CHAPTER 16

Market Transformation to Sustainable Energy

If we had every technology we needed to solve our energy problem, the job still wouldn't be finished. Even the best technologies don't always make it to the marketplace, or if they get to market, they don't win out in competition with lesser technologies. The market itself must be conditioned, or transformed, from oil and carbon-based fuels to more sustainable renewable sources and efficient use. The preceding chapters presented lots of technical and economic information about sustainable energy systems, and large-scale and rapid market transformation will fundamentally require economically competitive sustainable energy technologies—the **techno-economic solutions.** But market transformation depends on more than technical and economic feasibility. It depends on people and institutions making choices to change patterns of energy use, the subject of this chapter.

Technological and market forces and consumer choice are critical to market transformation, and government policies have a dramatic influence on both. Government market transformation programs and policies can, for example, spur the development and cost-effectiveness of new technologies, provide incentives for investment in sustainable energy, mandate efficiency improvements, regulate environmental protection that affects the relative cost of energy, and provide education and information that affect consumer choice. We call these the **policy solutions.**

Our choices are surely driven by technical and economic feasibility and policy mandates and incentives, but they are also affected by other factors including uncertainty, availability of products and investment capital, and personal and societal values. These values are affected by non-economic factors such as environmental protection, security, personal identity, and intergenerational equity, and they can influence not only consumer choice but also social movements that can accelerate market transformation. These values, choices, and movements are called the **social solutions.**

This part of the book turns from the technology of sustainable energy to market transformation and its policy and social dimensions. Chapter 17 looks at national energy transformation policies in the United States and other countries. Chapter 18 focuses on innovative state and local energy policies and programs in the United States. Before investigating these specific policies, this chapter introduces the key factors in the process of market transformation, and the role of techno-economic, policy, and social solutions.

The first section reviews some fundamentals of market transformation, including the effects of technology and market forces, market failure, and non-economic factors. The following three sections look more closely at the techno-economic solutions of technology innovation and cost-effectiveness, the policy solutions of market intervention, and the social solutions of consumer values, choice, and social movements.

16.1 Some Fundamentals of Market Transformation

We know that our global and U.S. patterns of energy use are not sustainable, and we need to transition to more sustainable non-carbon energy and efficiency before climate change and oil depletion inhibit our future options. In this section, we explore some of the theories and practicalities of energy market transformation. First, we briefly present the conceptual difference between technical, economic, and market potentials for emerging energy systems and efficiency measures. We then look at failures of the market that prevent or slow market transformation, and finally summarize nonmarket and noneconomic factors that influence market transformation.

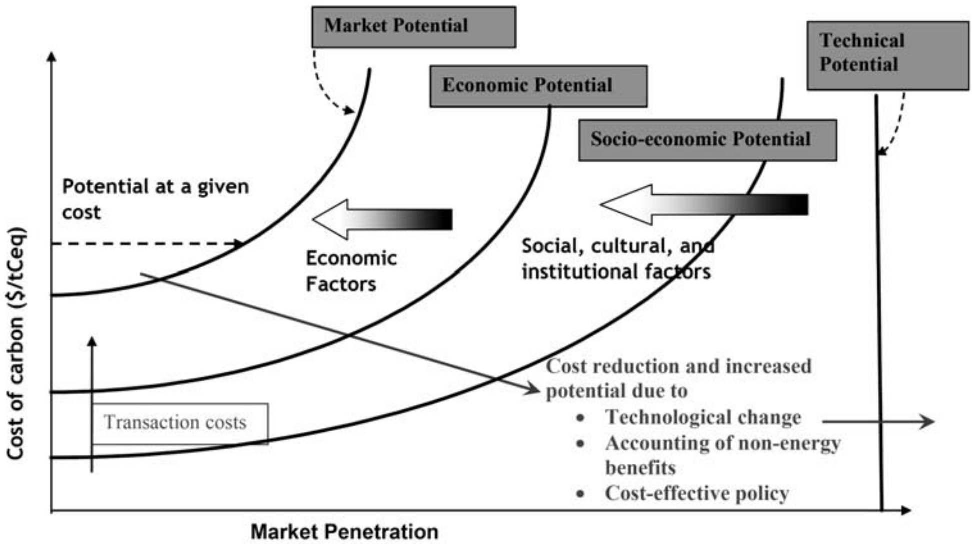
16.1.1 Distinguishing Technical, Socio-Cultural, Economic, and Market Potential

It is often said that the amount of solar energy falling on the Earth in one day is more than the energy in the entire world oil reserve. But obviously this ultimate potential is not available because of a variety of logistical, technological, and thermodynamic constraints. Even within these constraints there is a vast "technical potential" for renewable energy and efficiency. We would like to achieve this technical potential, but we know there are nontechnical economic, social, and institutional barriers that limit our ability to develop this potential to transform from a carbon to non-carbon energy economy. On the road to energy market transformation, it is important to identify these barriers.

Energy and economic analysts define "potential" in different ways. Here, we adopt the following definitions that are highlighted in Figure 16.1 from Sathaye, et al. (2004), that shows market penetration of an energy technology (e.g., compact fluorescent lamps or photovoltaic [PV] systems) on the horizontal axis and the cost of energy or emissions saved by that technology on the vertical axis. **Market penetration** is the portion of the consumer market served by a product or technology.

- **Technical potential** is constrained by technical limits. It is the maximum amount of market penetration of a technology or effect (e.g., energy savings, GHG emission reduction) achieved over time if all technically feasible technologies were used in all relevant applications without regard to their cost or user acceptability. Technical potential expands by technological advancement.

figure 16.1 **Distinguishing Technical and Market Potential**



Market potential is less than technical potential because of social and economic factors, including transaction costs, but technological change, accounting for nonenergy and noneconomic benefits, and government policy can reduce these barriers to market penetration.

Source: Sathaye, et al., 2004

- **Socio-cultural potential** is perhaps the most desirable level of market penetration from a societal point of view, because it assumes the elimination of market failures such as externalities (unpriced social costs) and transaction costs (consumer uncertainties and barriers). It is the maximum market penetration if all technologies were implemented that are cost-effective from a societal and cultural perspective, including noneconomic factors affecting consumer choice. Socio-cultural potential is constrained by limits imposed by social values and expands as cultural and consumer values for a technology change.
- **Economic potential** is the maximum amount of market penetration if all technologies are implemented that are economically cost-effective from consumers' point of view, assuming elimination of transaction costs. It is constrained not only by the technical and socio-cultural limits but also by economic limits including externalities. Economic potential expands as relative prices for a technology drop and shrinks as prices increase.
- **Market potential** is constrained by market limits including transaction costs. It is the amount of market penetration expected under forecast market conditions and consumer preference with no changes in policy. Market potential can expand as prices for this or competing technologies change and as policies regulate adoption and affect real prices and lower transaction costs.

So, reality falls short of technical potential because of consumer values (socio-cultural factors), externalities and false pricing (economic factors), and transaction costs (market factors). Public policy can affect all these barriers.

16.1.2 Market Failure: Transaction Costs and Externalities

One of the principal reasons that there is such a gap between market potential and socio-cultural potential is the failure of the free market to eliminate transaction costs of change and to internalize the externalities associated with all energy sources to level the economic playing field. Figure 16.1 shows that these market barriers (broad arrows pointed left) affect the levels of potential, and that transaction costs can drive up cost of energy saved. **Transaction costs** are the variety of barriers that confront consumers in making choices, thereby increasing the cost of those choices. They include poor and misinformation (e.g., consumers don't know about potential energy and cost savings), lack of access to capital (e.g., new choice requires investment and there is competition for precious cash), product unavailability, imperfect competition, and other hidden costs. Transaction costs are the main barrier between market and economic potentials. **Externalities** are external social costs such as pollution and GHG emissions that are not included in the cost of a technology such as coal-fired electricity. Externalities and consumer preference are the main barriers between economic and socio-cultural potentials.

The figure also shows that these barriers for renewable and efficient energy systems can be removed by cost reduction, technological advancement, government policies that reduce transaction and market costs and internalize externalities, and cultural values that consider nonenergy and noneconomic benefits and costs.

16.1.3 Noneconomic Factors and Market Transformation

Why do we buy the products we do? Cost of the product affects our ability to purchase it and which brand or model we choose ("the best deal"). We rarely compute the economic return of our purchases because the benefits (utility, convenience, entertainment, and pleasure) are hard to put in dollar terms, but we can easily recognize difference in quality or usefulness of consumer products. Generally, the choice to purchase renewable and efficient energy products and measures is somewhat different. These products provide the same basic functions or services as other conventional energy sources, and most consumers seek "the best deal" to provide these energy services.

So consumers often perceive that their "best deal" is the choice with the lowest initial cost. Well-informed, discriminating consumers of energy services will select the products and measures providing desired functions that have the *lowest life-cycle monetary costs*.

But there is more to consumer preference than simply monetary cost. Increasingly, even more discriminating consumers are selecting energy with the *lowest life-cycle sustainability costs*. Sometimes these latter choices will have greater monetary cost, but they meet the enlightened consumers' baseline of quality, and provide greater pleasure, as consumers know they are contributing to making society more sustainable.

For example, markets for "green" energy have developed for consumers willing to pay a bit more for environmentally friendly energy sources. These choices are made more rational by the improved means of life-cycle sustainability analysis, and certification systems like ISO 14000, LEED, and ENERGY STAR.

Kulakowski (1999) found that cost and payback alone do not determine energy investment decisions. In her study of institutional decisions to adopt energy-efficient technologies, she found that price and payback are very important and that higher initial costs of efficient technologies and artificially low energy prices (that do not internalize externalities) work against energy-efficient improvement. Transaction costs also impede adoption.

But she also found that *organizational structure, procedures, and culture* matter. Institutional culture and procedural rules influence availability of funds and decision making for investment in energy efficiency and new technology. And she found that *individual values and behavior* also matter. The personal values and commitment of individual consumers, institution or company leadership, and employees to the goals of energy efficiency and associated environmental benefits influence investment decisions. These values are examples of the social, cultural, and institutional factors shown in Figure 16.1 that define societal-economic-cultural potential.

However, price and monetary value still rule the roost. People face choices on how they invest their money. If we are to change our energy patterns on a large scale, renewable energy and efficiency must compete effectively against other investment choices. We discuss below the effect of price on market penetration and the importance of techno-economic solutions for market transformation.

