THE EFFECT OF GOVERNMENT POLICY ON ALTERNATE ENERGY TECHNOLOGY MARKET PENETRATION

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ABSTRACT

Federal support for alternate energy technologies has gone through a boom/bust cycle during the Carter and Reagan administrations. To investigate the effects of these policies, I use a system dynamics model of the industrial market penetration of parabolic troughs as a case study. The Reagan policy, a laissez-faire policy, lets free-market forces determine the market penetration. The Carter policy, an active government policy, combines research, development and demonstration with information dissemination and market financial incentives. The optimal policy depends upon future energy prices. If the price of conventional energy remains low, parabolic troughs never become competitive even with significant government support and thus the laissez-faire policy reduces federal expenditures by ~ $60 million with no negative effects. If the price of unconventional energy increases significantly, however, free-market forces do not develop parabolic troughs into a practical energy source without the benefit of an active government program. If this case study is generalizable to other alternate energy technologies, an active government role in alternate energy technology development should be thought as an insurance policy. How much is it worth to the U.S. today to insure future energy price stability?

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Federal support for alternate energy technologies has gone through a boom/bust cycle during the Carter and Reagan administrations. President Carter believed the energy crisis was the moral equivalent of war and spared no expense to develop technologies and markets for them. President Reagan believes that federal support for potentially commercial alternate energy technologies is an anathema to his economic philosophy. This analysis uses a system dynamics model to investigate the implications of each policy.

I use a case study of the industrial market penetration of parabolic troughs to analyze alternative roles for the federal government. Parabolic troughs are typical of many alternate energy technologies. Even using the most optimistic assumptions, parabolic troughs are not a panecea for U.S. energy problems, but they do have the potential for providing ~ 5% of all U.S. energy needs. Currently, parabolic troughs are also a relatively expensive and unproven technology as are other alternate energy sources. Parabolic troughs are, however, probably closer to being commercially competitive than most alternate energy sources, particularly for producing mid-temperature (200-600^{o}F) industrial process heat.

Two policies are tested. The laissez-faire policy withdraws all federal support for the parabolic trough technology during 1982 and lets free-market forces determine the market penetration. The active, government policy combines research, development and demonstration with information dissemination and market financial incentives.

MODEL STRUCTURE

The model consists of 5 interacting sectors, Figure 1: 1) the parabolic trough manufacturers, 2) the industrial energy consumers, 3) the federal government, 4) the market, and 5) the physical state of the parabolic trough technology.

The state-of-the-technology (efficiency, reliability and durability) provides the physical basis for determining the relative attractiveness of parabolic troughs. The manufacturers, consumers, and government are competing interests in the market. Simplistically, the manufacturers want to make a profit and stay in business; the consumers want reliable and inexpensive energy; and the government wants economic stability and military security. These constituency issues modify the physically based relative attractiveness of the technology. The ultimate market penetration time path is determined by whether each constituency's goals can be sufficiently satisfied. The balancing of these goals occurs in the market place where price per million btus is adjusted to clear either an undesired backlog of orders or an

undesired inventory. The producers and consumers goals conflict as price change reduces the producers desire to produce or the consumers desire to consume. Only government can intervene and increase the satisfaction of both consumer and producer. For the successful new technology, these forces result in a relatively predictable pattern of market penetration that can be divided into 3 distinct phases: pre-takeoff, takeoff and market saturation. Each phase is dominated by unique factors and each phase responds uniquely to government intervention.

THREE PHASES OF MARKET PENETRATION

The factors that dominate the pre-takeoff phase of parabolic trough market penetration are illustrated in Figure 2. Beginning in the lower right hand corner, government technology development improves the efficiency, availability, and durability of the technology. These physical characteristics combine to form the actual operating experience. A comparison of the actual operating experience to the expected determines the degree of customer satisfaction. As experience increases, the expectations are driven to reality, but in a rapidly developing technology this process takes time to occur. The actual experience relative to the expected experience is important because the consumer has based his decision to buy the technology on expectations. If expectations are not met then that disappointment is voiced. loudly.

