Military Literature Review" Sohbet Karbuz, Energy Bulletin, Jul 13 2006 http://www.energybulletin.net/node/18056

7. Mexico's super-giant Cantarell field, which peaked around 2005, has been declining rapidly, closely following the worst-case decline projections – even while Mexico's domestic oil consumption has increased. These opposing trends have led some forecasters at a recent conference on oil depletion to predict that by 2012 or 2013 Mexico may no longer be able to export oil.

8. For more on oil discovery challenges see "The End of Cheap Oil" Tim Appenzeller, National Geographic, June 2004

9. "The oil sands of northern Alberta are undergoing rapid growth. Nearly $100-billion will be spent in the coming decades to produce this resource which contains almost 175 billion barrels of oil— a reserve second only to Saudi Arabia's in size." Bruce March, National Post, November 12, 2008

10. It is much harder to scale-up production (the rate of extraction) of non-conventional oil when compared to conventional oil. In addition, because each barrel of non-conventional oil requires significantly more input energy to create it, there is a lower overall energy profit to society – a lower 'energy return on energy invested' or EROI. EROI limits, and production constraints make it difficult for any non-conventional oil or biofuel to be considered a 'scalable' substitute for conventional oil.

11. For further independent analysis of Saudi and OPEC oil data see "Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy" by Matthew Simmons

12. Association for the Study of Peak Oil and Gas (ASPO) Depletion Model, November 2008: http://www.aspo-ireland.org/contentFiles/newsletterPDFs/newsletter95_200811.pdf

13. Peer Reviewed Depletion Studies (ASPO – International website): http://www.peakoil.net/publications/peer-reviewed-articles

14. Mega-Projects Forecasts: "Prices holding steady, despite massive planned capacity additions" Chris Skrebowski, Petroleum Review, April 2006

15. Oil Mega-Projects Wiki: http://en.wikipedia.org/wiki/Oil_megaprojects

16. "IEA warns of new oil supply crunch" Carola Hoyos, Ed Crooks and Javier Blas, Financial Times, November 12, 2008

17. "Giant Oil Fields – The Highway to Oil: Giant Oil Fields and their Importance for Future Oil Production" Fredrik Robelius, University of Uppsala, March 2007

18. See more information (after About the Author) on the depletion models used in the transport demand scenarios

19. See more information (after About the Author) on the Dynamic Cities Project and the depletion models used for transportation demand scenarios (www.dynamiccities.org)

20. Ibid.

21. "While railroads generally were happy with their third quarter earnings for this year, trucking companies suffered the brunt of the nation's economic woes and high fuel prices." "Trucking Earnings Fall Below Railroads...." U.S. Rail News, November 13, 2008

22. "Several years and $61.4 million later, [Hagerstown, Md.] opened its... new 7,000 foot runway...two months after the airport lost scheduled air service altogether. Despite its costly investment...the airport has had no luck attracting a new carrier, as the industry struggles under soaring fuel prices." Micheline Maynard, New York Times, May 21, 2008