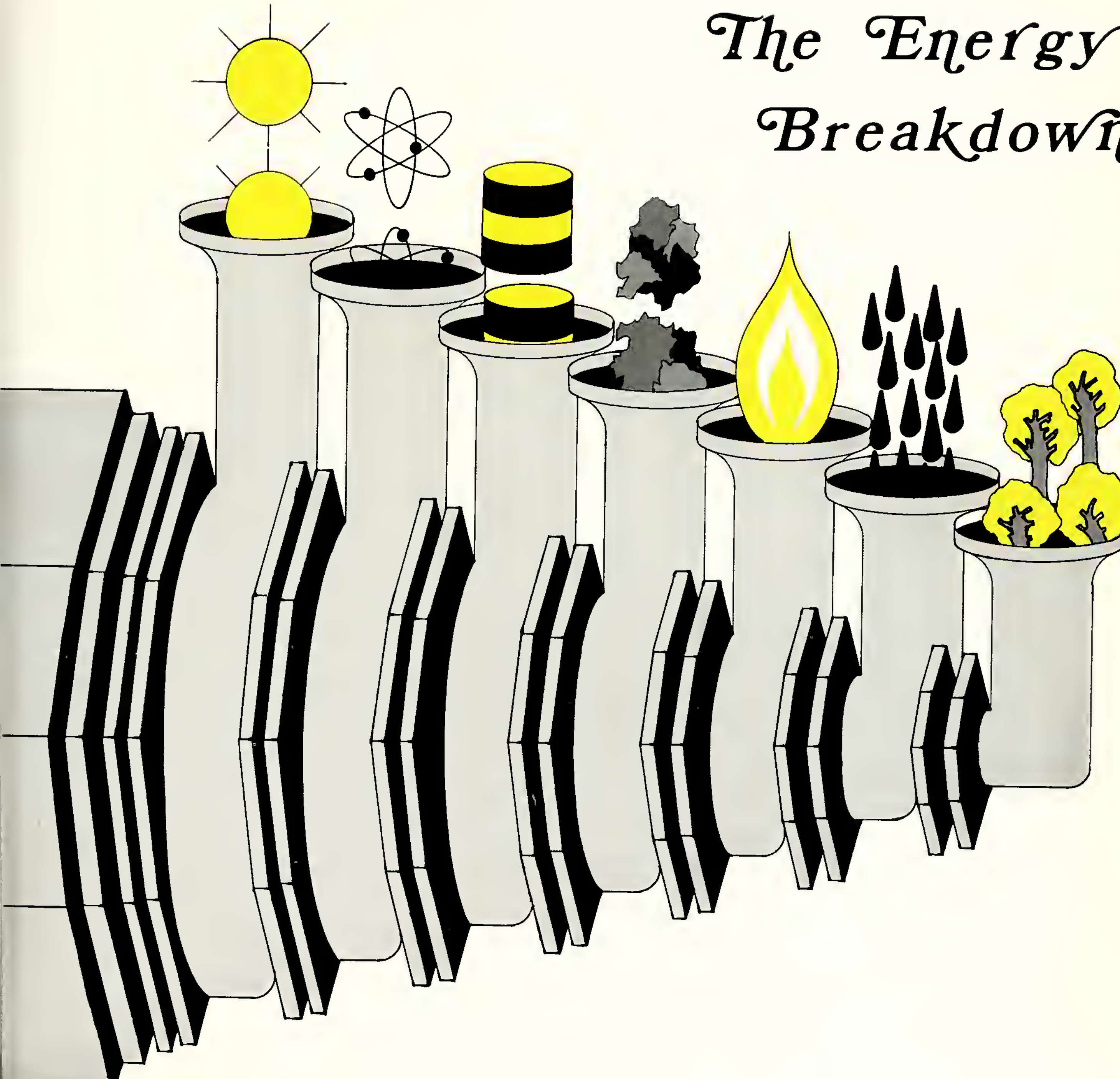
The Energy Breakdown



carolina planning

vol. 3 no. 1, winter 1977

Letters to the Editor

Editor's Note: *This issue marks the beginning of a section containing reactions to articles found in* **carolina planning**. *We welcome comments pertaining to any and all of the issues dealt with in the magazine.* **carolina planning**, *however, reserves the right to edit all letters without altering the basic contents of the materials printed. If there are any opinions you would like to voice, address your letters to: Editor,* **carolina planning**, *Department of City and Regional Planning, University of North Carolina, 404 New East Building 033A, Chapel Hill, N.C. 27514.*

Reaction to the Site-Value Tax

Dear Editor;

My attention was recently drawn to Edwin Chester's article on site-value taxation (vol. 2, no. 2, Summer 1976). I pursued this subject in depth during a Fulbright year in Australia. The most notable conclusion I reached was that there were no significant development differences in densities and land use patterns between suburbs which could be directly attributed to site-value taxation.

The question that continues to vex me is, why, if the site-value tax has such clearly demonstrated advantages, has it not been more widely adopted and put to use? Chester quotes Hagman and Schaaf on the technical difficulties and uncertainties which surround any change in tax assessment procedures. He also notes the real possibility that the community may not want more intensive use of their land resources.

This supports my view that the main obstacles to site value taxation are political more than anything else. My conclusions in Australia 10 years ago still seem to be valid, namely:

1. Politicians are more interested in revenue than in the incidental land use effects of taxes.
2. They are sensitive to the unequal burden imposed upon poor, inner city residents. Thus a system of tax rebates and deferments is introduced which does much to negate the land use distribution effects of a site-value tax.
3. There is no overwhelming mandate to change the system. The complexity of the issue makes it almost impossible for voters and politicians to form intelligent responses, so they opt for the status quo.

It is worth noting that in Australia and New Zealand, site-value taxation is optional. In New Zealand, local governments have a choice between site value, annual rental value and capital value taxes. Presently, about 75 percent of the cities use the capital value basis. So it is by no means a universally adopted measure even where the literature suggests it is a success.

A couple of other Australian and New Zealand observations which add to the muddle are the dynamics of an inflationary situation and the relatively small revenue needs of local governments in this part of the world. Where urban land is rapidly escalating in value (as in Auckland at the moment), owners can afford to sit on vacant land and pay the higher taxes in the anticipation of rising values and future profitable sales. Speculation taxes are peanuts. In both Auckland and in Australian cities, schools, fire and police protection, and health and social welfare services are central government and State responsibilities, respectively. The care-taking functions and revenue needs are minimal here in comparison to American cities.

It is not, then, a simple matter of latching onto a tax system that works elsewhere. The needs and conditions are obviously different. The use of a graded or differential tax method such as Pennsylvania's or Hawaii's for example are indicative of the political sensitivity involved in getting any changes off the ground.

In the planners' rush to find a panacea for current urban financial ills, the intracacies of reform are often overlooked. It will be a long, hard slog rather than any magical breakthrough. However, research like Chester's does help to keep the issues alight, and that in itself should make the going a bit easier.

J.P. Holl
Auckland, New Zealand

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carolina planning welcomes comments and suggestions on articles published and will be happy to accept new material for future editions. Manuscripts should be typed with a maximum of 20 double-spaced pages, and become the property of *carolina planning*.

