Chapter 1

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THE POLICY CONTEXT

For the U.S. electric power industry, the 1970s was a decade of unprecedented change. Beginning with the 1973-74 Arab oil embargo, forecasts of electricity demand growth and costs, based solely on past trends, proved virtually useless. Utility decision makers found themselves caught in a complicated and uncertain maze of interrelated financial, regulatory, and technological considerate ions.

Utilities had to pay, on average, 240 percent more for oil and 385 percent more for natural gas, in real dollars, in 1984 than in 1972. These price increases drove them to "back out" of oil- and gas-fired generation and in favor of coal and nuclear plants. Oil dropped from 16 to 5 percent in the utility fuel mix and gas from 22 to 12 percent between 1972 and 1984. But construction costs of new powerplants, particularly nuclear, rose dramatically during this period due to a combination of factors–increased attention to environmental and safety issues (leading to extended construction lead-times and added equipment costs), an unpredictable regulatory environment, an inflation-driven doubling of the cost of capital, and poor management in some cases. The higher costs of fuel and capital meant higher electricity costs, and utilities sought higher rates for the first time in decades. in addition, most utilities seriously underestimated the price elasticity of electricity demand. Growth in demand plummeted from **7** percent a year to less than 2.5 percent by the end of the decade as consumers used less electricity and used it more efficiently.

During the 1970s some electric utilities were brought to the brink of bankruptcy when forced to cancel large, unneeded powerplants; commitments to these plants had been made long before it was realized that electricity demand had been overestimated. The eroding revenue base accompanying declining demand growth coupled with the increasingly costly construction programs already underway left the industry for the most part struggling financially as bond ratings and stock prices fell precipitously.

Even now in the mid-l980s, although utilities have for the most part recovered from the financial trauma of the 1970s, ' the scars remain. The process by which utilities initiate, analyze, and implement investment decisions was changed fundamentally by the 1970s experience. In the 1960s, power system planners analyzed capacity expansion plans based on life cycle electricity costs of alternative plans. System planners now work much more closely with financial planners to analyze carefully the cash flow of the alternatives as well as the flexibility of alternative plans in accommodating unanticipated changes in demand, capital cost, interest rates, environmental regulation, and a host of other considerations. In short, their decisionmaking process has become much more financially cautious as well as more complex.

While power system planners for most utilities continue to focus on conventional generating technologies, as well as advanced combined-cycle systems or enhancements to pulverized coal plants such as supercritical boilers, limestone injection, or advanced scrubber systems, they now consider a much broader range of strategic options, including: life extension and rehabilitation of existing generating facilities; increased purchases from and shared construction programs with neighboring utilities; diversification to nontraditional lines of business; increased reliance on load management; and increased use of small-scale power production from a variety of both conventional and alternative energy sources. in

[1] Actually, even though 1984 was a very good year for utility stocks on average, as of early 1985, utilities fall roughly into three categories of stock performance some with little or no construction are quite strong, some with low to modest construction programs are stable but lackluster in performance, and finally some with large nuclear facilities under construction (or recently canceled) are still doing very poorly,

addition, most utilities have greatly expanded their conservation programs, both because it now offers the lowest cost means of meeting demand in many cases, and it provides the utility with a way to reduce future demand uncertainty. In considering these various options, utilities hope to chart an investment course that will enable them both to meet the largely unpredictable demand for electricity in the future and to maintain their financial health.