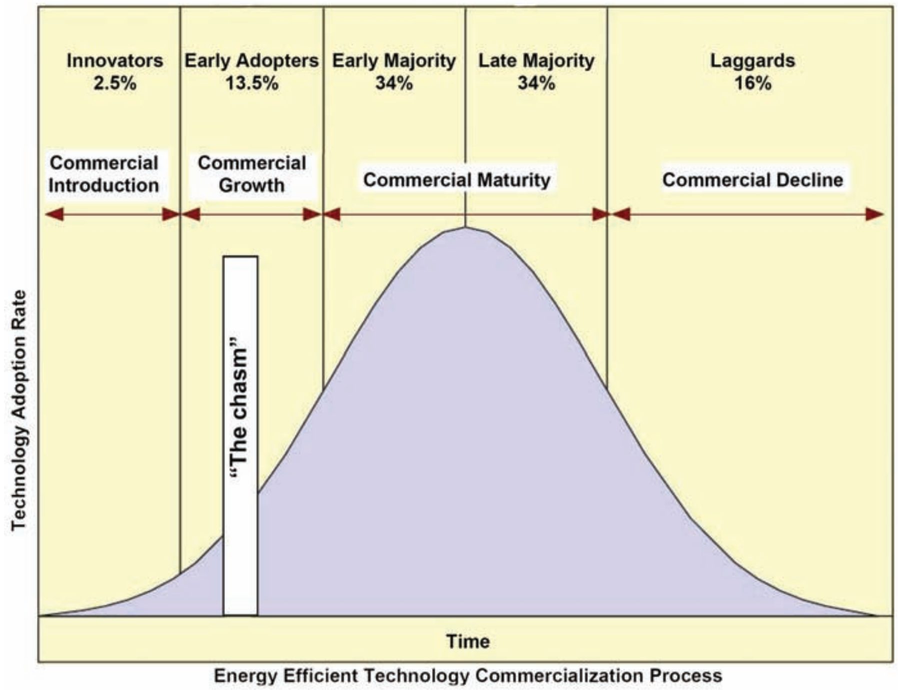
16.2 The Techno-Economic Solutions

16.2.1 Technological Change and Diffusion of Innovation

How does the market behave as new technologies such as efficient and renewable energy systems come into commercial use? The process of diffusion and adoption of technology is the subject of considerable research in economics and marketing, and it is generally characterized by Everett Rogers' bell curve of adoption of a product or technology (Figure 16.2). The process is initiated by "innovators," the first 2.5% of users who are the risk takers. These are followed by "early adopters" (13.5%) and the "early majority" (34%), after which adopters follow a "bandwagon" effect; the rate of adoption declines with the "late majority" (34%) and finally the last-to-adopt "laggards."

Figure 16.3 illustrates the diffusion process and market penetration for a variety of U.S. consumer products and activities in the years after they were introduced. Note the rapid increase in use of electronic equipment. The difficulty in market analysis is to predict market penetration. So we need to be able to predict similar curves for hybrid vehicles, LED lighting systems, residential PVs, and biofuels, and what factors will influence that penetration.

figure 16.2 Model of Adoption Diffusion of Energy Efficient Technologies



The technology adoption rate follows a bell-shaped curve from "innovators" and "early adopters" ultimately to "laggards." The difficult period in the process is overcoming "the chasm" in the early period of commercial growth.

Source: Jenkins, et al., 2004

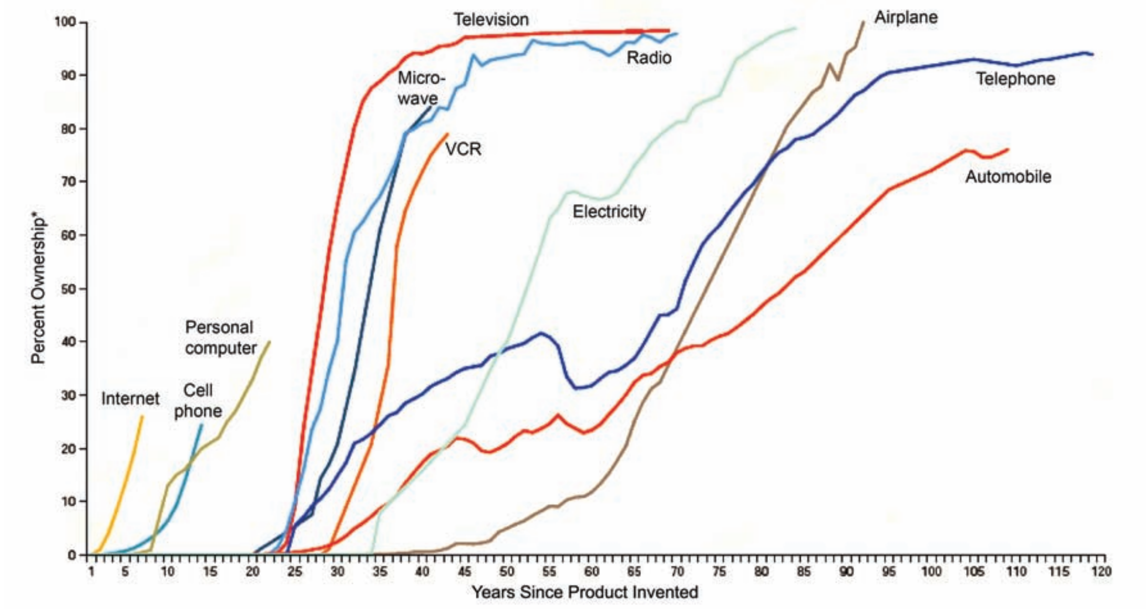
16.2.2 Market Penetration and Simple Payback

Recall that market penetration is the portion of the consumer market served by a certain product or technology. Many market penetration models are based on simple payback period (SPP). As we know from Chapter 5, SPP is the number of years an investment will take to pay for itself from its returned savings:

$$\text{Simple payback period} = \frac{\text{Initial \$ cost}}{\text{Annual \$ savings}} = \frac{\text{Intial \$ cost}}{\text{(Annual energy savings)(energy price)}}$$

SPP is often a good predictor of market penetration because it is an intuitive measure of "a good deal" and financial return. Because it is understandable, it's a good predictor of purchasing behavior across products when decisions are based on energy cost savings. Some models assume a maximum eight-year SPP as a prerequisite for market penetration (Institute for Sustainable Energy, 2004). The U.S. DOE National Energy Modeling System (NEMS), which is used to

figure 16.3 **Market Penetration of Selected Consumer Products in the United States (showing years after they were introduced)**



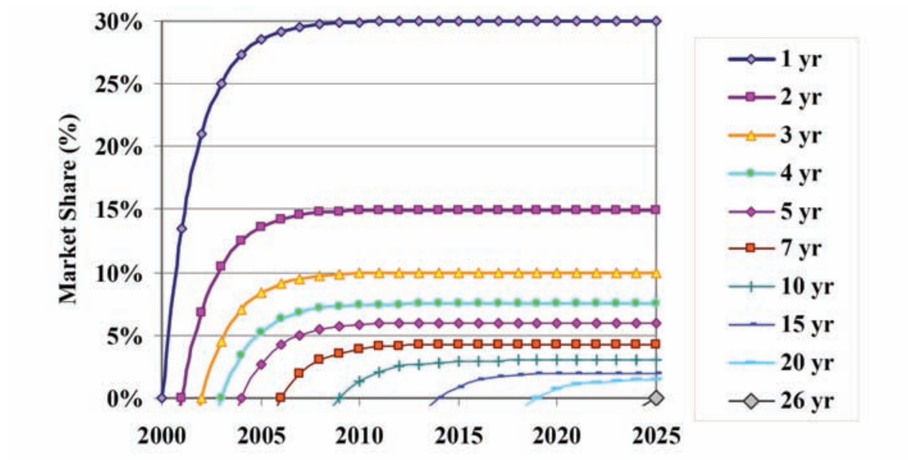
* Percent of households except airplanes (% relative to 1996), autos (% owned per adult > 16 yrs), cell phones (% phones owned per auto).
SOURCE: Federal Reserve Bank of Dallas, 1996 Annual Report

generate EIA's Annual Energy Outlook and other government projections, is more conservative and assumes market penetration into new construction based on SPPs given in Figure 16.4. This model has been used in several studies of distributed generation technologies in the building sector. The figure assumes that it takes some time for a new technology to "diffuse" into the market as adopters climb the learning curve and achieve ultimate penetration. Both the ultimate market share and the pace to get there are greater for longer SPP. The figure assumes that even with SPP as low as one year, the ultimate penetration rate in new construction may be only 30%.

16.2.3 The Price of Technology, the Experience Curve, and Learning Investments

The initial capital cost or price of a new technology or system is a critical factor in measures like SPP and the cost of conserved energy (CCE), which are important measures of performance and potential market penetration for a new technology. Basic microeconomics tells us that successful people, enterprises, and products do better as they operate and develop in competitive markets. Learning through market experience reduces price; reduced price then fuels additional demand and production; and more production experience further reduces price. The Learning Curve describes how marginal labor cost declines with cumulative production.