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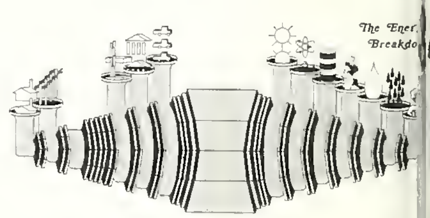
Communications, manuscripts, and subscriptions should be sent to: *carolina planning*, 404 New East 033A, Chapel Hill, North Carolina 27514.



This Issue's Cover

Cover design by Larry Epstein: On the front cover, energy resources begin the breakdown that leads to conversion and consumption: (from left to right) solar radiation, nuclear reaction, oil, coal, natural gas, water, and wood. On the back cover, the energy consumers engage together to compete for those resources: (from left to right) the residential sector, the electricity generators and transmitters, the industrial sector, the commercial and institutional sector, and the transportation sector.

Table of Contents

Introduction

During the recent winter months, North Carolinians, along with other Americans, have witnessed a crisis few believed could have happened. During a time of relative stability in the international petroleum market, this state and nation suffered a severe energy shortage. The culprit: a crippling winter.

In North Carolina, where 99 percent of all energy resources are imported, an energy crisis was declared because of natural gas, fuel oil, and kerosene shortages. Domestic thermostats were lowered to 62°F. Commercial businesses cut operation to 48 hours a week. A four day work week was initiated where possible. Several citizens froze to death in Durham from inadequate fuel oil supply. Some industries shut down. Workers were laid off their jobs.

Other parts of the nation paid a greater price than North Carolina. In Ohio over 5,000 plants closed. In the eastern industrial states and the Northeast, schools recessed, industries shutdown, and commerce was paralyzed. Nationwide, by the end of January, over 1.5 million people had been laid off from their jobs due to the energy shortage.

Direct and decisive action was taken. President Carter requested and received emergency powers from Congress to intervene in intrastate natural gas shipments to provide emergency home heating gas to areas most in need. At the state level, Governor Hunt declared an energy crisis and exercised his powers to mandate and encourage stringent energy conservation measures.

It appears the storm will be weathered. But, the rainy season is just beginning. The events of the recent winter months point inexorably toward one simple fact: a long term shortage of existing energy supply is emerging. Our natural energy resources are finite, and they are being consumed at a quickening pace. According to the Hubbert curve, widely recognized as a reasonable assessment of petroleum resources, this nation's petroleum production began to decline in 1971. The Energy Policy Project of The Ford Foundation, *A Time to Choose: America's Energy Future* indicates the decline in natural gas production could be permanent. Only a few sites remain for additional hydro-electric generation. Coal reserves appear to be adequate for the next century, but can only be used at substantial environmental cost. The volatile debate on the safety of nuclear power still rages.

In North Carolina, the ramification of such an energy shortage would be profound. The special character of the state's highly dispersed and small-sized settlement patterns could create severe problems. The now popular practice of participating in the best of both worlds, that is living in the country or a small town, while working in one of the state's larger cities, requires heavy dependence on automobiles and few opportunities for mass transportation. As petroleum supplies continue to dwindle and prices climb, something will have to give. Accentuating this spatial problem, will be the population and employment growth North Carolina must expect as a Sunbelt state. If the economy is to continue to thrive, energy consumption by the commercial and industrial sectors will most likely continue to grow—certainly a perplexing dilemma as existing energy sources become more scarce.

What this adds up to for North Carolinians, and for that matter, all Americans, is that state and national attention must focus more directly upon energy supply and use. Energy and energy-related policies must be rethought and reformulated over the next decade. Certainly, it will not be an easy task, or one to which any group has a monoply on the best solution. Therefore, a competent and far reaching planning effort must be launched. Sensible goals must be established, accurate information gathered, research stepped up, and serious conservation efforts tested. Our policy makers must be well informed in making energy-related decisions.

Admittedly, such an effort is more easily recommended than done, for Congress and the state legislature have been afforded previous opportunities to formulate long-term energy policy and have accomplished little. It seems as though few politicians have been willing to require the abrupt and difficult changes a sensible policy will make in lifestyles. Unfortunately, this past winter, the nation suffered from longstanding Congressional inertia and lack of direction. Action must be taken swiftly and directly. Programs must be launched to determine optimal energy relationships. Conservation efforts must be initiated. And, research for alternative technologies must be advanced dramatically.

This issue of *carolina planning* focuses on energy. The magazine's coverage includes a number of policy alternatives pertinent to state, local, and national decisionmakers in their deliberation over the energy problem. To provide some background information, the periodical begins with a short look at energy patterns and the institutional arrangements presently existing in North Carolina to manage resources. Next, an article and comment discusses national and state strategies for combatting a future petroleum crisis like the 1973 Arab oil embargo. Then, the benefits of a peak load pricing scheme are explained and proposed for North Carolina utilities. Following, are three articles on two widely discussed alternative energy forms: the Liquid Metal Fast Breeder Reactor and solar energy. The magazine concludes with an elaboration on energy conservation and the special role local governments might play in the effort. This collection, we feel, provides a broadly-based, yet in-depth assessment of important aspects of the state's and nation's energy problems, from the point of view of the planner, government official, and citizen.

Craig Richardson

An Overview: Energy and Policy

Over the past three decades, North Carolina, like the rest of the nation, has seen a spectacular rise in the consumption of energy. What are the major forms of energy use in North Carolina? Basically, the state's power comes from four sources: electricity (which is generated from coal, nuclear, hydroelectric, and fuel oil power), natural gas, gasoline, and fuel oil. How do the trends for each source measure up, and what plans are being made for management of the state's energy resources? The following description presents a brief overview of the existing situation, in terms of demand and supply of existing resources, and their management, in order to provide background information for this energy issue.

Electrical Consumption

Electricity, the major source of energy in the state, allows a detailed description of use through universal and use specific metering and studies of appliance usage. Between 1940 and 1970, consumption of electricity in the state rose 800 percent, and per capita electricity use increased 600 percent.[1] As Figure 1 indicates, this exponential growth is evident in all sectors of consumption since 1960. The residential sector experienced an annual growth rate of 13.4 percent in the consumption of electricity from 1960 to 1973.[2] This can be accounted for primarily by increasing appliance saturation (televisions, washers, dryers, freezers and refrigerators)—especially in the use of air conditioning, and a 2000 percent increase in the use of electricity for space heating in the same time period. Space heating and cooling, and the heating of hot water account for about 90 percent of residential electricity use.

A 400 percent increase in the use of electricity in the commercial sector is attributable largely to the same factors—increased use of air conditioning being the most notable. A 300 percent increase in the use of electricity in the industrial sector reflects the changing industrial mix in North Carolina to more energy intensive industries and technologies, as well as an industrial growth rate above that of the nation as a whole.

Electrical Supply

99 percent of North Carolina's electrical energy is generated by four class A (gross operating revenues greater than 2.5 million dollars annually) electric utilities. The four, Duke Power Company, Carolina Power and Light Company, Virginia Electric Power Company and Nantahala Power and Light Company are all investor owned utilities, and all except Nantahala provide substantial service outside the state. In the period from 1950 to 1973 they increased their total installed capacity by 2000 percent.

Up until 1973,when Duke Power opened their first nuclear plant, two-thirds of North Carolina's electrical generation was fired by coal; natural gas, fuel oil, and hydro-electric power accounted for the remaining third. This differs substantially from the nation's electrical generating mix which had only 46 percent of its generating capacity in coal burning plants.

