Scalability, Timing, and Alternatives

Comments to the San Francisco Peak Oil Task Force, 17 June 2008
David Fridley, Staff Scientist, Lawrence Berkeley National Laboratory

Thank you all for the opportunity to speak with you this afternoon. For today, I have prepared some short remarks to offer the group for consideration on the topic of the scalability, timing, and other issues that directly impact the prospects for alternatives to replace oil and other fossil fuels. As we move from plateau to decline in oil supply and oil prices continue to rise, there will be enormous pressures for us to commit considerable resources to alternatives development. None, of course, can replace oil, some will be feasible, others not, and some could perversely leave us worse off than we were before.

San Francisco is an integral part of a national and global energy market. California as a whole produces only 40% of the crude oil it consumes; only 16% of the natural gas it consumes, and from its own resources, only 29% of the electricity it consumes; it produces no coal and no uranium. Oil is imported from Alaska, Southeast Asia and Middle East, natural gas from the western US and Canada, and electricity from Arizona, Nevada, Oregon and Washington. As these markets tighten and competition for resources increase, prices will first go up, then absolute shortages may appear. This will affect every aspect of social and economic activity in the state.

The scramble for alternatives is on. In response to high oil prices, the main focus nationally has been put on alternative liquids such as corn ethanol and vegetable-oil biodiesel. Because concern over global warming has increased dramatically, solar, wind, tidal and other non-fossil energy have been offered as "green" alternatives for electricity production. The increasing negative impacts of corn ethanol production are being dismissed because "second generation" biofuels based on non-food sources are supposed to provide the solution to the problems caused by the original solution.

The public discussion over alternatives is often characterized by uninformed assertions, ignorance of basic science, a lack of appreciation of the magnitude of the problem, and the mistaken belief that adequate financial resources equates to adequate material resources. In evaluating the potential of any alternative, particularly liquid fuels, many factors come into play. The following are my thoughts on some key areas of consideration, a number of which are interrelated and overlap, reflecting the complexity of the energy system that we have created:

1. **Scalability and Timing**: For the promise of an alternative to be achieved, it must be supplied in the time frame needed, in the volume needed, at a reasonable cost. This factor is most often misunderstood in discussions of Canadian tar sands, which were described in last year's Chronicle as the fuel that will keep America's SUVs running. Production of tar sands is currently about 1 million b/d, compared to total global oil production of 86 million b/d, and reserves are estimated to be comparable to the conventional oil in the ground in Saudi Arabia. But how scalable is it? Tar sands production is mining and manufacturing, not the drilling of flowing oil. By Canada's own

estimate, production from tar sands may grow to 3.5 mmb/d by 2020, or 2.5 million b/d above today's level. That's 12 years from now. In contrast, global depletion of conventional oil is running at 3.5-4 mmb/d per year, which means we would need to find and produce 42-48 million b/d of new production just to remain flat. Tar sands, in this regard, are not scalable.

2. **Substitutability**. The question here is whether an alternative is a direct substitute, or whether it requires infrastructure changes to use it. This is particularly pronounced in discussions of the electrification of transportation, such as with electric vehicles. This would require extensive infrastructure changes, from retooling of factories to produce the vehicles, development of a large scale battery industry, development of recharging facilities (not everyone can recharge at home at night), deployment of instruments for the maintenance and repair of such vehicles, a spare parts industry, and likely, even more generation and transmission facilities to supply the additional electricity demand. Even ethanol today has proven to be a problematic substitute for gasoline: because it cannot be transported in our existing pipeline infrastructure, it requires expensive and small-scale truck or train transport, and new pipelines to carry ethanol would cost in the billions of dollars.

3. **Commercialization.** Is the alternative commercial today? People often see reports on laboratory breakthroughs or new technology development and assume that it will soon be ready for purchase or deployment. In reality, the average timeframe between laboratory demonstration of feasibility and full large-scale commercialization is 20 years. Processes need to be perfected and optimized, demonstration tests performed, pilot plants built and evaluated, environment impacts assessed, and so forth. The key message of the now-famous Hirsch Report, commissioned by DOE in 2006, was that we needed 20 years prior to peak to be able to mitigate the liquid shortages it will bring. This recognizes the very long timeframe of bringing new complex systems into being.