figure 16.4 Market Penetration for Various Payback Periods

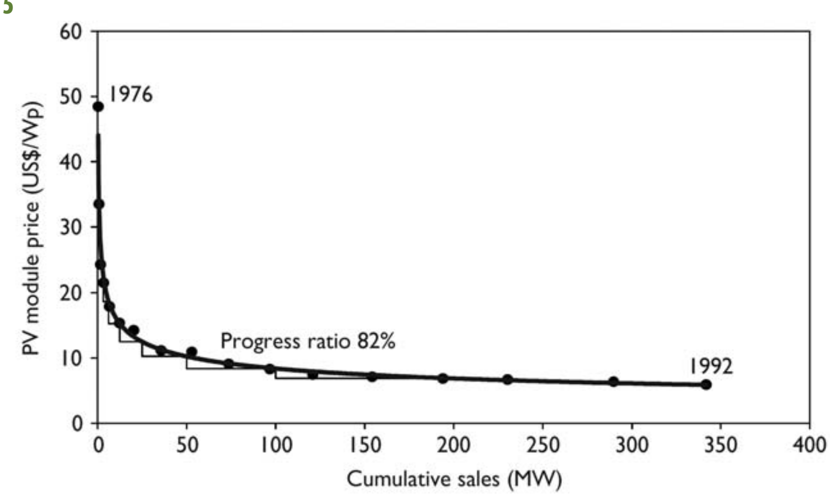


Source: LaCommare, et al., 2005

16.2.3.1 The Experience Curve

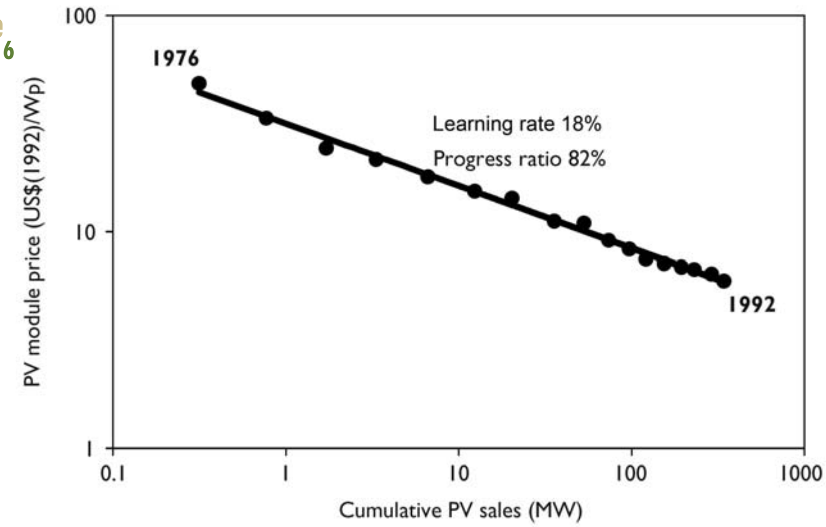
The Experience Curve describes how overall price declines with cumulative production. Bodde (1976) argues that the Experience Curve is very useful for gauging long-term trends and formulating long-range strategies for technology development. OECD/IEA (2000) suggests that it can be used to identify investments and public policy actions to advance renewable and efficient energy systems. Many other analysts have also applied it to energy systems (e.g., Duke and Kammen, 1999; Margolis, 2003; Buerskens, 2003; Swanson, 2004).

figure 16.5 Linear Experience Curve for Photovoltaics, 1976–1992



Source: OECD/IEA, 2000

figure 16.6



The double logarithmic Experience Curve represents the relationship between cumulative production and price as a straight line, which defines the Progress Ratio.

Source: OECD/IEA, 2000

The Experience Curve plots price versus cumulative sales. There is an obvious feedback loop that develops as technical advances and learning drive prices down, stimulating additional production, economies of scale, and research, which further drive prices down. Figure 16.5 gives price versus cumulative production for PV modules from 1976 to 1992 on a linear scale, meaning distances along the axes are directly proportional to *absolute* change in price or sales. The graph shows that large advances are made in the initial phases of development and they diminish quickly.

Figure 16.6 is a double-logarithmic graph of the same data; here, distances along the axes are directly proportional to the *relative* change in price or sales. This Experience Curve shows better that increasing levels of sales and production continue to affect price. The slope of this curve defines the **Progress Ratio (PR),** which measures how price will decline with every doubling of production sales. The Experience Curve is given by the following equations (Duke and Kammen, 1999):

$$P(t) = P(0) \times \left[\frac{q\,(t)}{q\,(0)}\right]^{-b}$$

where $P(t)$ = the average price at time t

$q(t)$ = the cumulative production at time t

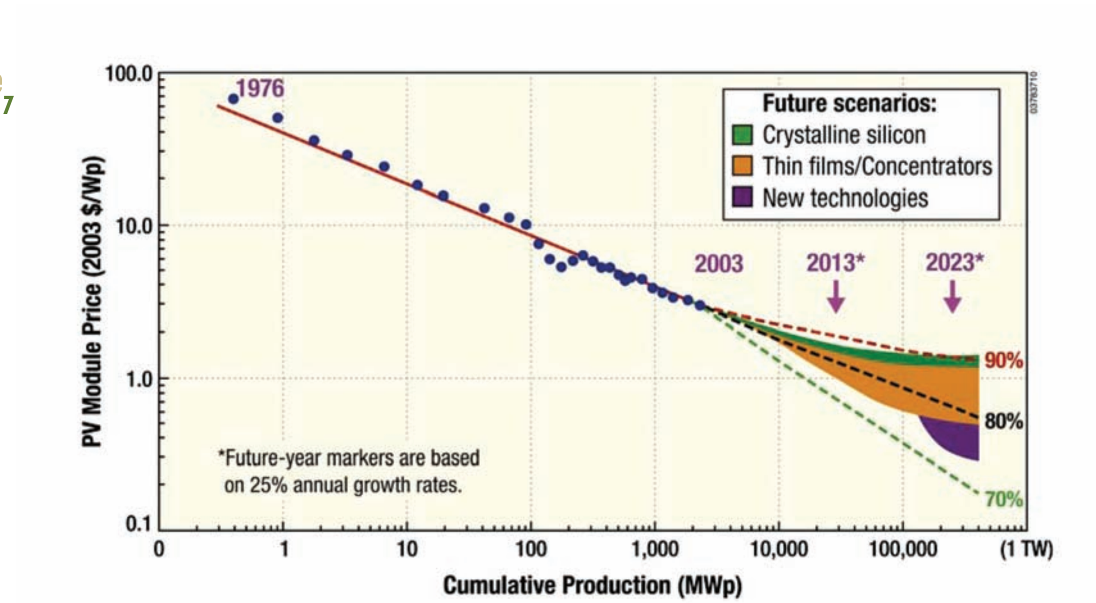
b = the learning coefficient

$$PR = 2^{-b}$$

where PR = the Progress Ratio

In this case the PR is 82%, meaning that for each doubling of PV sales, price will be reduced to 0.82 of its previous level. The **Learning Rate** is 100 – PR, or in this case 100 – 82 = 18,

figure 16.7



PV Experience Curve to 2003 with extension of current Progress Ratio of 80% (doubling of production will reduce price 20%) and *PR* scenarios of 70% and 90%.

Source: U.S. DOE, 2005

meaning each doubling of production will reduce price by 18%. The most successful technologies, such as semiconductors, have steeper Experience Curves, a smaller *PR*, and larger Learning Rates.

Figure 16.7 shows the Experience Curve for solar PV (see also Figure 11.21) with current learning rate of 80% extended and also 70% and 90% projections (U.S. DOE, 2005; Surek, 2005).

Figure 16.8 gives Experience Curves through 1995 for several power generation technologies in the European Union given in OECD/IEA (2000). More mature technologies have flatter curves. The natural gas combined-cycle (NGCC) option enjoyed the experience in the United States and elsewhere during the 1970s and 1980s.

16.2.3.2 Assessing Future Prospects and Estimating Learning Investments

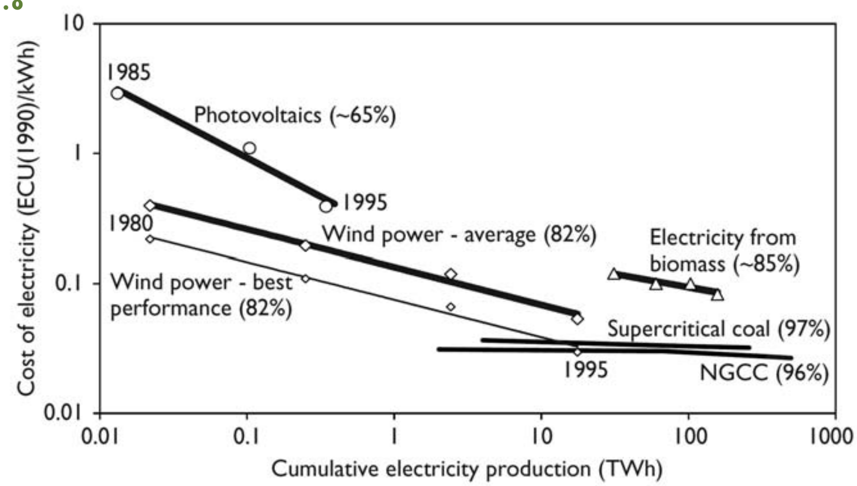
Experience Curves can be interpreted in energy analysis and policy making, including assessing future prospects, estimating "learning investments," and formulating policy and other actions to accelerate learning rates.

The trend line of Experience Curves can be extended into the future to estimate production levels at which a technology may compete with others. Figure 16.9 shows that for PV with a *PR* of 80%, a break-even price with the fossil fuel alternative (50¢/W_p) could occur at cumulative production of about 200 GW assuming this *PR* continues. Trends for two other *PR*s are also shown.

The shaded area under the curve is equivalent to the total investment in dollars, the so-called **Learning Investment** necessary to reach the break-even point. For this graph, it is equal to about $60 billion. After these learning investments are made and the technology reaches break-even, they will be recovered as the technology continues to ride down the Experience Curve.

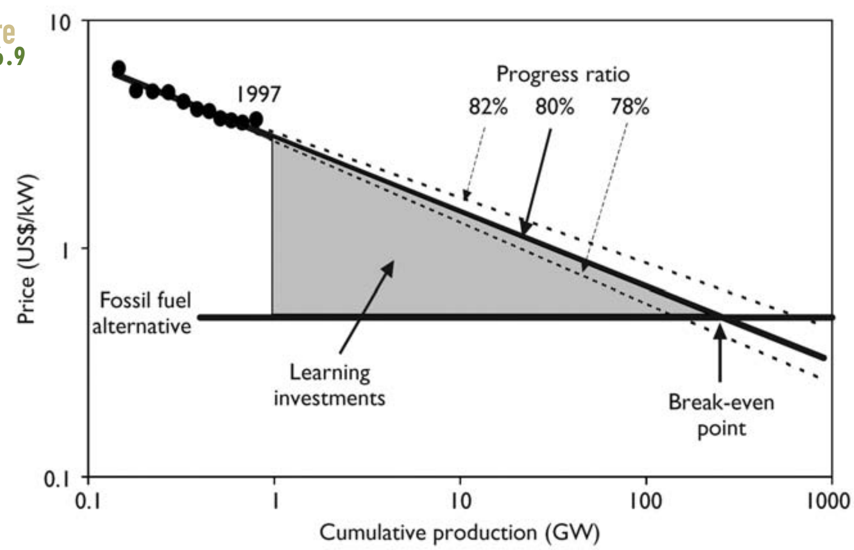
The curve shows the production (200 GW) and investment ($60 billion) needed to reach break-even for PV, but not when this will occur. This depends on the production growth rate of the technology to reach the break-even production level. For example, in

figure 16.8 **Experience Curves for Different Generation Options in European Union**



Source: OECD/IEA, 2000

figure 16.9



Extending the Experience Curve to break-even price identifies cumulative production necessary and Learning Investments needed to achieve it. The break-even production would decline for lower *PR* and increase for higher *PR*.

Source: OECD/IEA, 2000

2000, OECD/IEA estimated continuing the historic 15% growth of PV production would achieve production break-even with centralized power options in 2025; doubling that rate would move it up to 2015.