Nuclear power currently accounts for approximately 20 percent of the total electrical generating capacity in North Carolina. Both the Duke Power Company and Carolina Power and Light Company have planned exclusively nuclear development over the next 15 years. Duke has announced their intention to build 7300 megawatts of installed capacity by 1990. Engineering sources at Duke Power have indicated that their decision to move toward nuclear power was based solely on a fiscal benefit-cost analysis.[3]

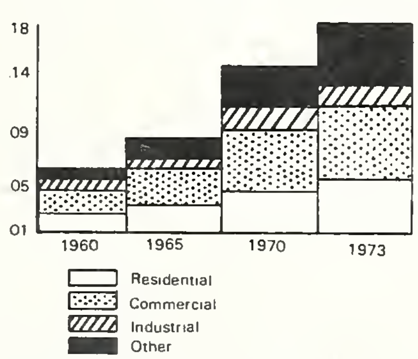
Natural Gas Consumption

Natural gas, which did not appear as a viable energy alternative in the state until the pipeline infrastructure was completed in 1958, has risen 300 percent in that short period of time. The industrial sector is the major consumer of natural gas in North Carolina (see Figure 2); its firm and interruptible industrial customers accounted for 70 percent of natural gas consumption in 1974.[4] The boilers and dryers of the textile industry burned up 35 percent of the natural gas. The fertilizer industry used 7.5 percent of the total as raw material in the production of nitrogen fertilizers. The state's other major consumers are the chemical, stone, glass and clay industries. Together, these activities account for 70.3 percent of the natural gas used in industry.

Natural gas consumption in the residential and commercial sectors was mostly for space and hot water heating. In 1972, natural gas accounted for 20.1 percent of residential space heating needs. This was up from five percent in 1960.[5] Total residential and commercial use of natural gas, as well as industrial use has been rising

Figure 1

Electricity[a] Consumad in North Carolina in Quads[b](10^15 BTU)



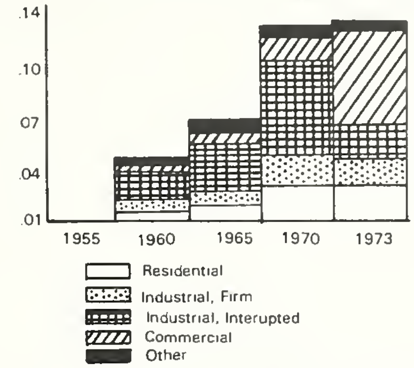
a. Source, *North Carolina Utilities Commission, 9th Annual Statistical and Analytical Report*, 1974

b. Coal-fired fossil fuel steam plants accounted for 86.7 percent of all coal consumed in North Carolina in 1975. Source: Center for Development and Resource Planning, Research Triangle Institute.

Drawing by Dan Fleishman

Figure 2

Natural Gas Consumed in North Carolina in Quads[a](10^15 BTU)



a. Source, *The North Carolina Utilities Commission, 9th Annual Statisitical and Analytical Report*, 1974

Drawing by Dan Fleishman

steadily. However, North Carolina differs drastically from the national pattern in that 13 percent of its energy consumption consisted of natural gas in 1974, in contrast to 39 percent for the nation as a whole. Before 1975, the growth of natural gas use was predicted to be 3.15 percent[6] per year, but the shortage this winter and the consequent price should force a shift to use of other fuels.

Natural Gas Supply

There are four class A (gross operating revenues over 1 million dollars), one class B, and eight municipal gas companies serving North Carolina.[7] North Carolina Natural Gas Corporation, North Carolina Gas Service, Division of Pennsylvania and Southern Gas Company, Piedmont Natural Gas Company, Inc., Public Service Gas Company, and United Cities Gas Company North Carolina Division are all served by Transcontinental Pipeline Company, the sole gas supplier to the state. Transco, as it is known, buys gas in Louisiana and Texas, and pipes it to North Carolina for resale to these companies. They in turn sell it directly to the public as well as to the eight municipal gas companies and electric companies that serve the state.

Gasoline

The 350 percent rise in the consumption of gasoline (see Figure 3) is a result of the increased dependency on the use of automobiles and trucks. This has paralleled a decline in the state's already underdeveloped mass transportation system.

Fuel Oil Demand

Fuel oil use in North Carolina is spread across all sectors of the economy. It is used in homes, commerical and institutional buildings for space heating. It is used in industrial plants for the production of process heat and on site generation of electric power. It is used in trucks, trains, and tractors of the transportation sector. And, it is used as a fuel in power plants for the generation of electricity.

There was a large rise in the demand for fuel oil in the last decade, but that trend has begun to reverse. In 1972, fuel oil (kerosene) accounted for 57 percent of residential space heating needs, but by 1975 it was down to 46 percent.[8]

Blair Pollock is a first year student concentrating in energy and environmental planning at the Department of City and Regional Planning, University of North Carolina, Chapel Hill. He received a B.A. in Environmental Studies and Urban Planning at the University of Wisconsin, Madison.

Fleming Bell is a second year student concentrating in land use and environmental planning at the Department of City and Regional Planning, University of North Carolina, Chapel Hill. A graduate of Duke University, he is currently helping to organize a colloquium series on "Energy and Patterns of Human Settlement," sponsored by the Center for Urban and Regional Studies, University of North Carolina, Chapel Hill.

Fuel Oil Supply

North Carolina has no oil refineries or oil fields. It is dependent on other states or international sources for its petroleum products. The petroleum products are delivered and retailed by a large number of small distributors and several large suppliers.

State Involvement

North Carolina state government's involvement with energy issues was minor prior to 1973. In that year, as the possibility of a serious shortage of petroleum products became apparent, Governor James Holshouser created an Energy Panel of cabinet-level officers, and the North Carolina Legislature established an Energy Crisis Study Commission. Both bodies were to assess the probable impacts on the State of a severe energy shortage and to recommend the types of action which the state government should take in the energy area. Based on the Commission's recommendation, the legislature created a permanent North Carolina Energy Division in the Department of Military and Veterans' Affairs to conduct energy-related research and to deal with emergency fuel allocation and energy conservation. The Governor established an Energy Panel Office to work with federal officials in allocating scarce fuels.[9]

At about this same time, the Office of State Planning and the Center for Development and Resource Planning at the Research Triangle Institute were developing the first part of a State Energy Management Plan. This document, published in June 1974, describes in detail energy use patterns in North Carolina, discusses the sources of that energy, makes assessments of how much energy consumption might increase in the future if present trends continue, and estimates the savings which various energy conservation strategies or changes in human activity patterns might provide. Later stages of the same project were to have produced a comprehensive energy program for the State.[10]

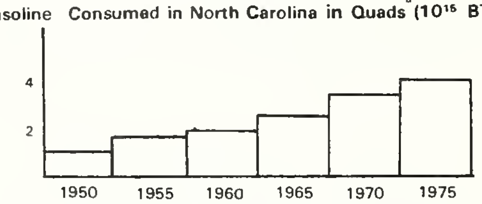
With the end of the Arab oil embargo and the immediate fuel shortage, the energy problem slipped to a much lower priority in the minds of the public and state legislators, and the project to develop a State Energy Management Plan was abandoned. However, in 1975 the legislature did appoint a North Carolina Energy Policy Council to work on an energy policy for the State.[11]

The Council has thus far been concerned with developing recommendations for the Governor and the 1977 Legislature about state energy policy. The Council is proposing plans concerning energy emergencies, energy conservation, energy management, and research and development.