The degree of customer satisfaction and the number of installations integrate to form an accumulated quality of experience.

The accumulated quality of experience has two effects on the parabolic trough order rate. First, accumulated experience, good or bad, increases or decreases the available market. Second, those that do consider the technology will apply a risk premium to the desired internal rate of return until the consumers accumulate a significant amount of positive experience with the technology. The risk premium increases the perceived energy price.

Government orders, the perceived energy price, and the accumulated quality of experience determine the parabolic trough order rate. The order rate integrates to installed capacity, which integrates to form the parabolic trough operating experience and contributes to accumulating the quality of experience. The parabolic trough operating experience then contributes to improving the efficiency, availability, and durability of parabolic troughs and the loop is closed.

This network of relationships represents an unstable process. Assume that expected operation is better than the actual experience. The perceived energy price is based on producing more energy than is actually forthcoming. The experience is bad, so bad operating experience accumulates. The negative operating experience simultaneously reduces the number of interested industrial customers, and the customers that are interested apply a higher risk premium and attribute the technology with lower energy production. All forces drive the number of customers downward. With fewer customers, experience accumulates more slowly and this slows the improvement of the technology.

A second scenario assumes that expectations and actual experience are equal. Positive experience is accumulated because customers receive the expected performance. Perceived energy price decreases and orders increase. Increased orders accumulate more experience faster and further increase the technology's reputation and its actual operating characteristics.

The pre-takeoff phase of market penetration ceases when the expected and actual operating experiences are equal and the accumulated quality of experience is sufficient to eliminate the risk premium. At this point, the takeoff phase begins.

The factors that dominate the takeoff phase of parabolic trough market penetration are illustrated in Figure 3. At the end of the pre-takeoff phase parabolic trough energy prices are falling and the market is small but growing. As the energy price decreases, the order and production rates increase. Mass production and economies of scale at individual sites drive the manufacturing cost downward. Falling manufacturing costs allow the existing manufacturers to pursue two basic strategies. First, price can be held constant so that the manufacturers receive increasingly high profits relative to cost. This causes the market for parabolic troughs to stay relatively constant because price is constant, meanwhile the increasingly high profits attract new manufacturers. The new construction overbuilds the market compared to existing consumer demand, but each manufacturer knows that price can be lower and still profitable. So when production exceeds demand, prices fall. Falling prices create a new, larger market which absorbs the excess inventory and again leads to further reductions in manufacturing cost.

The second choice of the manufacturer is to hold profit constant and decrease price. This approach creates excess orders. When the order rate exceeds the production rate, price and profit increase. The combination of increased orders and an attractive profit bring higher production and falling costs.

Once this process begins, the production rate, manufacturing cost, and price spiral until market saturation effects begin to dominate.

At the end of the takeoff phase, further economies of scale and mass production are increasingly more difficult to achieve. The factors shown in Figure 4 become increasingly dominant. The parabolic trough energy price has fallen for many years now through the pre-takeoff and takeoff phases. As the capacity increases, the suitability of new sites decrease. The deeper the market penetration, the more unsuitable the remaining sites.

Remaining sites include both totally new sites and the expansion of existing ones. The factors that drive price upward are availability and price of land, the availability of direct insolation, and the falling utilization of solar-produced energy as the solar fraction at any individual site increases. Solar fraction is the ratio of the energy produced by solar to the total energy used at a site.