4. **Input Requirements.** Unlike what many people assume, the input to an alternative energy project is not money, it is material goods, and the type and volume of those goods may in turn limit the scalability and affect the cost and feasibility of the alternative. Currently, a lot of focus is on thin-film solar, for example, which though less efficient, is much cheaper than the conventional crystalline silicon panels. But a key material input to thin film solar is indium, which is in short supply, and known reserves equal to only 13 years of current consumption, much less dramatically increased consumption.

5. **Land and Water.** The denser an energy form is, the less land is needed for its deployment. Alternative energies do not match the density of fossil fuels, and thus large-scale deployment will incur considerable land costs. For example, a single 1 000 MW coal-fired power plant requires 1-4 km2 of land, though not counting the land required to mine and transport the coal. In contrast, 20-50 km2, or the size of a small city, would be required to generate the equivalent from a PV array or solar thermal generation. For wind, 50-150 km2 would be needed, and for biomass, 4000-6000 km2 of land would be needed (LA is 1200 km2). In California, water is our Achilles Heel, and many

alternatives require substantial water usage. Coal-to-liquids requires 8-11 gallons of water per gallon of output; corn ethanol requires 4-6 gallons; and cellulosic ethanol 11 gallons per gallon of output, not counting the water required to irrigate the feedstock during our summer dry period. All of our state's water resources have been allocated, so existing uses would have to be reallocated to develop a water-intensive alternative. The water problems, though, promises to only intensify with global warming as our winter snow pack fades.

6. **Intermittency.** Our energy system operates 24/7/365 and our system has been built on this expectation. Some alternatives, particularly wind and solar power, produce only intermittently as the wind blows or the sun shines. To achieve large-scale deployment of either of these resources, we will need to find a way to store solar and wind energy efficiently for use when the sun isn't shining or the wind not blowing. We do not currently have a scalable solution to this problem.

7. **Maintenance**. Once an alternative energy facility is constructed and deployed, it has to be maintained. According to Simmons & Co., our current oil production, refining, and distribution system was largely built with corrodible steel that hasn't been maintained during the long period of low oil prices in the 1980s and 1990s, and it would require trillions of dollars to rebuild and millions of tonnes of steel. The same is true with wind mills, solar thermal, solar PV, geothermal, tidal or any other energy project—all require on-going maintenance requiring both fuel and materiels. Our current infrastructure, though, was largely built and maintained with $0.50/gal diesel fuel. Can we rebuild it and maintain it with $10/gal diesel fuel?

8. **The Law of Receding Horizons**. In the last 30 years, shale oil has been promised to be economic first at $2/bbl oil when oil was $1.50/bbl, then at $20/bbl when oil was $10/bbl. Then at $30/bbl when oil was $20/bbl, and most recently, at $90/bbl when oil was at $80/bbl. The reason the breakeven point has kept rising is because shale oil is extremely energy-intensive, and as energy prices rose, the inputs costs rose as well. Many alternative energy technologies are energy-intensive and face the same dynamic step-up in costs as oil and other energy prices rise. Financial and economic accounting is usually the culprit; it is preferable to consider the material and energy inputs to an alternative to better gauge its feasibility.

9. **Energy Return on Investment**. The complexity of our economy and society is a function of the amount of net energy we have available. What that means is that the energy used to produce energy is unavailable to society—it is only the energy left over after we subtract the energy we used to produce energy that allows us to have industry, transport, housing, agriculture, and everything else in the economy. Oil today still provides us 29 units of net energy for every unit we invest; coal provides 40-60 units for every unit we invest. In contrast, corn ethanol provides 0.2 units; biodiesel less than 1 unit, tar sands 1-2 units, and wind 10-20 units. As net energy declines, the complexity of the system must decline as well. Economically, that means less specialization and fewer

non-energy producing jobs (energy including food). This is a physical and ecological principal that is not subject to policy manipulation—all we can do is prepare for it.

There are a range of other issues to consider, but I hope these summary comments are useful. Having spent years considering the impact of peak oil and looking at this various issues regarding alternatives, I have come to just one conclusion, and that is that our energy consumption must decline, either deliberately, or it will be forced upon us. This is not a conscious choice for any living species aside from mankind, and even then, it may be not a possible conscious choice.