The Energy Division's Activities

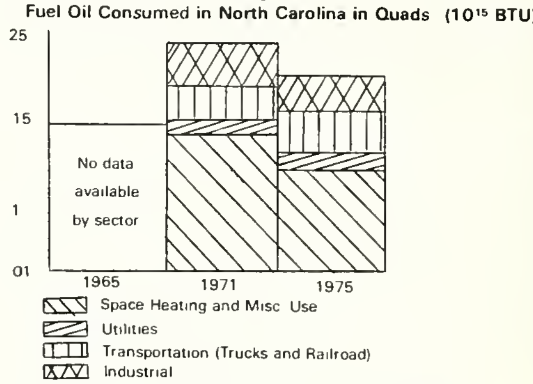
At present, the North Carolina Energy Division's activities are plentiful, even though it is not heavily funded. The Research Section of the Division has produced several reports analyzing energy consumption patterns in North Carolina. The Conservation Section, working with the North Carolina Building Code Council, has been active in the area of building code revision in order to incorporate energy conservation requirements in the State Building Code by January 1, 1978. In 1976 the Energy Division obtained funds under the Federal Energy Policy and Conservation Act (PL 94-163) for conservation planning in the state. The plans developed are to include conservation measures which will result in the reduction of North Carolina's projected 1980 energy consumption by five percent. If the North Carolina Conservation Plan prepared under this Act is approved by the federal government, federal money will be made available to the state for plan implementation. A draft copy of the North Carolina plan is presently being circulated, and public hearings on the plan have been held.

Figure 3
Gasoline Consumed in North Carolina in Quads[a] (10^{15} BTU)



a. Source, the State Revenue Department, Gasoline Tax Division
Drawing by Dan Fleishman

Figure 4
Fuel Oil Consumed in North Carolina in Quads (10^{15} BTU)



a. Source, North Carolina Oil Jobbers Association, Raleigh, North Carolina
Drawing by Dan Fleishman

State Utilities Commission

The North Carolina Utilities Commission, the oldest energy management institution in the state, is presently examining new price schemes. Experiments in peak load pricing, which is designed to "smooth" the peaks in electrical demand, may begin in North Carolina in the near future. A number of public hearings are being held on the subject. Studies are also being conducted by the Commission staff to provide independent forecasts of future electrical demands and the "mix" of types of new generating facilities needed to satisfy those demands.

These activities represent most of what is being done in North Carolina to develop energy plans and policies. A few local governing bodies, such as the Greensboro City Council and the Orange County Commissioners, have appointed Energy Task Forces to prepare energy-related recommendations for them to consider. A handful of cities including Durham and Winston-Salem, have considered or adopted Urban Services Districts, which attempt to contain urban development within a compact area for energy conservation and other reasons. However, these activities are the exception rather than the rule. The lack of a comprehensive energy program or policy at the national level has obviously affected the amount of planning being done at the state and local levels.

Footnotes

1. Dr. Jerome Kohl, "Energy and the Environment in North Carolina," Speech before the North Carolina Conference on the Environment, August 30, 1972.
2. *North Carolina Utilities Commission, 9th Annual Statistical and Analytical Report,* 1974, p. 33.
3. Don Voyles in a talk at the Department of City and Regional Planning, University of North Carolina, Chapel Hill. January 27, 1977.
4. Fowler W Martin, *Energy Sources and Uses for North Carolina.* Prepared for North Carolina State University Energy group, December, 1976, Table 5.
5. The Center for Development and Resource Planning, Research Triangle Institute, *A State Energy Management Plan for North Carolina,* June 1974.
6. *Ibid.,* p. 9.
7. *North Carolina Utilities Commission Report,* p. 38.
8. A State Energy Management Plan for North Carolina
9. Warren V. Rock, "Energy Planning at the State and National Levels," in *Abstracts from Public Seminars on Energy - A National and A Local Concern,* Report Summarizing Proceedings of Seminars Held Oct. 1 to Nov. 19, 1975, Sponsored by The Department of Physics & Astronomy, University of North Carolina, Chapel Hill and the Orange County Energy Conservation Task Force. p. 1-3.
10. The Center for Development and Resource Planning.
11. Rock, "Energy Planning," p. 2.

A Blueprint for Short-Term Petroleum

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or that matter, Organization of C) oil embargo do not provide e of personal y routines, conpened national nd saw most of tines, changed troleum prices, s. A sluggish o recovery. But blem of future petroleum embargoes, and subsequent economic and daily chaos, remained unaddressed. Would the national and state governments be able to respond quickly and boldly should another sudden supply interruption occur in the near future? Are we better prepared for this contingency in the near future, and if we are , at what levels of preparedness are we?

This paper is written to dispel some of the apprehension which now surrounds any discussion of petroleum embargoes. Its focus is short term supply crisis management caused by an embargo or natural catastrophe such as a break in the Alaskan pipeline. It describes the legislated national goals which will be operating during the next supply denial and briefly details the national programs which have been developed around them. It closes with a summary of actions which have been taken in North Carolina, and some comments on the basic orientation of the management framework and its implications to state and local policy making.

At the outset it is necessary to distinguish between long term and short term energy policies. Planning for the long term allows much greater flexibility in the choice of policy direction and implementation tools. Large capital expenditures can be made over extended periods. "Project Independence" is a long term effort. In the short term we are restricted to the capital stock at hand; we must focus attention on the societal preferences which define energy demand patterns, and institute programs which can be activated quickly without burdensome administrative machinery.

Clearly the only way to protect ourselves completely against future international petroleum embargoes is to attain total self-sufficiency in petroleum by a combination of increased domestic production, petroleum conservation and fuel substitution in the long run. This is the goal of the "Project Independence" program. It is evident from President Carter's campaign statements that the new administration will increase the importance of certain elements of "Project Independence" at the expense of others. We may expect greater emphasis on solar energy, conservation, and coal and lesser emphasis on nuclear fuel. Nevertheless, conservative estimates now place the time of complete petroleum self sufficiency 15 to 20 years in the future. Clearly a program is required to ease possible short term crises like embargoes during this interim period.

The current national program for accomplishing this is a direct outgrowth of the Emergency Petroleum Allocation Act (93-159) and the Energy Policy and Conservation Act (94-163) drafted by predominantly Democratic Congresses in 1973 and 1975. Its basic orientation is price control, governmental allocation of fuels, and emergency release of petroleum stockpiles. This emphasis on a governmentally controlled market is indicative of the party which controlled Congress during this period. With the Democratic party now in power in both the legislative and executive branches, a shift toward a freer market approach is highly unlikely. For these reasons and the fact that national policy makers will now most assuredly focus their attention on the longer term self-sufficiency solutions, we can expect little change in this short term crisis management blueprint. While there may be some slight modifications,the basic format will in all likelihood remain.

U. S. Vulnerability

In October 1973,the United States was consuming about 17.6 million barrels (mmb) of petroleum each day, of which 6.2 mmb (or 35%) were supplied by crude oil and refined product (residual oil) imports. The Arab oil embargo, which lasted from October to February of that year, reduced available petroleum supplies in the U. S. from 5-15 per cent over the period. It was most critically felt during the first

Thomas F. La Pointe is a Ph.D. candidate at the Department of City and Regional Planning, University of North Carolina, Chapel Hill. During the summer of 1976, he was employed by the Federal Energy Administration in their Strategic Petroleum Reserve Program.