GOVERNMENT POLICIES

The laissez-faire policy stops ongoing research and development during 1982 and stops all other government involvement in 1980. In response, government orders decrease from 15,000 in 1981 to 1,000 in 1982 to zero in 1983; see Figure 5. When the government orders cease, manufacturers begin to halt production, but lag slightly behind the decreasing orders. Inventories increase, capacity utilization decreases, and initially price decreases. Price decreases because manufacturers are trying to encourage private sales and reduce inventories. The reduction in price stimulates a few private sales, but as utilization continues to fall the capital investment per unit increases the manufacturing cost. Manufacturers fight to keep prices low, even operating at a loss, but the extremely high capital expense per unit forces them to continue raising prices. This further discourages new orders and by 1987; there is very little manufacturing capacity left and no production. After 1987, price begins to decline because there is almost no production and manufacturers are eliminating inventories. The price after 1987 is not very meaningful because the industry has already collapsed.

The active government policy consists of 1) completing the research, development, and demonstration program in 1986 at a post Carter administration cost of $60 million, 2) providing increased information dissemination, and 3) implementing financial incentives--the energy tax credit and 5-year accelerated depreciation from 1980 to 2000 (see Figure 6).

From 1980 to 1985, the government dominates all aspects of the market. In 1982, utilization decreases to 25 percent when government orders decrease and manufacturing capacity declines as some manufacturers are unable to survive. In 1984 and 1985, the utilization increases to almost 60 percent because of the MISR large-scale experiments. The manufacturing capacity continues its decline because it still has excess capacity. The government places almost all orders for troughs until 1986.

The parabolic trough energy price per million Btus over this period increases in 1981 and 1982 and then declines sharply until 1987. In 1981 and 1982, the price increases because the perceptions and reality of the availability and durability of the product merge and the expectations are of better performance than actually occurs. The same experience that lowers expectations improves actual performance, so that by 1983 performance is exceeding expectations. When the government pulls out of the market in 1985, there is excess capacity and increasing inventories as manufacturers try to maintain stability in their companies. The price, not too far above the annualized fuel costs in some markets, decreases further in an effort to capture those markets. At the same time, there are some upward price pressures from increasing energy costs and decreasing mass production economies. The downward pressures far exceed the upward pressures, bringing the price from $50 per million Btus to $15 in 1987, when the solar price at the most favorable sites equals the annualized fuel cost.

From almost zero in 1985 and 1986, sales jump to between 25,000 and 40,000 square meters per year during the 1988 to 1991 period. The increased orders, which exceed the remaining manufacturing capacity, allow the manufacturers to increase price so that profits are within a normal range. Manufacturing capacity begins a rapid expansion and utilization is high. During this period, installed solar capacity increases 12 percent per year and new construction starts increased 85 percent per year.

The period 1990 through 1995 continues the boom of the late 1980s. Manufacturing capacity, collector orders, and production now double annually. Manufacturers project high growth rates and act on those projections, each time building larger and more efficient plants and producing a more inexpensive product that induces more customers to buy.

The marginal energy price falls below the annalized fuel cost for the last time in 1992 and the market begins to increase from relatively small regional southwestern markets to the rest of the country. The principal reason for the declining price is increasing cost reductions caused by increasing mass production economies. Profits are high enough for competition within the industry to be applying some downward price pressure as well.

During the period after 1995, the accumulated experience begins to reduce customer resistance to the new technology. The parabolic trough transition from new technology status to accepted status occurs quickly because of the tremendous growth rates during the period. After 1999, no sales are lost because of customer mistrust. At this time the direct government investment per barrel of oil displaced is less than $10 per barrel. After 2000, the technology competes in the free market with no further subsidies.

CONCLUSIONS

A comparison of the 2 policies indicates that the "optimal" policy depends upon future energy prices. If the price of conventional energy remains low (~ 50 percent real increase by 2000 and constant thereafter) parabolic troughs never become competitive even with significant government support and, thus, the laissez-faire policy reduces federal expenditures by $60 million with no negative effects. However, even if the price of conventional energy increases significantly (4% per year real increase), parabolic troughs do not develop into a practical alternative to fossil fuels. Without government support, the initial hurdles for breaking into the market are too high. The manufacturing cost is too high at low production rates for competitive pricing, and the market does not sustain high production rates even with competitive pricing until consumers have experienced reliable, durable, and economically competitive energy production. Generalizing, with high future energy prices, the alternate energy technologies do not become available when needed to keep energy prices from increasing further if the laissez-faire policy is used.