16.2.3.3 Energy Policy and Learning

The learning system that contributes to the Experience Curve phenomenon is influenced by investments for new discovery through research and development and production cost savings through economies of scale and improved efficiency as production grows. Price reduction creates more markets, which leads to greater production, which further reduces prices in a "virtuous" cycle (Duke and Kammen, 1999).

Although this is primarily driven by the engine of the free market, public policy can influence the learning system, the *PR*, and the rate of production growth. For example, government research and development funding can provide Learning Investment to developing technologies; government procurement programs can increase the rate of production that will drive the technology down the Experience Curve; and government incentives such as tax credits can reduce price and drive further production. These are what Duke and Kammen (1999) call **Market Transformation Programs.** The Experience Curve can identify Learning Investments or price reductions that are needed to achieve production objectives. We explore these policy solutions in the next section.

If society decides that some "breakaway" technological advance is necessary, the Experience Curve can be useful to identify the parameters of change. For example, Figure 16.10 gives a variation of the Experience Curve showing carbon intensity of the world economy (kg C/$GDP) versus cumulative $GDP. The Progress Ratio of 79% is extended to an

figure 16.10 Experience Curve for Global Carbon Intensity versus GDP

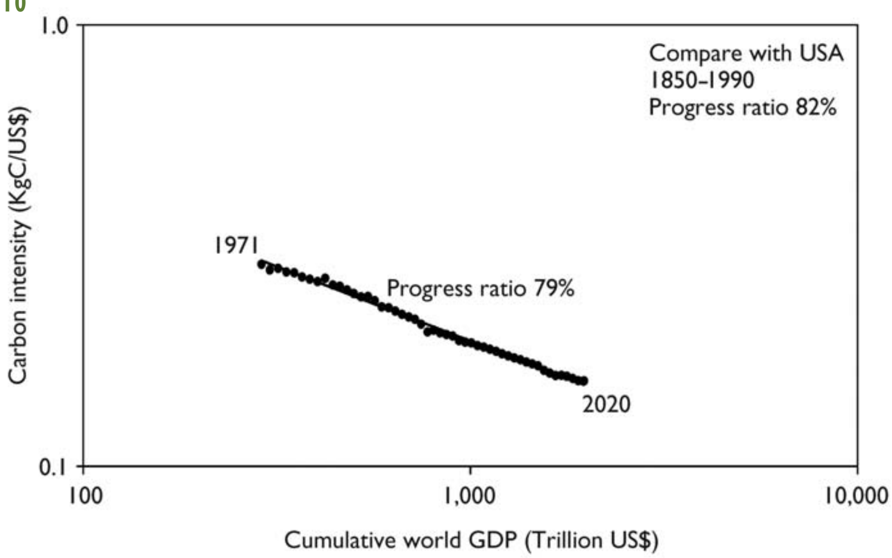


figure 16.11 **The Necessary Breakaway Path to Stabilize CO_2 Emissions by 2050**

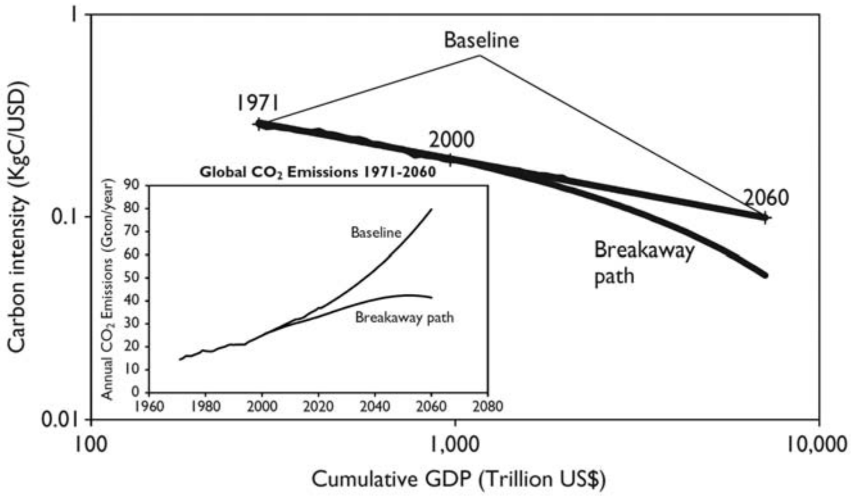
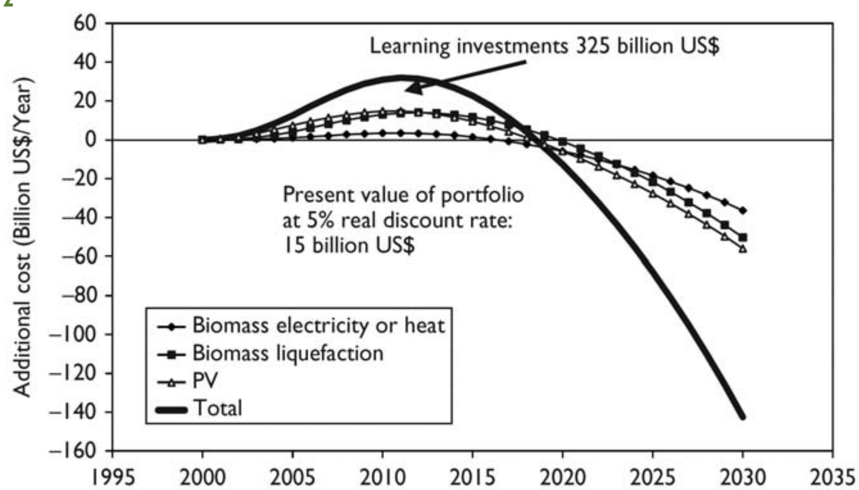


figure 16.12 **The Learning Investments Needed in a Biomass/PV Technology Portfolio to Achieve that Breakaway**



Experience Curves for these technologies indicate that $325 billion in investments by 2020 could achieve this result with substantial benefits thereafter, creating a Net Present Value of $15 billion at d = 5%.

Source: OECD/IEA, 2000

expected GDP in 2020. Figure 16.11 extends this curve to GDP level expected in 2060. Although the carbon intensity continues to go down, total carbon emissions would be four times 1990 levels. The figure also shows a breakaway path that would stabilize total emissions in 2050 (see inset). Converting this path to the Experience Curve, the resulting *PR* would need to be 50%.

This would require a steady increase in deployment of low/zero-carbon technologies. The OECD/IEA study provides one portfolio for achieving this deployment of equal parts biomass electricity, biomass liquid fuels, and PV technologies, shown in Figure 16.12. The learning investment of $325 billion by 2016 could provide a return on investment thereafter, and a positive present value of the portfolio of $15 billion.

16.3 The Policy Solutions

16.3.1 The Case for Market Intervention

There are at least three reasons for government intervention in energy markets to address the market failure and barriers introduced earlier in this chapter:

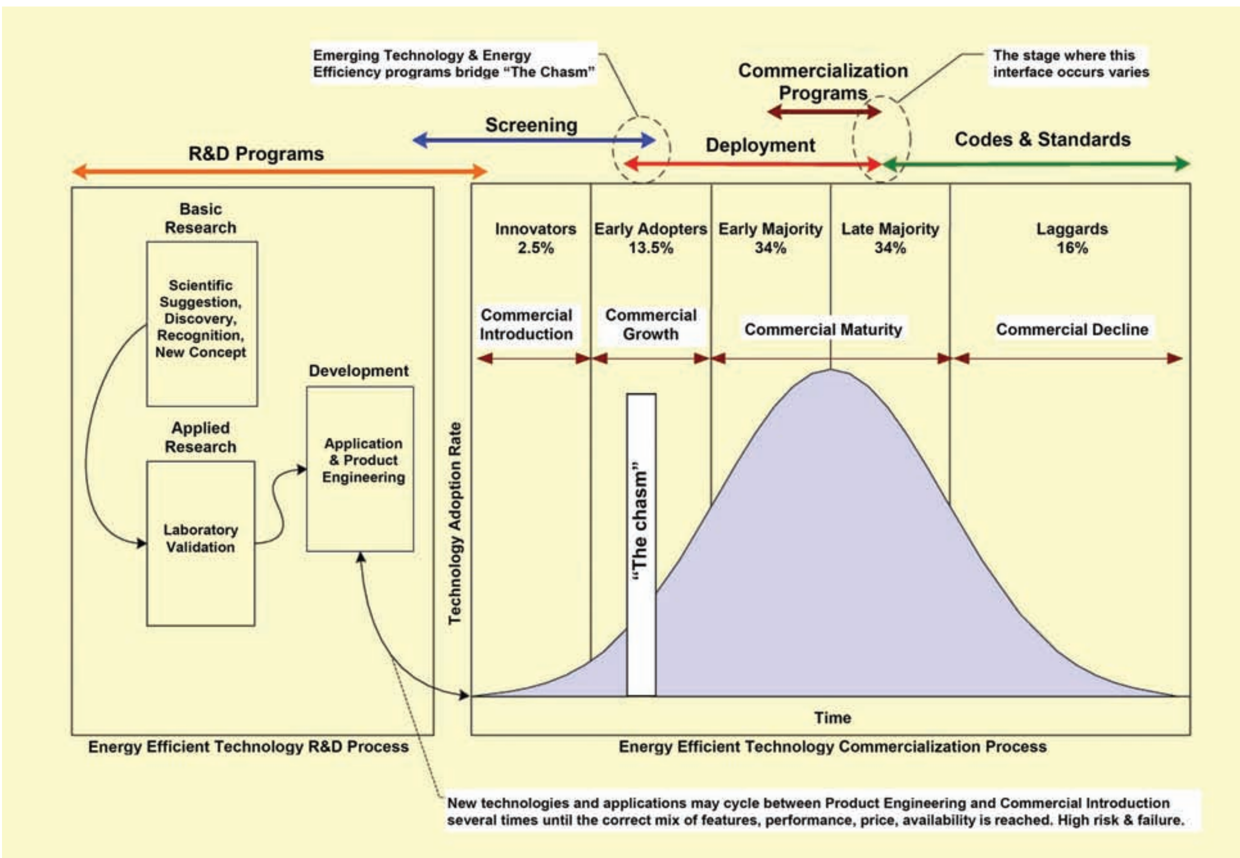
1. **Externalities:** Energy prices do not reflect the full range of costs and benefits associated with energy use, such as carbon emissions, urban air pollution, health and safety of coal miners, military costs to secure access to Middle East oil, and risks associated with nuclear safety and dependence on oil imports. Government intervention can internalize these external costs.
2. **Transaction costs:** Limited knowledge and information, poor access to capital, lack of availability of products, limited time, misplaced incentives and regulatory policies, and other market barriers inhibit investments in new technologies and efficiency. Government intervention can reduce these transaction costs.
3. **Poor future-orientation:** The market and consumers are today-oriented and give low priority to future energy problems especially when they are not felt today or are uncertain. Government intervention can make investments and help individuals and organizations make decisions that help themselves and society, today and for the future.