Fuel Oil Supply

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State Involvement

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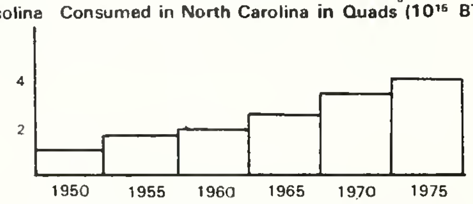

a. Source, the State Revenue Department, Gasoline Tax Division

Drawing by Dan Fleishman

Figure 4

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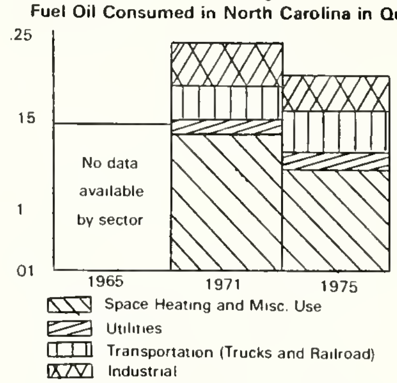

a. Source, North Carolina Oil Jobbers Association, Raleigh, North Carolina

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10. The Center for Development and Resource Planning.
11. Rock, "Energy Planning," p. 2.

A Blueprint for Short-Term Petroleum Supply Crises Management

For most North Carolinians, and for that matter, most Americans, thoughts of the Organization of Petroleum Exporting Countries' (OPEC) oil embargo during the winter and spring of 1973 do not provide pleasant memories. It was a time of personal hardship, dramatically changing daily routines, considerable inconvenience, and a deepened national recession. However, the embargo's end saw most of the population return to normal routines, changed somewhat to accomodate higher petroleum prices, but unhampered by fuel shortages. A sluggish economy began the long slow road to recovery. But suspicion still lingers that the problem of future petroleum embargoes, and subsequent economic and daily chaos, remained unaddressed. Would the national and state governments be able to respond quickly and boldly should another sudden supply interruption occur in the near future? Are we better prepared for this contingency in the near future, and if we are , at what levels of preparedness are we?

This paper is written to dispel some of the apprehension which now surrounds any discussion of petroleum embargoes. Its focus is short term supply crisis management caused by an embargo or natural catastrophe such as a break in the Alaskan pipeline. It describes the legislated national goals which will be operating during the next supply denial and briefly details the national programs which have been developed around them. It closes with a summary of actions which have been taken in North Carolina, and some comments on the basic orientation of the management framework and its implications to state and local policy making.

At the outset it is necessary to distinguish between long term and short term energy policies. Planning for the long term allows much greater flexibility in the choice of policy direction and implementation tools. Large capital expenditures can be made over extended periods. "Project Independence" is a long term effort. In the short term we are restricted to the capital stock at hand; we must focus attention on the societal preferences which define energy demand patterns, and institute programs which can be activated quickly without burdensome administrative machinery.

Clearly the only way to protect ourselves completely against future international petroleum embargoes is to attain total self-sufficiency in petroleum by a combination of increased domestic production, petroleum conservation and fuel substitution in the long run. This is the goal of the "Project Independence" program. It is evident from President Carter's campaign statements that the new administration will increase the importance of certain elements of "Project Independence" at the expense of others. We may expect greater emphasis on solar energy, conservation, and coal and lesser emphasis on nuclear fuel. Nevertheless, conservative estimates now place the time of complete petroleum self sufficiency 15 to 20 years in the future. Clearly a program is required to ease possible short term crises like embargoes during this interim period.

The current national program for accomplishing this is a direct outgrowth of the Emergency Petroleum Allocation Act (93-159) and the Energy Policy and Conservation Act (94-163) drafted by predominantly Democratic Congresses in 1973 and 1975. Its basic orientation is price control, governmental allocation of fuels, and emergency release of petroleum stockpiles. This emphasis on a governmentally controlled market is indicative of the party which controlled Congress during this period. With the Democratic party now in power in both the legislative and executive branches, a shift toward a freer market approach is highly unlikely. For these reasons and the fact that national policy makers will now most assuredly focus their attention on the longer term self-sufficiency solutions, we can expect little change in this short term crisis management blueprint. While there may be some slight modifications,the basic format will in all likelihood remain.

U. S. Vulnerability

In October 1973,the United States was consuming about 17.6 million barrels (mmb) of petroleum each day, of which 6.2 mmb (or 35%) were supplied by crude oil and refined product (residual oil) imports. The Arab oil embargo, which lasted from October to February of that year, reduced available petroleum supplies in the U. S. from 5-15 per cent over the period. It was most critically felt during the first

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Are we prepared to confront a future petroleum embargo? Photo by Alan Geir, The Daily Tar Heel

quarter of 1974 when imports were 2.2 mmb below previously projected volumes.

The impact of the embargo on the nation's economy was severe. First quarter 1974 Gross National Product (GNP) figures showed a 7 per cent drop where a slight increase had been forecast. The projected slowdown became a deep recession. A subsequent economic analysis[1] estimated the GNP loss at 3-4 percent for the duration of the embargo or 15-20 billion dollars in damage to the trillion dollar economy.

The most severe economic impacts that consumers still feel every day, were a result of the dramatic increase in the price of crude oil imports, an increase directly traceable to the events of the winter of 1973. Those refiners whose businesses and customers were directly imperiled by the October supply cut-off entered the world market in panic. Their bidding for the small amounts of excess productive capacity which then existed in non-embargoing nations such as Iran pushed prices to double and triple the pre-October prices. Petroleum, which was originally selling at $5.00 per barrel, now brought $15.00. Recognizing this high value, and the degree of short term demand inelasticity, OPEC nations immediately doubled world price and since then have artificially managed supply to support higher prices.

Supply Situation is Not Changing

While nationally the impacts of the embargo were severe, in some regions they bordered on the catastrophic. States along the east coast, North Carolina among them, suffered supply shortfalls well in excess of the 10 per cent national average. According to one report released recently by the Federal Energy Administration (FEA),[2] February 1974 gasoline supplies in North Carolina fell 19 percent short of estimated requirements. At the same time, in some oil rich states (notably Texas, Oklahoma, and Louisiana) supplies were up to 20 percent in excess of demand. The Eastern region, with little domestic oil production, received a large percentage of its imported supplies from insecure resources in the Arab bloc.

Since the embargo high petroleum prices have forced consumption downward. However, import volumes have not been correspondingly reduced because domestic production, due either to naturally dwindling resources or controlled prices has fallen by almost the same amount as consumption. In fact, even though total demand is lower, imports today comprise a greater percentage of total supplies (40 percent of current supplies are imported, 18 percent from Arab nations). The future is no brighter. Alaskan oil and exploration of the outer continental shelf will increase domestic production; but a reduction in present Canadian imports, continued declines in yields from domestic fields, and a now obvious reversal in demand patterns will perpetuate our long term reliance on Saudi and other Mid-eastern oil.

To make matters worse, the current high price of petroleum has forced out of the economy many low-valued uses. Price has forced people to conserve. Thus, a loss of substantial petroleum supplies (of the order of 1973) would wreak much greater economic havoc today than three years ago.