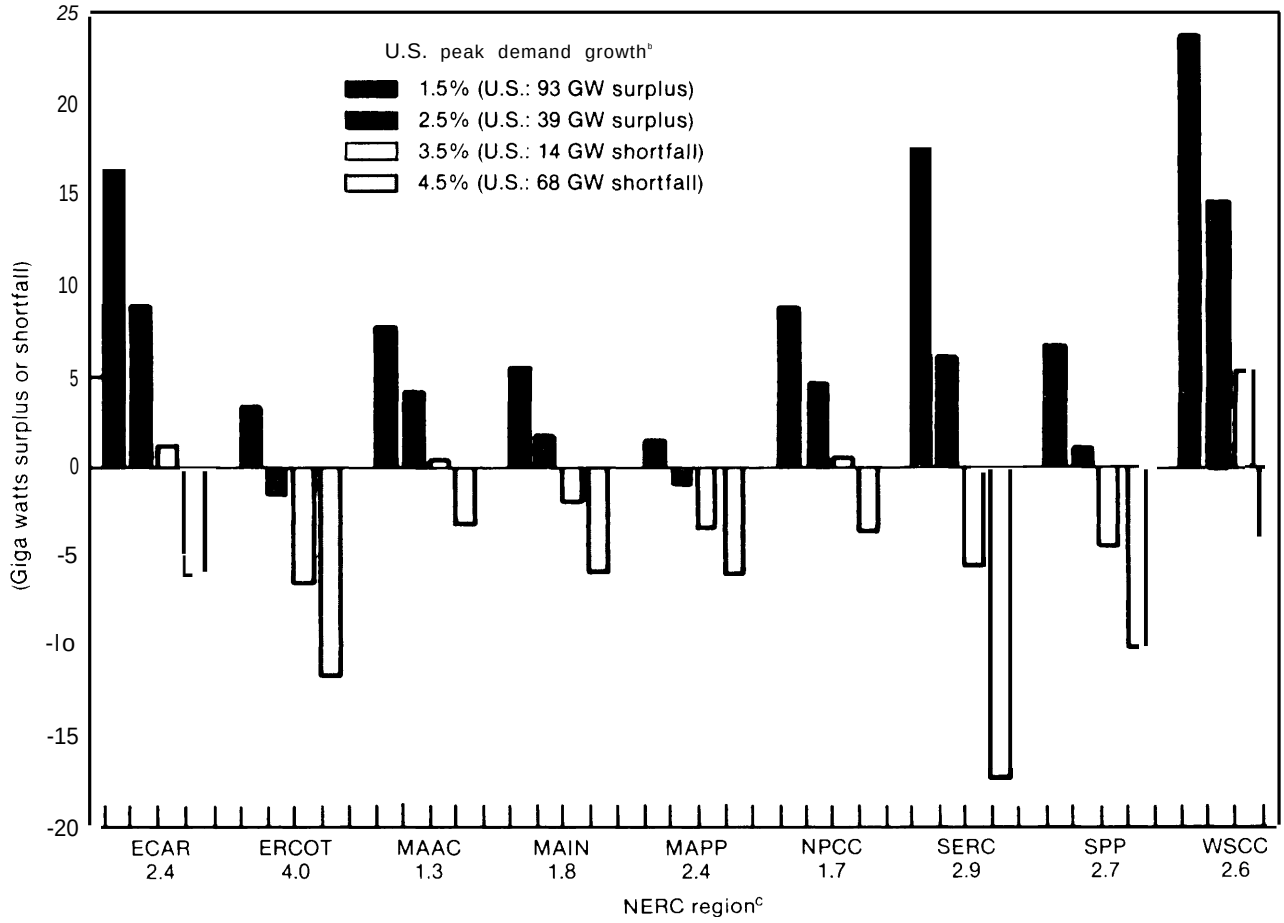
The most critical legacy of the 1970s is the uncertainty in electricity demand growth. After 1972, not only did the average annual demand growth rate drop to less than a third of that of the previous decade, but the year-to-year changes became erratic as well. Users of electricity were able to alter the quantity they used much more quickly than utilities could accommodate these changes with corresponding changes in generating capacity. Moreover, as of 1985, there is saturation in some markets—many major appliances in homes—and the future of industrial demand is clouded as many large industrial users of electricity, such as aluminum and bulk chemicals, are experiencing decline in domestic production due to foreign competition, At the same time, rapid growth continues in other areas such as space conditioning for commercial buildings, industrial process heat, and electronic office equipment. predicting the net impact of these offsetting factors, along with trends toward increased efficiency, has greatly complicated the job of forecasting demand,

Since requirements for new generating capacity over the next two decades depends primarily on electricity demand growth (as well as the rate at which aging plants are replaced with new capacity and, in some regions, net imports of bulk power from other regions), planning for new capacity has become a very risky process. To illustrate the demand uncertainty, this assessment looks at a range of different growth rates–1 .5, 2.5, 3.5, and 4.5 percent increases in average annual electricity demand through the end of the century. This range is based on analysis carried in the 1984 OTA study, *Nuclear Power in an Age of. Uncertainty.* Figure 1-1 correlates these different demand growth rates with the currently planned generating capacity for 1993 in the regions of the United States defined by the North American Electricity Reliability Council (N ERC)–the NERC regions are defined in figure 1-2. In all regions, capacity surpluses are now projected by 1993 if annual demand growth is 1.5 percent; and in seven of the nine regions, there would be capacity surpluses if demand growth is 2.5 percent. But a 3.5 percent growth rate could mean capacity shortfalls in five of the nine regions; and with a 4.5 percent growth, there could be shortfalls in all regions.