"For the future" is especially relevant to energy and sustainability. Some economists tell us not to worry about peak oil or even the impacts of global warming, because the market will make necessary adjustments to replace oil with other fuels and develop new sources to prevent impacts. But like most markets, energy markets are geared to today's economic forces in which demand and supply determine price, which in turn affects demand and supply. While we have "futures" markets for energy, especially oil, that future is usually only three to six months away. And markets can't by themselves correct large-scale, long-range problems such as climate impacts.

This system of the free market works very efficiently, *except* for the externality, transaction cost, and social welfare issues given above, and *except* for replacement costs beyond the short timeframe of futures markets. For limited nonrenewable conventional oil and natural gas, future replacement costs may be significant but current markets undervalue those costs and therefore underprice those fuels. Those low prices inhibit investment in replacement alternatives and improved efficiency of use. We saw significant increases in oil and gas prices in 2005–2007, but the market did not anticipate those increases and cannot respond fast enough with alternatives. And once we feel the full brunt of effects of global warming, it may be too late to reverse course. We need to plan ahead and we need to act more quickly than the market's slow pace of change.

Government intervention can "correct" these market imperfections; use the market to meet economic, environmental, and societal goals, including enhanced sustainability; and help the market plan for the future. Let's return to our model of commercial diffusion of technology, given in Figure 16.2, and see how government market transformation programs can help market forces in adoption of energy innovation. Figure 16.13 shows that energy

figure 16.13 **Effect of Government Market Transformation Programs on Commercialization of Energy Efficient Technologies**



Research and development (R&D) funding spurs initial technology development and commercial introduction. Emerging technology and deployment programs help overcome the difficult "chasm" in the adoption process. Codes and standards finally push the remaining market into adoption.

Source: Jenkins, et al., 2004

technology research and development programs can help fuel innovation. Energy efficiency programs, including improved information and incentives, can enhance commercialization and deployment, speeding the diffusion process. Ultimately codes and standards validate established technologies.

We will review a wide range of government market transformation programs in this section, but it is important to understand at the outset that enacting such policies is not straightforward. Government often has conflicting policy objectives, and there is constant political debate about the appropriate extent of market intervention and the specific industries and technologies to be advanced by policy initiatives. For example, some political interests aim to use policy to raise conventional energy prices to reflect external costs and create an incentive for more sustainable energy, but others fear that higher energy prices will slow economic growth with serious consequences. And of course, there is much at stake for different energy industries and other stakeholders who seek policies to protect or advantage their interests, so the policy process is further complicated by competing economic and political interests.

We will look at the politics of energy later in the chapter, but first, this section reviews various energy policy approaches to improve energy markets.

16.3.2 The Range of Market Transformation Policies and Programs

Market transformation policies and programs include a range of policy approaches using regulations, economic incentives and disincentives, learning investments, and direct assistance (Table 16.1). We provide below a general description of these approaches, and the following two chapters describe specific energy policy initiatives by the U.S. federal government and other national governments as well as U.S. state and local energy policies.

16.3.2.1 Regulations

Regulations provide one of the most direct means of market transformation because they require action by producers and consumers and are not solely dependent on market forces for change. Because they are mandatory, they achieve a high penetration rate close to 100% for new efficient products. Economic incentives affecting price and payback period cannot approach this market penetration as Figure 16.4 suggests.

Energy regulations can be grouped into product efficiency standards, production standards, utility and other energy industry regulation, and environmental regulation.

Product efficiency standards. We have introduced several product efficiency standards in previous chapters, including building codes, appliance efficiency standards, and vehicle efficiency standards. These regulations aim to transform markets where market forces are not sufficient to produce potential economic, environmental, or societal benefits. The potential market transformation and energy and economic savings associated with efficiency standards are significant because of near 100% market penetration.

table 16.1 **Array of Energy Market Transformation Policies and Programs**

Regulations
- Product efficiency standards
- Production standards
- Utility regulation and market reform
- Environmental regulations
- Price controls

Economic and Financial Measures
- Tax incentives and disincentives
- Financing assistance and risk insurance
- Research and development funding
- Procurement
- Energy assistance

Energy Planning and Information
- Energy planning
- Information and training

Capacity Building, Partnerships, and Voluntary Action
- Voluntary agreements and partnerships
- Capacity building and civil society

Product manufacturers often oppose stricter efficiency standards because of compliance costs, but if standards are applied equitably, they place the same requirements on all, and higher costs if any are passed on to all consumers. Some manufacturers who are early adopters producing efficient products may have a competitive advantage under stricter standards, but perhaps they should be so rewarded.

Although efficiency standards may have significant environmental benefits, the strongest case for them comes from the economic benefits to consumers. For example, cumulative net consumer savings to 2030 from energy cost savings of U.S. federal appliance standards enacted through 2007 are estimated at $250 billion (Nadel, et al., 2006; ASAP/ACEEE, 2008).

Production standards. Whereas product efficiency standards focus on the demand side of energy use, production standards focus on the supply side. They require a certain amount or percentage of supply to come from energy sources determined to be beneficial by public policy. Two production standards in use today are the Renewable Portfolio Standard (RPS) for electricity and the Renewable Fuels Standard (RFS) for vehicle fuel. Several states have adopted an RPS that requires each electric utility serving customers in the state to provide a certain percentage or amount of their marketed power from renewable sources by a certain date. Some states and the 2005 and 2007 federal energy policy acts include an RFS requiring that gasoline suppliers provide a minimum quantity or percentage of fuel from ethanol. For example, the federal RFS is 36 billion gallons by 2022, and the Minnesota RFS is 20% ethanol in gasoline fuel by 2010 (see Chapters 14, 17, and 18).

The primary purpose of the production standards is to establish a minimum market for renewable energy and thus greater certainty for developers and investors. Investments and greater production can help the industries move down the Experience Curve, lowering prices and growing their market penetration.

Utility regulation. Certain energy industries do not operate in competitive markets and are regulated to avoid abuse. The best examples are investor-owned electric and natural gas utilities that have designated service areas. Such utilities have operated as monopolies because consumers within the service area are essentially captured and have little choice. As discussed in Chapter 9, the Public Utility Holding Company Act (PUHCA) of 1938, the Public Utility Regulatory Policies Act (PURPA) of 1978, and other federal laws established guidelines for utility regulation mostly by state utility commissions. For decades, the rates, generating plants, transmission lines, services, and other practices of utilities have been subject to review and approval by state commissions. Because some utility operations, such as interstate transmission, cross state lines, federal law established the Federal Energy Regulatory Commission (FERC) to review and approve such operations.

From the late 1970s to the 1990s, many state commissions used their regulatory authority to encourage and mandate utility programs to enhance energy efficiency through demand-side management. The Energy Policy Act of 1992 established opportunities for restructuring of utility regulations and several states experimented with new regulatory structures that aimed to provide greater choice and competition in utility markets, which could lead to lower utility rates. Although California's restructuring failure (see Section 9.7.6) put a damper on several other states' attempts, consumers in most states now have greater choice in source of electricity, better access to renewable sources of power, and increasing opportunities for on-site generation through net-metering, than ever before as a result of utility market reforms.

Still, as discussed in Chapters 17 and 18, utility regulation remains a moving target. The Energy Policy Act of 2005 repealed PUHCA and amended PURPA. Although some states have moved more slowly toward further restructuring, others have moved forward by adopting RPS and greater consumer choice.

Environmental regulations. Environmental laws and regulations aiming to reduce the many environmental impacts of energy production, transport, and use have a significant effect on energy markets. The cost of compliance acts to reduce or internalize some of the externalities associated with energy options. For example, compliance with coal mine land reclamation regulations, miner safety and health laws, and air pollution control rules increases the cost of coal-generated electricity. The resulting higher price of coal power helps other, less environmental impacting power sources, such as wind, solar, and combined-cycle natural gas, compete with coal. Environmental laws affecting the cost of energy include air and water quality regulations, waste management controls, nuclear safety and fuel cycle management, energy facility siting requirements, and others.

Some regulations include a market component to enhance implementation. An **emission caps and trading** system is used in the U.S. Clean Air Act for control of sulfur oxides. Coal power plants are allocated caps on SO_x emissions; if they reduce emissions below the caps they can sell credits to other plants, which can use those credits in lieu of their own emissions reductions. The European Union (EU) uses a similar system for carbon emissions from industry (see Chapter 17), and such a carbon emissions control system is currently proposed in the U.S. Congress.

Energy price controls. Government has the authority to regulate wholesale and retail prices of energy. Indeed, utility regulation has essentially controlled electricity rates. But electricity price controls were at least partially blamed for California's electricity crisis of 2001. Most efforts in restructuring utility regulation have enabled more competition and integration of market forces into rate structures.

Government has used its authority over utilities to affect not only retail pricing but the rates utilities must pay non-utility generators supplying electricity to the grid. These can include a homeowner with rooftop PVs, a large windfarm, or an industry with a combined heat and power system. These so-called **buy-back** or **feed-in** rates will determine in large part the cost effectiveness of these on-site efficient and renewable electricity systems. Under the PURPA of 1978, these rates in the U.S. were to be based on the costs avoided by utilities for buying the on-site power. These rates were generally too low to provide an effective financial incentive for developing such systems. Most states now offer net metering for small-to-moderate on-site systems, essentially requiring utilities to buy back power at retail rates. In many European countries, especially Germany, feed-in rates are set well above retail, and this has led to an explosion of wind and solar systems that has made Germany the world leader in both (see Section 17.1.2.2).

Beyond utility rates, the evolving political climate for deregulation of markets has diminished government interest in direct control of consumer energy prices. This climate was affected by ineffectual efforts to regulate price of oil and natural gas. In 1971, the U.S. federal government had a complicated system of price controls on crude oil produced in this country, but by 1979 they were deemed ineffective and were repealed with an accompanying "windfall profits" tax on excess oil company profits from the higher prices that followed the repeal. Since that time, oil and natural gas prices have been determined largely by international markets. Recent record oil company profits in 2005–2007 resulting from record world oil prices have renewed proposals for windfall profits taxes, but they have not mustered sufficient political support for enactment.