"These post 1973 trends of increasing reliance upon imports and deepening economic vulnerability have established the need for a contingency strategy at the national level."

These post 1973 trends of increasing reliance upon imports and deepening economic vulnerability have established the need for a contingency strategy at the national level. Planning activities over the last three years, in both the legislative and executive branches of government have resulted in a sharply defined program for facing future crises in petroleum supply. In order to place the components of this response strategy in a viable planning framework we first must consider the national objectives which will be pursued during a future embargo.

National Objectives

The basic focus of the national response is stated clearly in two national energy policy bills: the Emergency Petroleum Allocation Act (PL 93-159) passed during the 1973 embargo, and the Energy Policy and Conservation Act (PL 94-163) passed two years later. The four national goals to be pursued in combatting a supply crisis were clearly enunciated in the EPAA and unchanged in the later bill. They are to:

(1) Meet national priority needs especially with respect to public health, safety and welfare, national defense, agriculture, basic public services, and energy production.

(2) Achieve an equitable distribution of crude oil, residual fuel oil, and refined petroleum products at equitable prices among all regions and areas of the United States, assuring full refinery operation to the extent practicable.

(3) Protect market shares of independent refiners, small refiners, and nonbranded independent marketers.

(4) And maintain economic efficiency by minimizing economic distortion, inflexibility and unnecessary interference with market mechanisms.

To advance these goals, three major programs were outlined in the Act: one of price controls, another to equitably allocate crude oil, and a third to distribute petroleum products according to a priority system.

The Energy Policy and Conservation Act maintained these programs except for minor refinements and mandated the formulation of standby coupon rationing and energy conservation plans. The core proposal of the EPCA, the creation of a Strategic Petroleum Reserve (SPR), marked a dramatic shift in contingency planning; a shift away from conservation and allocation toward replacement of lost supplies with additional petroleum sources. This change in emphasis reflects the perceived increasing economic vulnerability of the United States to petroleum import interruptions and the rising cost in inconvenience, delay, and economic hardship associated with crash energy conservation programs.

The Strategic Petroleum Reserve (SPR), as authorized by Congress, is an 8-10 billion dollar project designed to store between 500 million and 1 billion barrels of crude oil and petroleum products. The massive size of the program would provide six months to one year of direct supply substitution for a very severe embargo on the order of 3mmb a day.

The SPR program has been justified by a cost/benefit analysis which computed the economic losses averted by the reserve expressed as GNP and consumer surplus, for specific embargo scenarios (i.e., duration, magnitude, time of occurrence). These benefits were then compared against the cost of particular reserve volumes.[3]

Most of the Strategic Reserve will be stored as crude oil in natural salt dome formations along the Gulf of Mexico. The National Petroleum Council[4] suggested storing two types of crude oils: one a high density, high sulfur variety, and the other of low density and low sulfur content. The first report of the Reserve Program to Congress is due by December 1976. Filling should commence shortly thereafter. It is projected, however, that the 500 mmb mark will not be reached until 1982.

The programs established by the acts, or those growing out of the stipulated national goals fall into four broad categories: programs to increase available supplies, programs to control petroleum prices, programs to reduce petroleum demand, and programs to allocate crude oil and petroleum products.

Table 1 lists the current status of these programs: whether they are currently operating and significantly affecting petroleum supply and/or demand; operating but of major importance only during a supply shortfall; or operational only upon activation by the President or his representative during a supply crisis. Figure 1 is a summary schematic showing the relationship of each program to the various elements of the petroleum distribution chain.

The burden each program will bear in meeting the crisis, will to a large extent, depend upon the circumstances surrounding the interruption; however, together they represent the extent of the non-military

Table 1

Status of Strategic Programs

Category	Program	Status
Increase supplies	International energy program	Emergency Standby
	Strategic Petroleum Reserve	Emergency Standby
	Temporary Pumping Rates	Emergency Standby
Control Prices	Two-tier Price System	Currently operating with substantial supply/demand impact. Phasing out over next 3 years.
	National Average Price (Entitlements Program)	Currently operating. Phasing out.
	Cost Pass Through	Currently operating. Phasing out.
Reduce Demand	Voluntary Conservation	Emergency Standby
	Mandatory Conservation	Emergency Standby
Allocate Available Supplies	Buy-Sell program	Currently operating but of little impact except during supply crisis.
	Refinery Yield	Emergency Standby
	Mandatory Product Allocation	Currently operating but of little impact except during a supply crisis.
	Coupon Gasoline Rationing	Emergency Standby

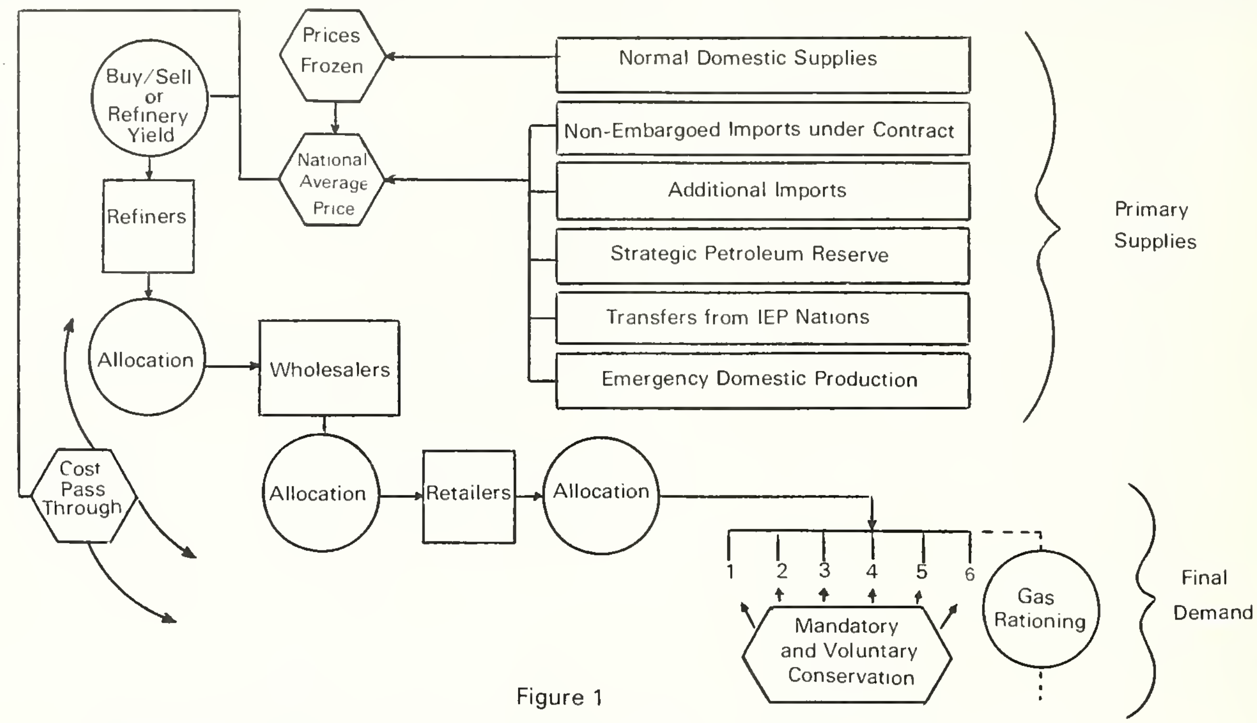

Figure 1

Impact of Contingency Programs on Elements of Petroleum Distribution Chain

strategic response. Following is a brief description of each program and a glimpse at what the situation might look like the next time around.