At the center of the policy debate over the future of electricity supply is the mix of power generation technologies that will be deployed by either utility or nonutility power producers over the next several decades. Those anticipating a strong resurgence in electricity demand in the 1990s support the building of more large powerplants. They cite economies of scale of such plants that, in their view, would minimize electricity costs over the long run. Others, who believe demand growth to be more uncertain, favor a strategy of flexibility which includes the possibility of small-scale capacity additions as well as increased reliance on other methods of dealing with demand uncertainty such as conservation and load management.

Complicating this controversy is the utilities' evolving attitude toward new technology, another consequence of the 1970s. While traditionally conservative in adopting new technology, the electric utility industry has grown particularly cautious in the wake of its experience with nuclear power. Utilities now impose rigorous economic performance tests on new technology investments. Perhaps because of this caution, projects initiated by nonutility power producers under the Public Utility Regulatory Policies Act (PURPA) since 1978 have served as the principal test bed for first generation commercial applications of many new generating technologies.

Figure I-I.— 1993 U.S. Generating Capacity Surplus or Shortfall Under Alternative Peak Load Growth Scenarios[a]



[a]Surplus or shortfall is the projected 1993 capacity less 1993 projected peak load (including 20% reserve margin)
[b]Average annual growth in peak demand for 1983-1993; regional growth rates for the 2.5% reference case are given at the bottom of the chart
[c]The North American Electric Reliability Council regions are defined in figure 1-2.

SOURCE: Reference projections for installed generating capacity, 2.5 percent average annual growth (national), and regional growth rates are reported in North American Electric Reliability Council (NERC), *Electric Power Supply and Demand, 1984-1993* (Princeton, NJ: NERC, 1984).

Figure I-2.—Map of North American Electric Reliability Council (NERC) Regions

ECAR	East Central Area Reliability Coordination Agreement	NPCC	Northeast Power Coordinating Council
ERCOT	Electric Reliability Council of Texas	SERC	Southeastern Electric Reliability Council
MAAC	Mid-Atlantic Area Council	SPP	Southwest Power Pool
MAIN	Mid-America Interpool Network	WSCC	Western Systems Coordinating Council
MAPP	Mid-continent Area Power Pool		

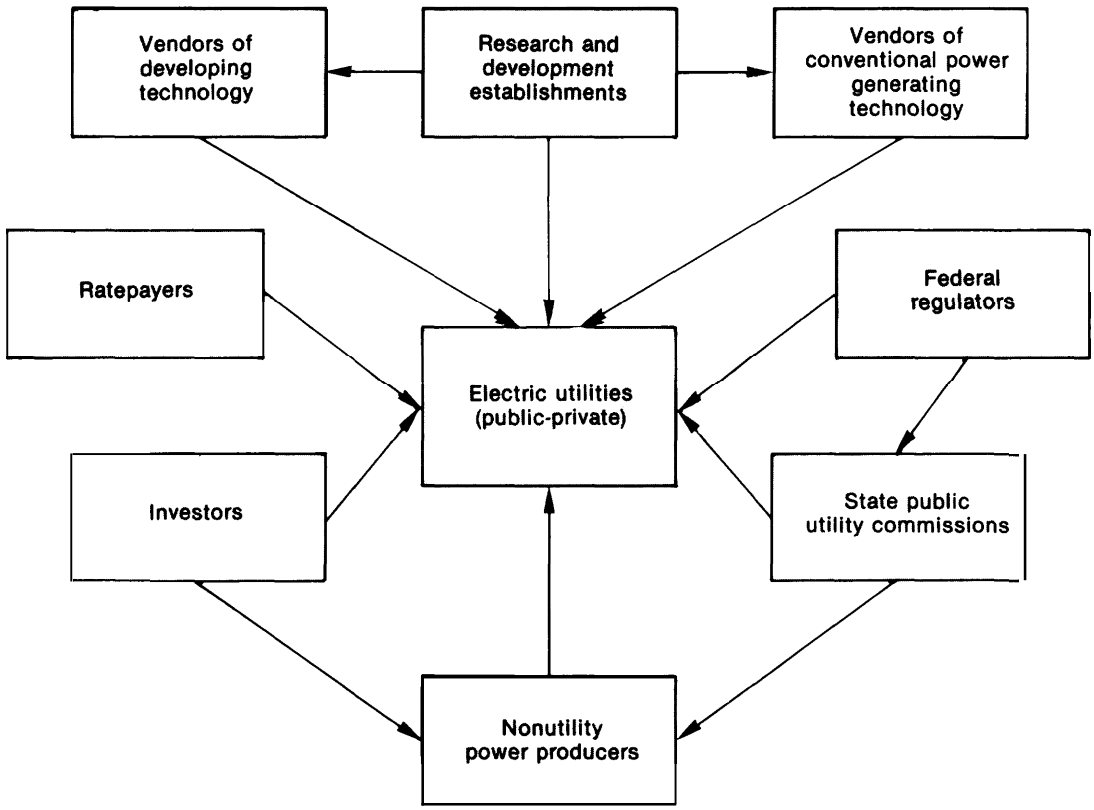
SOURCE: North American Electric Reliability Council (NERC), *NERC At A Glance* (Princeton, NJ: NERC, 1984).