16.3.2.2 Economic and Financial Measures

This is not to say that government policy does not aim to affect the cost of energy or energy systems. Government economic and financial measures are powerful policy tools used to affect investors, energy developers, and energy consumers. These measures can reduce financial risk, lower investment cost, fund development of new technology, and assist those hardest hit by the cost of energy. We can distinguish five basic types of economic and financial energy policies: tax policies, other financing and risk assistance, research and development funding, government procurement, and direct assistance.

Tax incentives and disincentives. Most individuals, firms, and investors are very sensitive to the taxes they pay, and energy tax policy can affect behavior of consumers, developers, and investors. There are different types of tax incentives and disincentives:

1. **Energy taxes and surcharges** increase the price of conventional energy, and higher prices can reduce demand and increase the value of energy saved by efficiency or alternative sources, and thus improve their SPP. An example of an energy tax is the excise tax on gasoline. In 2006 the average excise tax on gasoline in the United States was $0.39/gal, which has little effect on demand and energy saved by efficiency and conservation compared to the U.K. tax of $4.00/gal (see Figure 13.12).

   A surcharge per kWh electricity consumption is a common way state utility commissions have allowed utilities to generate revenues for demand-side efficiency programs.

   Broader taxes on energy, such as carbon or Btu tax, have been debated in the EU and the United States. For example, in 2007 Columbia Business School Dean and former Bush economic advisor Glenn Hubbard argued for a carbon tax, saying if you want to fuel innovation, you have to price it. Others argue that a carbon tax would be more effective and more easy to implement than a carbon cap and trade systems because it would apply to all energy markets at the point of sale including households and vehicles, whereas successful cap and trade systems have only been applied to large stationary sources. The fate of a carbon tax in the United States is uncertain because energy taxes are politically charged, and past federal proposals have been soundly voted down.
2. **Energy investment tax credits** aim to spur investment in qualified energy efficiency measures and production facilities by effectively lowering the initial cost by the value of the tax credit. For example, the 2005 Energy Policy Act provides a 30% tax credit for business investments in solar energy systems.
3. **Energy production tax credits** provide a direct incentive for the production of qualified energy sources. For example, producers of electricity from qualified renewable sources in the United States receive a tax credit of 1.8¢/kWh generated for commercial sale. Blenders of fuel ethanol receive a tax credit of 51¢/gal of ethanol blended for fuel sales.
4. **Energy research and development tax credits** are applied to expenditures on qualified energy research, removing some of the financial risk associated with such ventures.
5. **Energy investment and production deductions** on taxable income for investments provide an incentive similar to tax credits, but at a considerably lower rate. Solution Box 16.1 illustrates the different effects of an energy tax credit and tax deduction.

Financing assistance and risk insurance. Tax incentives can lower the initial cost of energy investments, but financing assistance can have a more direct effect in certain situations.

SOLUTION BOX 16.1

SOLUTION

Comparing Energy Tax Credits and Deductions

The U.S. federal government wants to encourage consumers to buy energy-efficient, low-emission vehicles and provides tax incentives for the purchase of hybrid electric vehicles (HEV). In 2002–2005, the incentive was a \$2000 federal tax *deduction* for the purchase of such a vehicle. The 2005 Energy Policy Act changed this to a tax *credit* of up to \$3400 depending on the specific vehicle mileage and on its marketing success (i.e., the credit goes down as more such vehicles are sold). The Toyota Prius has an mpg rating to qualify for the full \$3400 credit, but because of its marketing success in 2006, let's assume it will be eligible for a \$2000 tax credit. How does the \$2000 tax credit compare to the \$2000 tax deduction in reducing the purchase price of a \$20,000 Toyota Prius for a household with \$100,000 taxable income and a 30% tax bracket?

Solution:

Purchase in 2005: \$2000 Tax Deduction

Deduction is subtracted from income to which the tax-bracket percentage is applied:

Without deduction: tax = \$100,000 × 0.30 = \$30,000
With deduction: tax = (\$100,000 – \$2000) × 0.30 = \$29,400
Tax savings = \$30,000 – \$29,400 = \$600
Or tax savings = (tax deduction claimed) × (tax bracket %) = \$2000 × 0.30 = \$600

Purchase in 2006: \$2000 Tax Credit

Credit is subtracted from tax obligation:

Without tax credit: tax = \$100,000 × 0.30 = \$30,000
With tax credit: tax = (\$100,000 × 0.30) – \$2000 = \$28,000
Tax savings = \$30,000 – \$28,000 = \$2000

The tax deduction lowers the purchase price by \$600 or 3%, whereas the tax credit lowers the price by \$2000 or 10%.

There are four types of government financing and insurance assistance, all of which may incur higher government administrative costs than tax credits:

1. **Low- or zero-interest loans:** To improve access to and reduce the cost of capital for energy investments by consumers, governments can offer, or direct utilities to offer, incentive financing for qualified energy systems or measures.

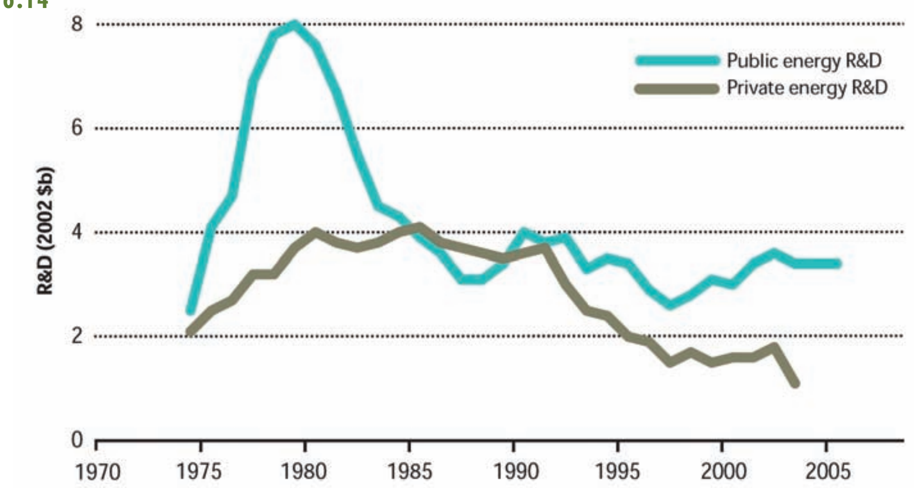
2. **Rebates:** Direct rebate of a portion of investment in qualified energy systems or measures. These are similar in effect to tax credits, but payment to consumer is more direct because it does not require filing a tax return.
3. **Feebates:** Rebates are paid out of government taxpayer funds or are rate-based by utilities and paid by all utility customers. Amory Lovins popularized the "feebate" that combines a fee or tax on consumers using high amounts of energy or purchasing inefficient products and a rebate for those consumers using less or buying efficient products. The fee builds a fund to pay for the rebate so the program is revenue neutral and does not cost taxpayers or utility customers.
4. **Loan guarantees:** Reduces the risk of investments by guaranteeing partial loan repayment if venture fails to meet certain return. They are generally applied to large industrial, high-risk ventures such as new nuclear reactors or synthetic fuel conversion plants.
5. **Risk insurance:** Government underwrites or provides insurance to reduce risk to ventures with high financial or safety risk. For example, the Price-Anderson Act, reauthorized in 2005, limits the liability to utilities for a nuclear accident at about $10 billion and provides a mechanism for the entire industry to share the damage cost to that amount, and for government to cover damages above that amount. Also, the 2005 Energy Policy Act authorized $2 billion in "regulatory risk insurance" to the nuclear industry to cover the cost of regulatory delays at six new reactors.

Research and development funding. Research and development (R&D) is critical for creating new commercial technologies for market transformation. This is especially important for energy technologies involving new energy sources, conversion systems, storage devices, and efficiency measures. Private funding of R&D is essential to advance energy technologies, but there is considerable risk in investments for long-term options. Therefore public government funding of R&D is important to support high-risk activities, to reduce risk for private investments, and to create incentives for additional private funding. If any one policy action is to prepare us for the energy future, it is R&D; it is our future.

Despite its importance and the considerable economic development potential of new energy technologies, both public and private funding of energy R&D in the United States has diminished considerably since the early 1980s (Figure 16.14). Kammen and others lament this "underinvestment" and call for an increase in public R&D investments of five to ten times the current levels (Kammen and Nemet, 2005; Margolis and Kammen, 1999).

Procurement. The government is a major consumer, and one way to stimulate market transformation is to create a dedicated market for sustainable energy technologies by requiring government to purchase them. Such requirements also help test the technologies and educate private consumers by example. To spur the alternative fueled vehicle (AFV) market, the 1992 Energy Policy Act required government vehicle fleets to include a large proportion of AFVs. Federal agencies were also required to purchase ENERGY STAR rated equipment. Government, or utilities under its direction, can also use bulk procurement of efficient lamps,

figure 16.14 U.S. Energy R&D Funding, 1975–2005



Kammen and Nemet (2005) argue that public energy R&D funding should increase by 5–10 times. Energy R&D as a percentage of total U.S. R&D has fallen from 10% to 2% since 1980.

Source: Kammen and Nemet, 2005. Used with permission.

refrigerators, and other devices at reduced unit cost and use them to replace inefficient ones in selected consuming sectors (Geller, 2003).

Energy assistance programs. Energy costs add extra financial demands to the budgets of low-income consumers, especially when prices increase significantly. Low-income consumers are usually burdened with inefficient cars, housing, and appliances, which make matters worse. In response, government can complement social welfare programs with energy assistance.

Programs can provide financial assistance to eligible households to help pay utility bills, like the $5 billion per year U.S. federal Low-Income Home Energy Assistance Program (LIHEAP), or they can provide improvements in energy efficiency of eligible households, like the $500 million per year Weatherization Assistance Program (WAP). Whereas the former approach simply pays for fuel and electricity with no lasting return in efficiency improvements, the latter invests in housing energy efficiency that will continue to reduce energy bills in future years.

16.3.2.3 Energy Planning

Good energy decisions, be they consumer choices or government policies, require good information and good planning. Many have argued that our current energy problems are the result of poor planning. We simply have not prepared a strategic course of action to lead us to a sustainable future. In Chapter 3 we discussed the abysmal efforts at energy forecasting done in the past three decades. Forecasting is part of planning. But planning is broader and more normative and is simply defined as "figuring out what needs to be done and how to do it" through a process of problem solving. As John Friedmann says, it is "applying knowledge to action."