In contrast, a well-designed, active government policy that combines research, development and demonstration, information dissemination and market financial incentives can create the pressures necessary for parabolic troughs to successfully penetrate the industrial market. Figure 7 compares U.S. savings from displaced oil to the direct government expenditures and lost tax revenues of the active government policy.

Shortly after 2000, the <u>annual</u> savings from displaced oil is more than 20 times the <u>total</u> cost of direct and indirect subsidies. Thus, assuming moderate future energy price increases, the active government policy is extremely cost effective.

Because these policies must be implemented long before the need is apparently urgent, an active federal role in energy development can be thought of as an insurance policy. How much is it worth to the government today to insure that energy options are available for the future? If energy prices don't increase significantly, then the money will have been spent ineffectively; however, the U.S. economy will not be constrained by energy price or availability. If energy prices increase and if the federal programs are effectively managed, the supported technologies will be available to compete in the free-market when needed to hold energy price within bounds. This guarantee of future energy price stability, even if at relatively high price, may be crucial to future U.S. and world stability.

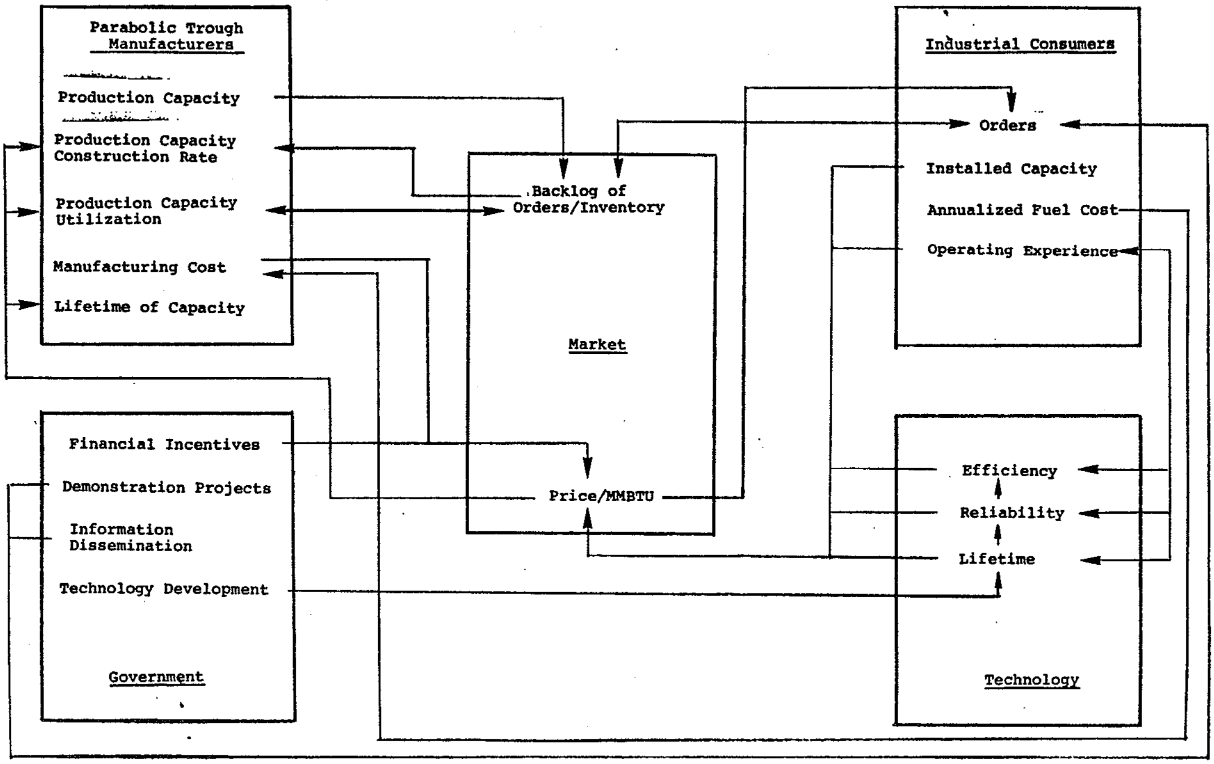

Figure 1. **Sector** Boundary Diagram for Parabolic Trough Industrial Market Penetration Model.

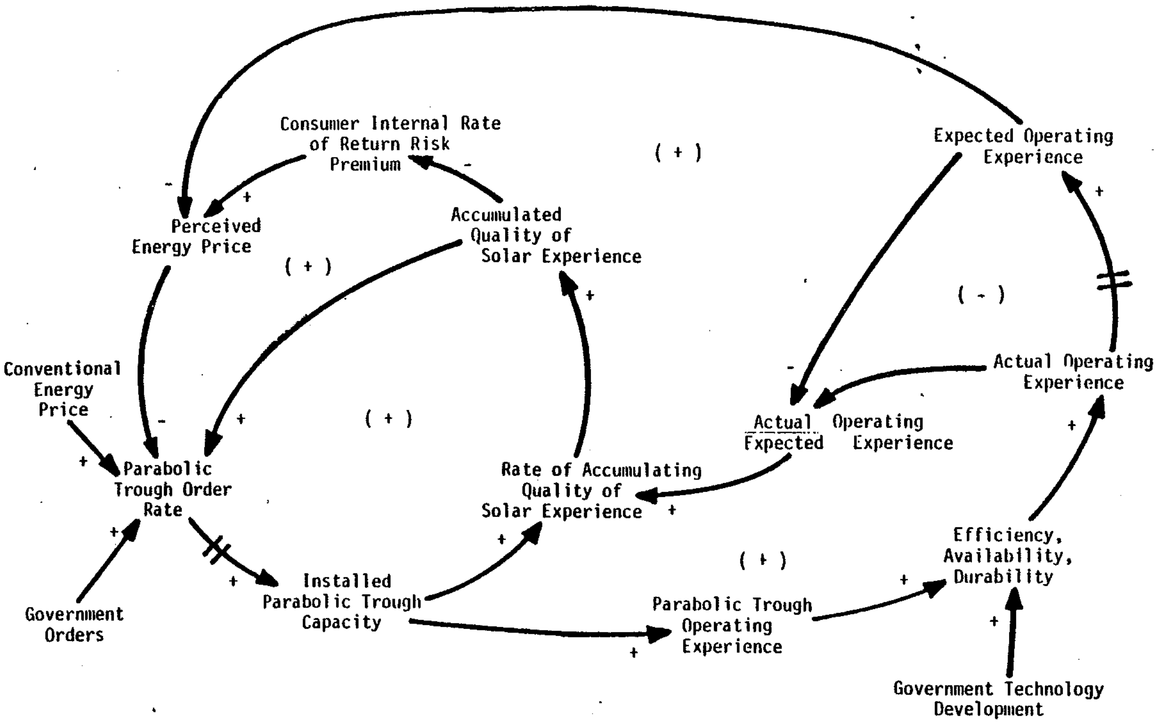

Figure 2. Casual Loop Diagram of Factors Dominating Pre-Takeoff Phase of Parabolic Trough Market Penetration.