THE PLAYERS

Any Federal policy decision affecting the electric power industry affects a wide range of interests. The changing conditions of the 1970s along with increased activity in new technology development have increased the number of participants who affect the industry. Each brings a very different perspective to electricity policy issues, especially with respect to new technologies. These participants, depicted in figure 1-3, are as follows:

- **Electric utilities,** both public and investor owned, differ widely in financial health, existing facilities and fuel use, and in their attitudes toward new technology.

Figure 1-3.—The Players Shaping the Future of U.S. Electric Power



SOURCE: Off Ice of Technology Assessment,

- **Nonutility power producers** have reemerged as a potentially important force in the future of electric power in the United States, particularly with respect to application of new technologies. With the enactment of PURPA, such producers (which includes all entities other than electric utilities) have begun to provide a noteworthy source of innovation in electric power generation. The relationship which evolves between these electricity producers and utilities will certainly influence the degree of deployment of new power generating technologies over the next two decades.
- **State public utility commissions** exert considerable influence over utility choices by what is permitted to enter the rate base. Commissions differ widely in their attitudes toward treatment of research and development, rate structure design, cost overruns of construction programs, as well as toward new technology.
- **Federal regulators** such as the Federal Energy Regulatory Commission, the Nuclear Regulatory Commission, and the Environmental Protection Agency, in carrying out their assigned missions, affect the electric power industry profoundly. The prospect of extensive deployment of new technologies over the next several decades may hinge as much on the regulations promulgated by these agencies as on the competitive cost and performance of the technologies.
- **Ratepayers'** response to electricity prices as well as their attitudes on issues such as nuclear power costs, nuclear safety, coal pollution, and acid rain, etc., will play major roles in determining the future of the electric power industry. In particular, ratepayers' response to prices—i.e., their demand for

electricity, and attitudes on electricity supply-related issues–will largely determine the technologies that will be employed in power generation.

- **Investors'** attitudes on the comparative risks in selecting future utility and nonutility power generation projects are important considerations and will affect the financial health of both industries. As the utility industry recovers from a financially troubled period, the degree to which investors are willing to put their money into large new generating plants again will greatly affect utility investment decisions. Similarly, the access of new electricity-generating technologies to traditional (other than venture) capital sources, which is so critical to the continued development of many of these technologies, will depend on investors' perceptions of the technologies' cost and performance prospects.
- Ž **Vendors of conventional power generating technology** have enjoyed a long relationship with the electric utility industry, This relationship heavily influences new technology investment decisions.
- **Vendors of developing technologies** include many businesses that have not traditionally dealt with the electric utility industry. New technology developers, which in many cases also include traditional vendors, range from giant petroleum companies and aerospace firms to small independent firms. In many cases, the newcomers are only beginning to establish working business relationships with electric utilities and other nonutility power producers. For some technologies, these firms are much more diverse in terms of age, size, financial position, etc., than conventional technology vendors. The relationship between such firms and the utilities as well as non utility power producers is still evolving and will affect future investment decisions.
- **Research and development (R&D) establishments** such as the U.S. Department of Energy and the Electric Power Research institute (EPRI) are now important forces in the development of new electric power technologies, Traditionally, until the 1970s, research, development, and demonstration of new electric power technologies was primarily within the province of a handful of equipment vendors cited above, i n some cases supported by the Federal Government. increasing Federal involvement in energy R&D in the 1970s and establishment of EPRI in 1972 contributed to expanding the range of public and private entities involved in commercial development of new electric technologies.