Government policy should direct careful, rational, iterative, and participatory planning to develop the most effective, efficient, and equitable actions to achieve energy sustainability. As applied problem solving, the planning process has the following basic steps:

1. **Let's scope out the problem and the process.** This can include identifying issues, stakeholders, and needs for data and information; developing scenarios; or articulating a desired future condition.
2. **Where are we now?** This includes baseline analysis of existing conditions, constraints, opportunities, objectives, and uncertainties.
3. **What can we do?** This step formulates alternative policies, projects, programs, designs, or other courses of action that might achieve objectives or a desired future condition.
4. **What should we do?** This assesses and evaluates the economic, environmental, and social effects of alternatives on objectives and future scenarios, and selects a course of action.
5. **Let's do it!** This is the implementation of the selected course of action, including post-implementation monitoring, evaluation, and modification if necessary.

Energy planning is conducted at all levels of government, by private companies, and by civil society organizations. Planning studies develop information and knowledge that can clarify uncertainties, articulate choices, and lead to better decisions.

Future energy is plagued by uncertainties, and this is the reason for the abysmal forecasting of the last three decades. As we discussed in Chapter 3, energy planning should not forecast "a future," but embrace uncertainty by formulating scenarios of possible futures and the conditions, consequences, and uncertainties related to them. We will review examples of energy planning at the national, state, and local levels in the next two chapters.

16.3.2.4 Capacity Building for Energy Action

Market transformation to sustainable energy requires action by everyone—government, energy companies, energy-consuming industry and commerce, civil society organizations, and individual consumers. Government policy can facilitate action through better information, voluntary agreements, partnerships, and capacity building of organizations and individuals.

Information and training. Inadequate and inaccurate information plagues planning and policy decisions. To improve information, government policies support research and analysis. For example, the U.S. Department of Energy's national laboratories and Energy Information Administration continuously support, develop, and disseminate new energy information to inform decisions.

In addition, market imperfections and transaction costs are driven by incomplete, unavailable, or incorrect information on available products, sources, costs, and benefits. Market transformation requires enhancing the quality of information for consumers, producers, and institutions. Government programs can develop and disseminate such information through product testing and labeling (e.g., EPA fuel economy ratings), certification programs (e.g., ENERGY STAR), and energy education and training.

Voluntary agreements and partnerships. Voluntary action can and must push market transformation beyond the limits of regulation and financial incentives. This involves countless participants from major industries to institutions to individual homeowners to make voluntary choices about their energy use. This voluntary approach is facilitated by the growing number of "green" or energy efficient and environmental protocols and certification systems such as ISO 14000 and LEED that help those taking voluntary action to make valid choices.

Government policy can also facilitate voluntary action through agreements and partnerships. Government-industry energy agreements have been very popular in Europe and have helped improve appliance efficiency and reduce auto CO_2 emissions (Geller, 2003).

Capacity building and civil society. Market transformation requires a knowledgeable public and the institutions to create and disseminate knowledge to the public. Government agencies, labs, and funding for energy studies contribute to this effort, but government cannot perform this task alone. It involves many participants in energy assessments, plans, and implementation, including K–12 schools, colleges and universities, energy research and demonstration centers, national public interest groups, and community organizations. Government programs can help build the capacity of these organizations through grant funding, technical assistance, and partnerships.

16.3.3 Pitfalls of Market Transformation Programs

There is considerable evidence of the benefits of government market transformation programs over the past thirty years, but there are also critics, many of whom argue that estimates of energy savings from efficiency programs are inflated and that leads to overinvestment in them. In a study done for the International Energy Agency, Geller and Attali (2005) provide a review of these critiques and draw on the literature of experience in IEA member countries to learn from them. The following list illustrates the pitfalls of energy efficiency programs identified by critics as well as Geller and Attali's responses.

1. **The "rebound effect" will erode energy savings.** The rebound effect is the increase in demand for energy services when the cost of service goes down because of efficiency improvements. If I make my house more efficient, I can turn up the winter thermostat and pay the same as before. My car is more efficient, so I'll drive more vehicle miles.

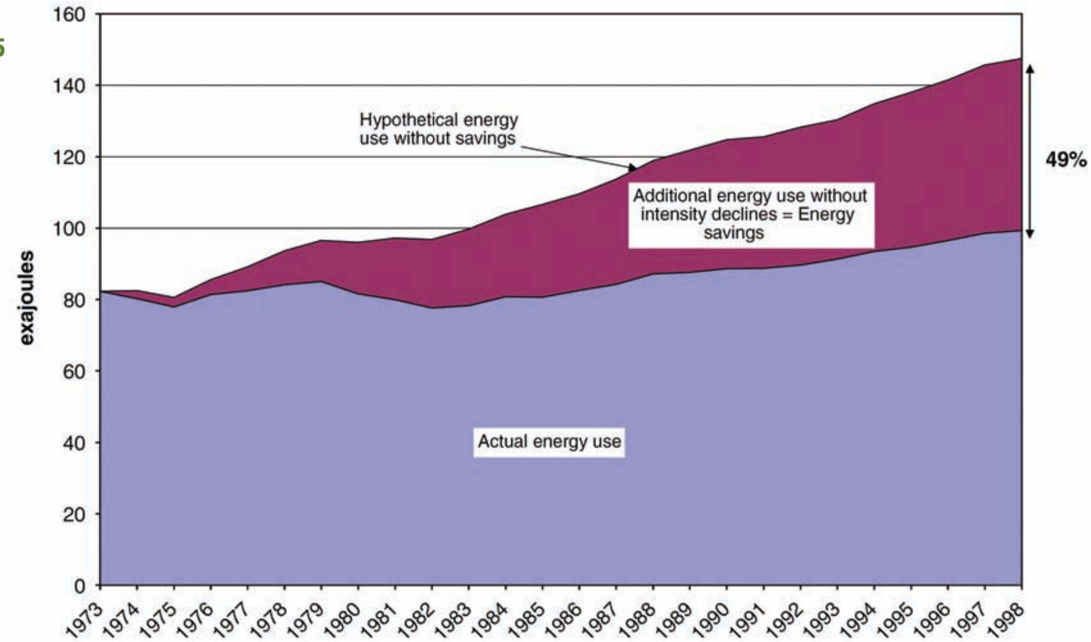
The rebound effect is real, but it is smaller than critics claim, and there are benefits associated with the greater services provided.

2. **The economy-wide effect will also erode energy savings.** Efficiency improvements can lower demand, which can reduce energy prices, which in turn can lead to economic growth and greater energy use. Research has shown that this effect is small (1%–2% of energy savings), and there are benefits to the economy.
3. **Most energy savings would happen anyway due to technical advances or rising energy prices.** This is true, but these "autonomous efficiency improvements" are slow and incomplete.
4. **Discount rates used to justify energy efficiency policies and programs are too low.** Critics suggest using "consumer purchase" discount rates of about 20%, but there is a good theoretical case for using "implicit" discount rates in evaluating government programs, in the range of 4%–8%, and even lower if the objective is for long-term benefit like GHG emission abatement.
5. **Rate- or taxpayer-funded energy efficiency programs are an unfair subsidy that hurts non-participants and low-income households.** Program participants do benefit more than non-participants, but carefully designed and administered programs should benefit all customers with lower rates than would otherwise be the case, and all society with less air emissions and greater energy security. Most programs dedicate a large share of program resources to low-income households.
6. **Energy efficiency programs are much less effective than their proponents claim.** It is important to use empirical data when evaluating energy efficiency programs.
7. **The market failures frequently used to justify energy efficiency programs are mostly a myth.** Externalities and transaction costs are well documented.
8. **Energy savings are impossible to meter and too difficult to estimate accurately.** Although savings are difficult to measure, there has been great progress in monitoring and evaluation methods for "before and after" assessment and estimation of "free riders" and net savings.
9. **Energy efficiency is a failure because energy use has been increasing.** Energy use has increased but not as fast as it would have without government market intervention programs. Figure 16.15 shows actual energy use and estimated energy use without programs for eleven OECD countries. Figures 1.8 and 1.9 give a similar assessment of U.S. energy use.

16.4 The Social Solutions

Some, like Lovins, et al. (2004), argue that the *techno-economic solutions* of efficiency, renewables, and new clean and safe fossil and nuclear technologies, along with economic market forces, will lead us to more sustainable energy patterns. Others, like Geller (2003) point out that market forces acting alone are too slow, and we need to accelerate the transition to sustainable energy through government *policy solutions*.

figure 16.15



Actual energy use and hypothetical energy use without energy savings in eleven OECD countries, 1973–1998.

Source: IEA, 2004; Geller and Attali, 2005

Still others, like Smil (2003) and Mallon (2006), think that market imperfections and the paralysis of government policy making dictate the need for the complementary *social solutions* of civil society activism and widespread consumer choice for sustainable energy on the scale of a social movement. Such a social movement for sustainable energy would give political support to aggressive government energy market transformation policies and could lead to widespread consumer choice for both efficiency investments and conservation behavior.

16.4.1 Energy Politics: Achieving Necessary Market Transformation Policies

Development of government policy should be informed by sound technical and economic analysis, but ultimately the adoption of policy initiatives is a political process. That process is a competition of ideas, data and information, and ideologies that are somehow reconciled in legislative programs and policies described in the previous section. Energy policy initiatives are influenced by diverse stakeholders representing a wide array of financial, economic, environmental, industrial, and civil society interests in energy.

But it is rare to find common ground among political stakeholders promoting variously coal or oil and gas or nuclear or renewables and efficiency. Conflicting interests also exist between those pushing for higher efficiency standards and the manufacturers that have to respond to them. As a result policy initiatives are often plagued by political paralysis and inaction, or they try to provide something for everyone without a clear prescription for market transformation. Such appears to have been the case with the 2005 U.S. Energy Policy Act discussed in the next chapter.

Good examples of inadequate or slow responses in U.S. policy include vehicle fuel efficiency standards, research and development funding, a meaningful national strategy for GHG emissions reduction, and a national renewable portfolio standard, among others.

The political process for meaningful policy change requires converging interests of government, industry, consumers, and civil society. If public awareness and support for sustainable energy grows to the scale of a social movement, elected officials will become more responsive to public opinion, and if they do not, they will be elected out of office. Energy industries and energy-consuming product manufacturers will begin to cater to social indicators for purposes of public relations, civic responsibility, and more importantly to their bottom line, market share.

A social movement for sustainable energy can galvanize public, private, and civil society stakeholders to political action and the adoption of aggressive energy policies. This has happened in many European countries, and there are signs of a sustanable energy movement in several U.S. states and cities, as we will see in Chapter 18.