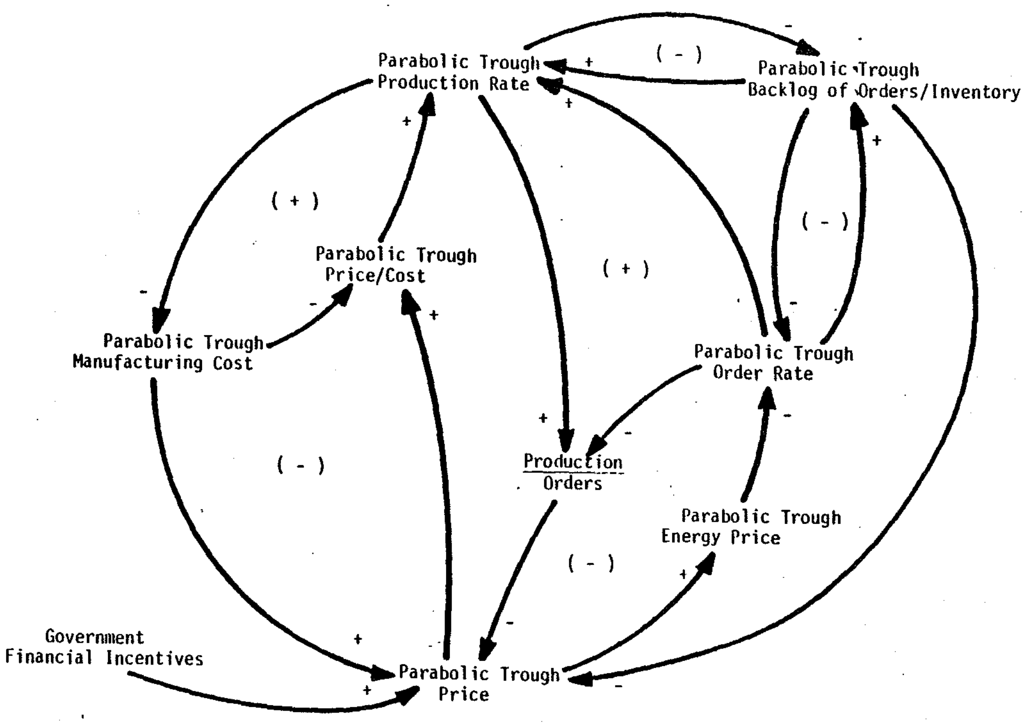

Figure 3. Causal Loop Diagram of Factors Dominating the Takeoff Phase of Parabolic Trough Market Penetration.

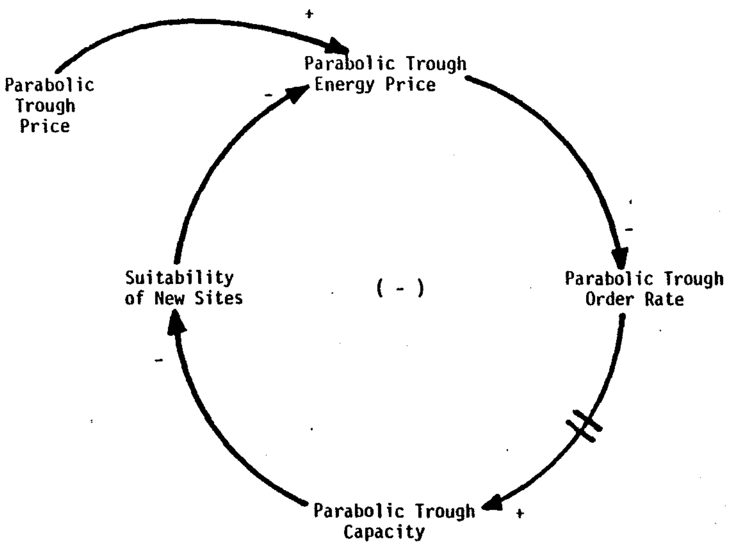

Figure 4. Causal Loop Diagram of Factors Dominating the Market Saturation Phase of Parabolic Trough Market Penetration.

