MACROECONOMIC EFFECTS OF THE ENERGY TRANSITION: A Dynamic Policy Analysis

John P. Sterman
System Dynamics Group
Alfred P. Sloan School of Management
Massachusetts Institute of Technology

The United States is currently undergoing a transition from nonrenewable energy sources to "unconventional" energy sources. Since 1973 there has been growing awareness that the transition away from nonrenewable fuels will take longer and be more difficult than anticipated. As oil imports grew, so did concern over the economic repercussions of the energy transition.

A common view among energy analysts in industry, academia, and government is that the transition from depletable oil and gas to unconventional energy sources will be accomplished when the price of conventional energy exceeds the cost of producing the unconventional sources. On this view, since unconventional sources such as shale oil, coal synthetics, nuclear power, and solar energy are either not depletable or draw on very large resource bases, the real costs of these technologies should remain fairly constant while depletion of conventional oil and gas will soon drive their marginal costs above those of the synfuels. Investment in unconventional energy will then supplant investment in conventional energy, placing a cap or backstop on energy prices.

The history of the unconventional sources, however, shows that far from remaining constant, the real costs of these technologies have been rising, often faster than the price of the OPEC oil they are intended to replace!

This paper explores the following questions:

1. What are the economic consequences of escalations in unconventional energy costs in terms of

   - economic growth
   - inflation
   - real energy prices
   - energy production, consumption, and imports

2. To what extent are escalations internally generated by interactions between the energy sector and the rest of the economy?

A large model of the national economy and its coupling with the energy sector is the vehicle for the analysis. Growing out of the National Model project at the MIT System Dynamics Group, the model provides a fully dynamic, behavioral theory of energy-economy interactions. The model consists of four production sectors (consumer goods, capital plant and equipment, conventional [depletable] energy, and unconventional energy), and household, financial, government, and OPEC sectors. The model endogenously generates the major energy and economic aggregates including GNP, consumption, investment, real and nominal wages and prices, the rate of inflation, interest rates, and energy production, consumption, imports, and prices. The model also incorporates realistic representations of various policy initiatives such as price controls, tax credits, and subsidies for energy production.

Simulation results (see figures) show that depletion and the transition to unconventional energy can cause a significant intermediate term reduction in economic activity, employment, and the standard of living. One of the major causes of the large impacts is a large overshoot of real energy prices above the long run equilibrium value. The overshoot is primarily caused by escalation in the price of unconventional energy, causing continued dependence on nonrenewable conventional fuels and delaying the transition.

The escalation in unconventional energy prices is caused by several factors:

1. Unconventional energy is very energy intensive. As depletion raises the price of conventional energy, production costs for unconventional rise to the extent unconventional depends on energy, creating a positive feedback loop of higher prices, escalation, continued reliance on and depletion of conventional osurces, and higher prices. The positive feedback loop is reinforced by other indirect effects: unonvetnional energy is capital intensive; as energy prices rise, capital prices rise and boost unconventional costs further; capital production depends on capital, adding a third positive loop.

2. Unconventional energy has long lead times, leading to shortages of capital and the use of labor (at sharply diminishing returns) to help meet demand.

3. The unconventional industry faces rapid growth in demand as conventional energy prices rise. To attract workers fast enough, wages in the unconventional industry are bid up above the national average, further raising costs. Materials bottlenecks would also raise costs.

4. Long lead times, capital intensive production, and rapid demand growth lead to chronic cash flow problems, higher than normal bankruptcies, and higher risk. High risk reduces the external financing available to unconventional industries and raises the cost of capital, further boosting costs.

These forces reinforce each other and lead to escalations in excess of 20%, even when the potential for substituting other inputs for energy is high.

Tests of the model explore the sensitivity of the escalation and economic effects to the potential for substituting labor and capital for energy, the potential for retrofits to the energy requirements of existing capital, the cost of unconventional energy, and the energy and capital intensity of unconventional energy.

Retrofits, shorter lead time unconventional energy facilities, and reductions in the energy and capital intensity of unconventional energy appear to be high leverage points for reducing the escalation and mitigating the macroeconomic effects of the energy transition.