OBJECTIVES OF THIS ASSESSMENT

Electric power supply issues have been actively discussed in recent years in Congress as well as by regulators, electric utilities, and other interested parties. All parties have expressed renewed interest in alternatives to large, long lead-time powerplants. In 1981 the House Committee on Banking, Finance, and Urban Affairs requested that OTA examine the prospects of small power generation in the United States, citing that:

> . . . considerations of energy policy have not taken adequately into account the possibilities of decentralizing part of America's electrical generating capabilities by distributing them within urban and other communities.

At this time, the effects of the implementation of PURPA were beginning to appear. This act defined a role for grid-connected, nonutility small power producers in U.S. electricity generation, requiring utilities to interconnect and pay these producers for electricity provided to the grid. During the early 1980s, it became clear that the most active nonutility area of small power production would be (and still is) industrial cogeneration of steam and electricity. Consequently, in 1983 in response to the Banking Committee's request, OTA completed an assessment of industrial and commercial cogeneration.[2]

[2]U.S. Congress, Office of Technology Assessment, *Industrial and Commercial Cogeneration* (Washington, DC: U.S. Government Printing Office, February 1983), OTA-E-192.

As the cogeneration assessment was underway, the effects of errors in electricity demand forecasts and continued demand uncertainty on utility decision making were beginning to be felt throughout the industry as proposed new plants were canceled or deferred indefinitely. These cancellations were particularly damaging to the nuclear power industry which was already struggling to deal with increasing public opposition. OTA completed an assessment of the future of nuclear power which was released early in 1984. s In the course of that study, the possibility of resurgent electricity demand growth in the 1990s (argued by some as quite likely) was raised as a very difficult planning issue for the utility industry, particularly if utilities continued to rely on large powerplants at a time when they were financially stressed. To address these issues and to explore benefits of small-scale, shot-t lead-time alternatives to central station powerplants, the House Science and Technology Committee requested that OTA examine the status of such technologies as **photovoltaics, fuel cells, wind turbines, selected geothermal technologies, solar thermal-electric powerplants, atmospheric fluidized-bed combustors, coal gasification/combined-cycle plants, advanced utility-scale electricity storage technologies, and load management.**

In response, in late 1983 OTA undertook this assessment of developing electric generating technologies. The assessment addresses four major issues:

1. What is the current status of new electric generating technologies compared with conventional alternatives and how is their status likely to change over the next 10 to 15 years? In addition, what are the most promising R&D opportunities that could affect the deployment of these technologies over this period and beyond?
2. What is the nature of the industry supporting these technologies (vendors and manufacturers)? And how sensitive is their viability to electric utility orders over the next 10 to 15 years, Federal support (e.g., tax incentives and/or demonstration programs), and foreign competition?
3. What are the regional differences that affect the attractiveness of these technologies to electric utilities and nonutility power producers, particularly compared to other strategic options in those regions such as increased purchases of power from neighboring utilities, life extension of existing facilities, conservation, and so on?
4. What are the alternative public policy initiatives (e. g., tax credits, loan guarantees, demonstration projects, etc.) for accelerating the commercial viability of these technologies?

This OTA assessment focuses on the group of newer developing generating technologies that, while not fully mature, could figure importantly, under some scenarios, in the plans of utility or nonutility producers in the 1990s. Those technologies considered relatively mature including conventional coal and nuclear plants, conventional gas turbines, conventional combined-cycle plants, biomass technologies, vapor-dominated geothermal technology, low-head hydroelectric facilities, and others are not considered in detail. It is important to note, however, that in many cases these technologies are the principal benchmarks against which the technologies considered here will be compared in the 1990s. Also not considered are technologies not likely to contribute significantly to the U.S. generation mix by the 1990s—e.g,, fusion, ocean thermal energy conversion, magneto hydrodynamics, and therm ionic energy conversion.