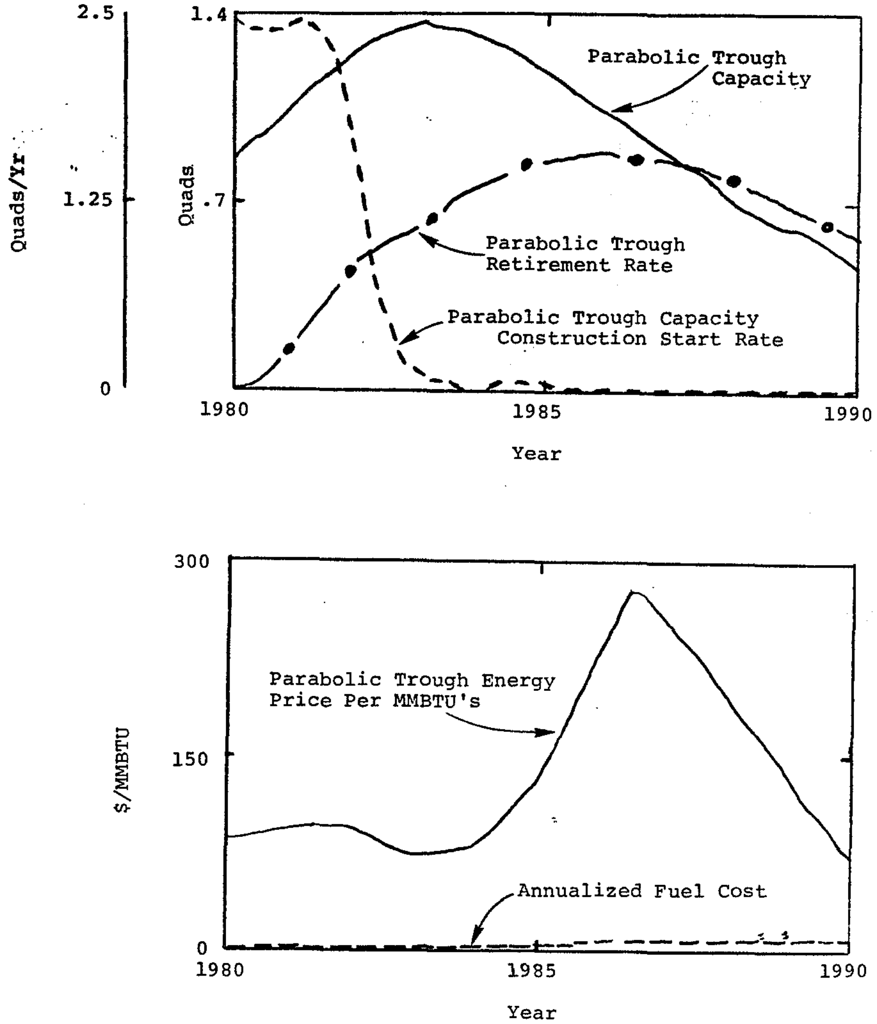

Figure 5. Laissez-Faire Policy

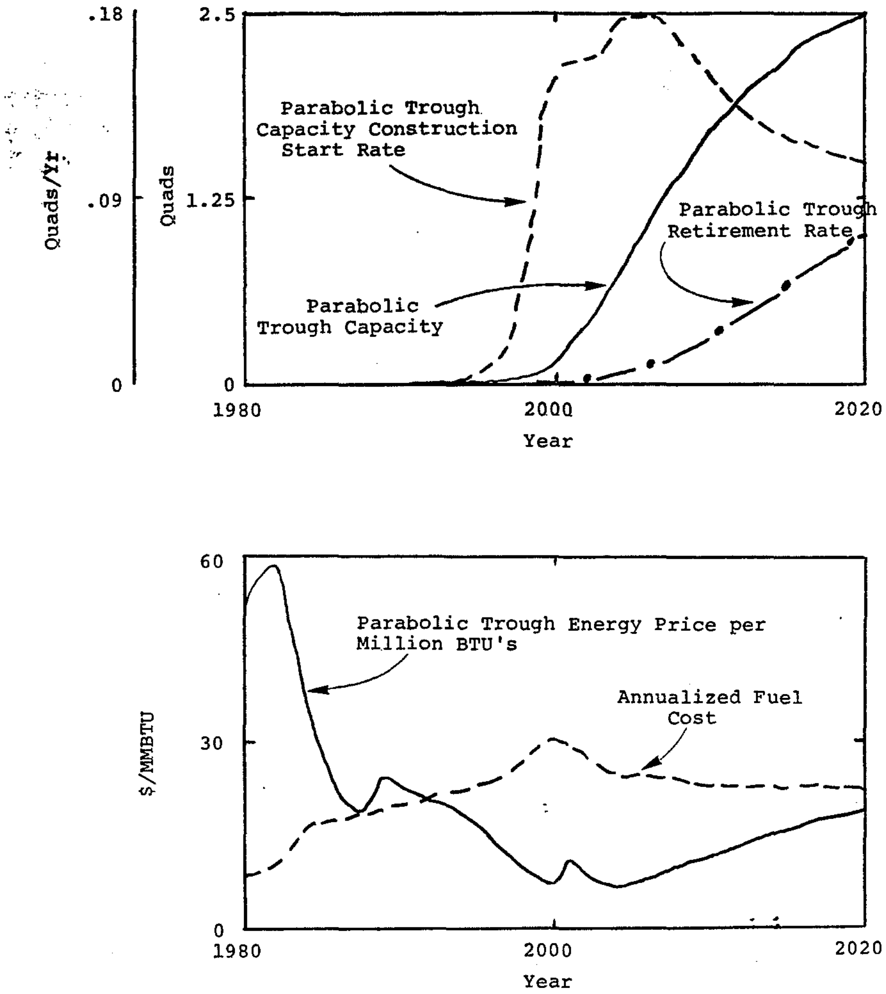

Figure 6. Active Government Policy