Increase Available Supplies

The quickest way to defeat the embargo would be to arrange for long term substitution of the petroleum supplies lost. This minimizes economic damage and alerts the perpetrators that to be effective the embargo must be very long in duration and very great in the amount of petroleum denied. Four programs are directed at increasing available supplies.

International Energy Program. If the interruption is directed against one or a few nations the International Energy Program (IEP) will act to distribute the remaining total imports among all importing nations. This will result in a net increase in supplies to the nations against which the embargo is specifically targeted. Most oil importing nations, the United States, the countries of western Europe, and others, belong to the IEP. The program is activated if any one member experiences a supply loss of 7% or greater. Supplies are redistributed up to the point where all nonembargoed members suffer a loss of 10 percent of their own supplies.[5] Since the United States is the most likely victim of a future Arab oil embargo we should derive considerable benefits from the program.

Increase Imports from Non-embargoing Nations. The decrease in world demand for petroleum brought about by the sudden price increase has left many petroleum exporters with excess capacity. This excess capacity represents a readily available "reserve". However, we do not want importing firms to enter the market in a state of panic, as happened during the 1973 crisis, bidding prices up to new excessively high levels. The government must act to relieve the price pressure and at the same time offer incentives for seeking out reasonably priced additional imports. The Strategic Petroleum Reserve, besides reducing economic damage by supplying additional oil, is well suited to this task.

Strategic Petroleum Reserve. The reserve will probably be one of the first programs instituted in a sudden supply loss. However, the operation of the reserve will require a number of specific policy decisions at the time of release. Once reserve use has been initiated, decisions must be made about the amount of petroleum to be drawn down, the price to be charged for the petroleum, and the proportions of different types of reserve crude which will be sold. The reserve will most likely be drawn down at a rapid rate in the initial stages in an attempt to break the will of the embargoers and prevent citizen panic. Reserves will be depleted at lower rates as the embargo period lengthens and other programs begin to show results; for example, as mandatory and voluntary fuel conservation force demand downward. The price charged for the released petroleum, if set slightly above pre-embargo prices, would act to encourage the contracting of additional imports and at the same time place a ceiling on import prices. All else being equal a refiner seeing two sources of supply will opt for the cheaper of the two. In this sense the SPR functions as an additional petroleum exporter in competition with non-embargoing exporters. In times of a severe shortfall, the amount of reserve released could be put up for bids subject to some minumum price. Thus import prices would be forced to equilibrate with reserve price. Pricing and drawdown strategies for the reserve are still in the early stages of formulation but optimal strategies are essential if full benefits are to be derived from the SPR.

Emergency Pumping Rates. The EPCA gave the President the authority to order increased pumping rates from certain domestic natural gas and petroleum fields. The President may require these fields to produce at the maximum efficient rate for the duration, and at a temporary production rate for a period not to exceed 90 days. The temporary rate carries the risk of permanent rupture of the oil reservoir if prolonged, and most domestic fields currently produce at the maximum efficient rate due to a price incentive.

Only minimal additional supplies are expected from these programs, and some price incentives would have to be offered to assure the increased production.

Control Prices

The price control program has three major elements. Its foundation is a two-tier price system and a cost pass-through. Complementing this is a program to average petroleum prices among purchasers. The program is designed to prevent inordinate profit-taking, equitably distribute the differences in the prices of oil from different sources, and provide economic incentives for developing additional sources of supply.

The two tier system currently imposed on all oil supplies went into effect with the passage of the EPAA and will gradually be phased out over the next three years. However it will most likely be reinstated in a similar form in the event of a future embargo. The program establishes two base prices for crude oil. The lower tier is a price set on 1972 volumes of domestically produced oil. This price is currently $5.25 per barrel. The higher price, approximately that of imported oil, applies to imports, small well production and volumes above those of 1972. Together the two prices act to prevent huge profits on traditional domestic supplies which would be brought about by allowing these supplies to equilibrate with artificially high OPEC prices while providing a price incentive for increased production.

In order to eliminate the competitive price advantage of those companies with large domestic supplies controlled at the lower price, a national average price is calculated and revenues are consequently divided among suppliers and importer. The cost pass-through program assures that dramatic increases in price or supply related costs are passed through to the consumer on a strictly dollar for dollar basis. No additional profitting is permitted at any step in the distribution chain from primary supplier to retail distributor. Such a program permits the search for more expensive sources, but ensures that final consumers will derive full benefits from additional supplies.

Since a price control program will be in effect, it follows that price will not be used to equilibrate supply with demand nor will it bear the burden of fuel allocation as it would if prices were allowed to float. Thus, if the combination of emergency supply increases and small price rises fail to accommodate the perceived national demand, additional programs must take on the task of reducing that demand and allocating the supply available. To reduce demand, a contigency conservation plan has been drafted, but as of this date it has not been submitted to Congress.[6]

Reduce Petroleum Demand

Two kinds of fuel conservation programs are outlined. The mandatory program consists of those measures which will be taken under penalty of legal prosecution. Presently five measures are proposed. These are: (1) restrictions on heating and cooling of public, commercial, and industrial establishments, (2) restrictions on available commuter parking spaces, (3) elimination of weekend gasoline sales to privately operated motor vehicles, (4) requirements to increase industrial boiler efficiency, and (5) reductions in illuminated advertising and natural gas lighting. Taken together these measures could save between .3 and .5 mmb per day.

In addition to these mandatory programs, citizens and business establishments will be requested to undertake a number of voluntary activities aimed at restraining demand. Suggested actions made through the media will include thermostat adjustments, reduced electricity use, automobile tuneups, and elimination of nonessential motor vehicle use. The last embargo revealed a willingness on the part of the American people to reduce demand in a crisis. We can therefore expect some voluntary demand restraint in the future, although probably less than the last crisis situation due to the higher value (price) petroleum now has in our society.

If the reduced demand is not sufficient to eliminate the supply/demand shortfall, an allocation program must be introduced. Particular quantities of fuels must be targeted for specific consumers. Currently two allocation programs are operational. The first allocates crude oil among refineries, while the second takes the outputs from the refineries, — gasoline, distillate fuel, residual oil, etc., —and distributes them by the type of end use to which they will be put.

Petroleum Allocation

The crude oil program, aimed at refineries, is designed to equalize the crude shortfall among the primary producers of petroleum products with the hope that by so doing regional inequities will be reduced and relative market shares will be protected. As currently set up, this program, (called the buy/sell program) calculates a national fraction of base period supply. A refinery is classified as buyer or seller depending on how its supplies compare to the national fraction. If it is above the national fraction, the refinery will be forced to sell the excess to those who fall below it.