This assessment was carried out with the assistance of a large number of experts reflecting different perspectives on the electric power industry—utility executives, system planners, financial planners, State public utility commissioners, environmental and consumer groups, Federal regulators, engineers, technology vendors, nonutility small power producers, and the financial community. As with all OTA studies, an advisory panel comprised of representatives from all these groups met periodically throughout the course of the assessment to review and critique interim products and this report, and to discuss fundamental issues affecting the analysis. Con-

[1]U.S. Congress, Office of Technology Assessment, *Nuclear Power in an Age of Uncertainty* (Washington, DC: U.S. Government Printing Office, February 1984), OTA-E-216.

tractors and consultants also provided a wide range of material in support of the assessment.

Finally, OTA convened a series of workshops to clarify important issues to be considered in the assessment and to review and expand upon contractors' analyses.

The first workshop dealt with investment decisionmaking in the electric utility industry. It focused on how the decision making environment is changing in the industry and on identifying the principal considerations by utilities in making new technology investments. in addition, the workshop addressed utility approaches to accommodating non utility power production, the Federal role i n commercialization of new electric power generating technologies, and major policy contingencies that could affect the relative attractiveness of alternative generating technologies over the next several decades. For example, such contingencies as acid rain control policies and increased availability of natural gas for electric power generation were considered.

About midway into the assessment, OTA convened a series of seven workshops dealing with the cost and performance of new generating and load management technologies. These workshops reviewed and refined the benchmark cost and performance figures generated by OTA contractors and identified the most important R&D opportunities necessary for continued advancement of the technologies being considered. The results of these workshops, coupled with the subsequent contractor and OTA staff analyses, formed the basis of the comparative assessment of generating technologies and the likelihood of their contributing significantly to U.S. electric power generation in the next two decades under various policy scenarios.

The final workshop convened in the course of this assessment dealt with economic regulatory issues affecting the development and deployment of new generating technologies. The principal issues addressed were regulatory treatment of research and development by electric utilities, implementation of PURPA, regulation of affiliated electric utility interests involved in new generating technology, and scenarios for deregulating electric power production.

Based on the workshop discussions, advisory panel recommendations, contractor and consultant reports, and OTA staff research, a set of alternative policy options were developed and analyzed. Advisory panel members, workshop participants, contractors, and other contributors to this assessment are listed in the front of this report.

This report is organized as follows:

- Chapter 2 is a summary of the entire report.
- Chapter 3 establishes the context in which electric utility investment decisions are made. In particular, it examines the range of strategic options being considered by utilities and the relative importance of new generating technologies with those options.
- Chapter 4 defines plausible ranges of cost, performance, uncertainty, and risk which are likely to characterize new electric generating and storage technologies in the 1990s, In addition, the prominent R&D needs are identified and discussed.
- Chapter 5 establishes benchmark cost and performance figures for the conventional technologies against which the new technologies are likely to compete over the next two decades. In addition, the prospects for rehabilitating or extending the lives of existing generating facilities and for increased reliance on load management as alternatives to new generating capacity are considered.
- Chapter 6 discusses the impact of decentralized power generation on the performance of electric power systems. The focus is on questions of standards for and costs of interconnecting such sources with the grid as well the effects of increasing penetration of such sources on power system control, operation, and planning.
- Chapter 7 analyzes the differences among U.S. regions that could influence the potential usefulness of new electric generating technologies in those regions. The principal differences include electricity demand growth and peaks, existing fuel use and generating facilities, indigenous energy resources, and interregional transmission capabilities.
- Chapter 8 compares the competitiveness of new technologies with conventional tech nol-

ogies, In particular, the sensitivity of investments in different technologies to factors such as demand growth, construction lead time, cost and performance, Federal tax policy, and environmental regulation.

- Chapter 9 examines the industry supporting new generating and load management technologies. For each of the technologies considered, the market infrastructure, obstacles to domestic industry development, alternative development paths, and foreign competition are discussed.
- Chapter 10 presents a n u m ber of a lterative policy options that cou ld affect the development of new electric power generating and load management technologies over the next two decades. The implications of different policy strategies employing these options are discussed.