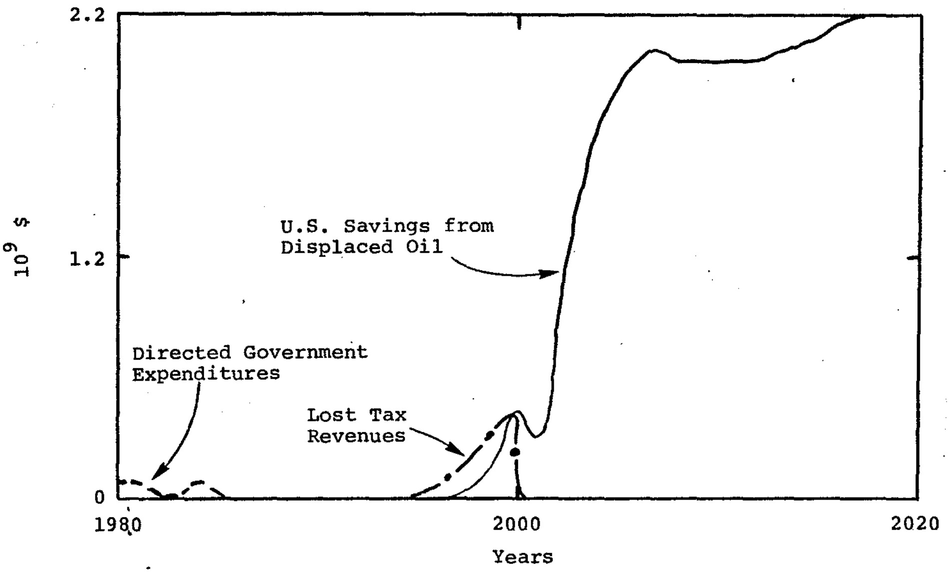

Figure 7. Annual Government Expenditures, Lost Tax Revenues and U.S. Savings from Displaced Oil for the Active Government Policy.