16.4.2 Consumer Values and Choice

Many analysts, and indeed much of the attention of this book, assume that we can "engineer" our way out of our energy problems. They argue that through efficiency and new technology, enabled by more favorable economics enhanced by government policy, we can have our cake and eat it too. We can maintain the increasing levels of energy services we now enjoy but with greater efficiency and a more sustainable mix of energy sources.

However, there may be three fundamental flaws with this assumption:

1. Experience shows that significant improvements in efficiency of vehicles, equipment, and buildings in the United States have been offset by greater consumption for more vehicle-miles-traveled per capita, more and bigger houses and commercial buildings per capita, more appliances and equipment per capita, all resulting in greater energy consumption not less. Despite significant improvements in vehicle, appliance, and building efficiency, U.S. energy per capita is essentially the same in 2006 as it was in 1974.
2. Because of slow adoption of sustainable energy technologies due to inadequate market signals and government policies, new technology adoption alone looks insufficient to transform markets in the time frame necessary to avoid the impacts of petroleum and carbon dependence.
3. Led by the U.S. lifestyle as a model, the world's affluent continue to expand in per capita consumption of materials and energy. There appears to be no end in sight. In fact, many argue that the world's economy requires the driving force of consumption, even over-consumption, to maintain its necessary growth. Meanwhile the poor majority of the world's people struggle to reach a subsistence level of energy use.

SOLUTION BOX 16.2

Energy Needs for U.S. or European Consumption Rates for 10 Billion People

Global annual energy consumption is about 488 × 10^9 GJ or 75 GJ/p-yr (2005 data). If the population grows to 10 billion as most demographers expect sometime in the second half of this century, what would the global energy consumption be at today's per capita levels? . . . at today's average European's per capita use? . . . at today's average U.S. per capita use?

Solution:

At current global per capita use: 10 billion people × 75 GJ/p-yr = 750 GJ/yr or 54% more than today

At current German per capita use: 10 billion × 185 GJ/p-yr = 1850 GJ/yr or 3.8 times today

At current U.S. per capita use: 10 billion × 359 GJ/p-yr = 3590 GJ/yr or 7.4 times today

SOLUTION

Vaclav Smil (2003) and others see these flaws as the greatest challenge facing our energy future, as well as the future of our economy, environment, and global justice. Smil calculates that a subsistence level of energy use for an acceptable quality of life (based on food, water, health, education, employment, leisure, human rights) is about 50–70 gigaJoules (GJ) (47–66 million Btu) per person-year.

Coincidentally, the average world per capita consumption (2005) happens to be 75 GJ/p-yr (72 MBtu/p-yr [see Table 1.2]). But we know this is not evenly distributed. The average Bengali consumes 5 GJ/p-yr of commercial energy, the average Indian 16 GJ/p-yr, the average Chinese 54 GJ/p-yr. This compares to the U.S. average of 359 GJ/p-yr. The average for Germany, Japan, France and the UK is about 185 GJ/p-yr.

Can the world's energy support an expanding global population at U.S. or European levels of per capita consumption? This question is addressed in Solution Box 16.2. The answer is that at the U.S. level of energy consumption, a global population of 10 billion people would require more than seven times the current global energy use. Can we develop the energy capacity for this? Few think so. But which of the following do you think is more possible or likely?

- Our ability to expand global energy by more than seven times current consumption to meet a global population's demand at U.S. current per capita energy or by nearly four times to meet European per capita energy or

- Our ability to reduce energy consumption per capita among the world's affluent without diminishing quality of life, a trend that would help to accommodate the rising per capita needs of the poor in an energy constrained world

The former prospect is plagued by current constraints of oil and carbon and the pace at which we can develop non-carbon alternatives. This is a *difficult* problem.

But the latter prospect of arresting "over-consumption" is a *wicked* problem. It assumes that technical efficiency and new sources are not enough, and that we may need to move beyond "energy efficiency" to "energy conservation." Recall from Chapter 2, energy efficiency improvements do not assume any change in the functions provided or people's behavior, and energy conservation is defined as behavioral changes to save energy by cutting back on the functions energy provides, or at least the growth of those functions.

Arresting over-consumption through energy conservation assumes that at some point, *people will voluntarily choose to be satisfied* with a level of material consumption and the energy it requires. It assumes there are limits to what, on average, each person will want in the number and size of vehicles, equipment/appliances, and living spaces; the vehicle and air miles traveled; the lumens of light, gallons of water, and food calories consumed; the list goes on.

Surely such limits exist, but will they be so high that only a precious few can attain them and the rest will be left behind within the energy constraints we face? Or will these limits be reasonable so that many can attain them, while even more are able to rise to subsistence levels of energy? Within such reasonable limits, energy use per capita would decline with greater efficiency, contrary to recent trends in the United States. We seem to not have yet found those limits in the United States, although people in other countries seem to live quite well with half the U.S. per capita energy.

As evidence of global warming becomes increasingly hard for the general public to ignore and as gas and oil prices keep rising to record levels, there is an emerging social movement for energy efficiency *and* conservation. It is well developed in Europe, and even in the United States there are signs that many are *voluntarily choosing to be satisfied* and are modifying behavior and consumption. The movement responds to dissatisfaction with some dysfunctional aspects of the fast-paced, high-energy-consumptive lifestyle: auto dependence and congestion, reduced sense of community, and wasteful practices. The movement is characterized by increasing interest in slower and simpler lifestyles (such as the "slow cities," "slow food" movements), walkable communities, transit orientation, and resource conservation.

The popular literature in 2006 and 2007 has been filled with indicators of such a movement. A mid-2006 issue of *Newsweek* carried the cover story: "The New Greening of America: From Politics to Lifestyle: Why Saving the Environment Is Suddenly Hot" with the byline: "with windmills, low-energy homes, new forms of recycling, and fuel-efficient cars, Americans are taking conservation into their own hands." Although the article presents only anecdotes of environmental and energy activism sweeping the nation, it may be indicative of a cultural "twitch," if not a genuine cultural shift. The news media continued to fixate on this social movement throughout 2007. Time will tell if it is a lasting movement or a passing fad.

If it is lasting, it could lead to widespread consumer choice for efficient vehicles, green buildings, marketed renewable power, biofuels, onsite and community distributed generation, and other sustainable technologies. Such a growing market would elicit a response by energy producers, product manufacturers, and investors. While enlightened consumers might buy sustainably, they might also limit overall material and energy consumption, voluntarily choosing to be satisfied.

Sustaining such a movement beyond a passing fad is a challenge. Successful movements of the 1960s dealing with civil rights, environmental pollution, and gender equity, ultimately became engrained in public policy and social norms (although many think there is still much work to be done). But social movements often suffer from a "social entropy," similar to the entropy facing natural and societal systems: without a constant input of "energy" (in this case leadership, hard work, and collaboration of individuals and institutions), they will tend toward disorder and disarray. This is especially true of sustainable energy, where public interest and public policy wax and wane with the volatility of energy prices.

Germany provides a useful lesson. It has had perhaps the most active "green" energy social movement in the world that led to decisions for a phaseout of nuclear power, a 21% reduction in GHG emissions from 1990 levels by 2012, and the world's most aggressive development of wind power, PVs, and biodiesel. Despite these efforts, there appears to be resistance among some stakeholders to the large incentives for renewables (coming from the nonrenewable energy industry lobby) and the siting of wind farms (coming from some community advocacy groups; Runci, 2005). (See Chapter 17.)

Some argue that the social movement for renewable energy that existed in the United States in the 1970s to 1990s met its demise when renewable technologies were taken over by big corporations such as BP, Shell, and General Electric; they argue that corporations worked more to inhibit development than to advance it. What is needed, they say, is a more community-based energy movement that tackles "contemporary society's preference for abundance over sufficiency, for waste over frugality, for replacement over repair, and for frugality over utility" (Glover, 2006, p. 263). This latter point is consistent with the need for social solutions, but necessary market transformation cannot rest alone on lifestyle changes or "backyard renewables" as Glover implies. It also needs huge learning investments, large-scale infrastructure, research and development, and growing production to slide down the Experience Curve. Private investments and corporations are critical participants in transforming energy markets. Policy and social solutions can push them in that direction.

The good news is that the context for social solutions is better today than it has been in past decades. Because of policy advances, corporate innovations, and support from civil society organizations, energy consumers are faced with a much wider range of choice for efficiency, renewables, and conservation than ever before.

In many states, they can choose renewable sources for their electricity. In some areas, they can buy or lease rooftop PV systems and run their utility meters backward with excess production. They cannot yet go to Wal-Mart or Home Depot and buy PV arrays with built-in synchronous inverters that they can simply "plug and play" these devices, but these products are not far away.

They can buy more efficient hybrid vehicles, and in a few years they can move on to flex-fuel plug-in hybrids that give them greater fuel choice (gas, electric, and/or E85 ethanol) especially when E85 becomes more available. They can replace appliances and equipment with high-efficiency models meeting improved standards or go beyond those standards with ENERGY STAR rated units.

They can buy energy-efficient "green" houses, built by certified builders following trustworthy and documented green protocols, like LEED. They have more choices to live in walkable and transit-oriented communities that are less dependent on the automobile. Better transit and light rail systems and better bikeways are giving them better choices of transportation modes.

16.5 Summary

Market transformation is necessary to transition from our current oil- and carbon-based energy patterns to sustainable energy characterized by greater efficiency of use, limited oil, and limited carbon emissions. This market transformation requires techno-economic solutions, policy solutions, and social solutions.

Previous chapters emphasized technical solutions, and this chapter looked at some concepts of market transformation including existing barriers to achieving technical potential. These barriers include imperfect market forces, market inertia, transaction costs, and social and cultural factors. Market forces are driven by the price or initial cost of a technology and its energy and dollar savings. The price of a new technology depends on its stage of development, and the Experience Curve helps track and predict price reductions as cumulative production increases. The curve can also be used to estimate learning investments necessary to achieve a certain production and price level. Government policies can help new technologies move down the Experience Curve.

In practice, even short simple payback periods do not achieve significant market penetration. Because of transaction costs and other market imperfections such as external effects of energy on the environment, there is a need for government policy to intervene into energy markets, and to accelerate the market penetration of sustainable energy through regulation, tax policy, direct funding, and planning.

But achieving meaningful energy policy is complicated by the high stakes and competitive politics of energy. Diverse interests fragment political support and many government policies fall short of the aggressive market transformation programs necessary to speed our path to sustainable energy. What may be necessary to build political support for meaningful policy is the social solution of a sustainable energy social movement. Such a movement could also effect widespread consumer choice for sustainable energy, including efficiency improvements through technical advances and conservation behavior through voluntary action.