In times of severe crisis or substantial reductions in petroleum product imports, another program much more complex than the buy/sell will be activated. While still on the drawing board, the Refinery Yield Program is designed to optimally use available refinery capacity to produce a specific mix of products. For instance, if an embargo were to occur during an especially cold winter, concern for public safety might require the sacrifice of some gasoline production in favor of producing a greater percentage of middle distillate fuels for home heating. That is, for each barrel of crude oil processed a much larger fraction of distillate oil would be produced than is normally the case. By shifting the product mix in this way no new supplies will be created. We simply trade disruption brought on by gasoline unavailability for the health of those living in oil heated homes. Such a program could use price or allocation as incentive for the production shift. For instance, during the 1973 episode the government wanted to effect a shift away from gasoline and toward production of middle distillates. The shift was accomplished by allowing a 2 cent per gallon price increase for heating fuels at the same time reducing allowable gasoline prices by 1 cent per gallon. A shift could also be affected by allowing the more flexible refineries or those with historically higher yields of preferred products proportionately larger crude oil supplies. This would favor large refineries like those in Texas and Louisiana with more internal flexibility over smaller operations. A possible deliberate inequity in crude oil allocations would have to be reversed by money or refined product transfers among affected refineries.

Output from refineries is distributed by the Mandatory Product Allocation Program. This program assigns a priority classification to each end user and associates with each classification a certain percentage allocation based on available supplies. Six priority groups are defined. National defense and agriculture, designated as priority one users, receive 100 percent of current requirements. Emergency services and mass transportation systems, among others of priority two, are allocated their current requirements adjusted by an allocation fraction which relates current supplies to those that were expected given traditional demand. The next four priority groups receive a decreasing fractional percentage of their base period demand or current requirements. Private motor vehicles are assigned the lowest priority for gasoline and no individual allocations are made (the only legal stipulation being that a retailer must not discriminate among purchasers). Table 2 gives a list of some common petroleum users, and the percent of supplies to which they are entitled from the three major petroleum products. The table is not all inclusive since some users receive different allocations over the spectrum of petroleum products.

To insure a smooth operation of the product allocation program each state may reserve three to four percent of available supplies. These are dispensed by petition to customers of wholesalers and retailers particularly hard hit by high priority demands.

The final allocation program designed specifically for priority seven is gasoline coupon rationing. The EPCA mandated that a gasoline coupon rationing plan be developed and the plan is scheduled for submission to Congress some time next year. The ration-

Table 2
Petroleum Uses and Mandatory Allocations

Fuel Type	Energy Uses	Allocation
Motor Gasoline	Agricultural Production	100% C.R.
	National Defense	100% C.R.
	Emergency Services	100% C.R. x A.F.
	Mass Transportation	100% C.R. x A.F.
	Industrial Use	100% B.P. x A.F.
	Commercial Use	100% B.P. x A.F.
	Governmental Use	100% B.P. x A.F.
Middle Distillates	Agricultural Production	100% C.R.
	National Defense	100% C.R.
	Space Heating of Hospitals And Nursing Buildings	100% C.R.
	Emergency Services	100% C.R. x A.F.
	Drug Manufacture	100% C.R. x A.F.
	Industrial Space Heating	100% C.R. x A.F.
	Commercial and Residential Space Heating	100% B.P. x A.F. or .88B.P (Whichever is greater)
Residual Fuel	Agricultural Production	100% C.R.
	National Defense	100% C.R.
	Electric Utilities	Equal percentage cutback within specified groups
	Industrial Use	100% B.P.

Legend

C.R. Current Requirements
B.P. Base Period Demand
A.F. Allocation Fraction (Equal to supplies available divided by projected demand after a certain priority group have been allocated fuel.)

ing program would allow a "white market", the above-board selling of ration coupons, and would act to alleviate long gasoline lines and inconvenience and annoyance. However, the actual price of gasoline would increase as coupons are bid up. The number of coupons released would approximate projected gasoline production.

Are We Prepared?

To state that we are more prepared thanwe were in 1973 would be saying little, since the events of 1973 took us all by complete surprise. Since that time energy conditions in the United States have drastically changed. Nevertheless, the detailed strategy plans have been prepared and the larger projects like the Strategic Reserve are moving forward. While it is not possible to "arrange" a trial embargo to evaluate these elaborate plans under fire, their existence and continuing refinement should remove much of the uncertainty, apprehension and fear associated with a repeat of October 1973. Although we may still be called upon to make considerable sacrifices we will not be taken by surprise.

Of particular importance to North Carolina is the fact that considerable care has been taken in these plans to protect those of us on the east coast; that is, to regionally distribute any shortfall related economic hardship. Also, the Federal Energy Administration has encouraged individual states to adopt contingency conservation and distribution plans of their own.

Because of our bitter experience during the last embargo, the state of North Carolina is well along in this effort. In October of this year the Emergency Energy Program Subcommittee of the state's Energy Policy Council published a draft form of a state contigency plan.[7] This document, entitled *Emergency Energy Program,* proposes a variety of conservation measures, describes the procedures for administering the State Set Aside, and details the organizational structure which will supply the interface required for the national programs to operate effectively. The state's program is developed in such a way as to function in the event the crisis is local in effect or before a state of national emergency has been declared.

The long list of conservation programs in the state's plan includes restrictions on times of gasoline sales, increased use of public transportation and car pools, reduced shopping trips, and increased fuel efficiency by specific suggestions on vehicle operation and maintenance.

Efficient implementation of the State Set Aside Program; well detailed in the Emergency Energy Program will be especially important in helping protect our elderly population, who because of location and general conditions within the general distribution system, may have no other recourse in the event of allocation imperfections. The State Set Aside is a channel to quickly rectify spot changes.

With the proper preparation, resolve, and citizen trust, both locally and nationally, we will be able to economically fight back. The Arab nations are becoming increasingly dependent upon oil revenues. The next embargo will impact them to a much greater degree and will put us in that much stronger a position. As time goes on and the Strategic Reserve approaches its design volume, our position can only improve, and as a direct consequence, the likelihood of another embargo will diminish.

Domestic fuels are given high priority rating
Photo by Bruce Stiftel

However, this is not to say that the national and state strategies are without important implications for North Carolinians or that a future embargo will require no more than a few modest changes in lifestyle. Rather the very orientation of these programs will make it a very hard time for those people and regions heavily dependent on motor gasoline for essential daily activities.

Implications and Comments

Of the three major uses for petroleum which most concern our daily well being—electric power generation, home heating and transportation—North Carolinians are relatively secure with two. Unlike the Northeast, where air quality constraints compel the use of low sulfur residual fuel oil, electric power in North Carolina is generated primarily from coal burning and nuclear facilities. For example, only 3% of Duke Power's total generating capacity from fossil fuel and hydroelectric plants is petroleum based.[8] This small percentage which is considerably less upon inclusion of nuclear generation is almost totally due to a number of small peak load internal combustion plants. Such peak load facilities are only activated during the hot summer months, the least vulnerable time of the year from the standpoint of a petroleum embargo since demand for distillate fuels for home heating is negligible. With this low reliance on petroleum-derived electricity we should expect no brownouts, nor will the utilities serving the state be forced to make large orders for emergency coal shipments. Business as usual should suffice.

The state, however, is quite reliant on petroleum for home heating. A recent energy study in Orange County, not a representative area but indicative of our reliance on petroleum based home heating, estimated residential heating to be 12% of total petroleum consumption.[9] Seasonal variations probably double or triple that percentage during the winter. A considerable reduction in distillate fuel supply would create a sizable public health hazard. It is to alleviate this threat to the public health that the Mandatory Product Allocation Program places a floor of 88 percent of base period use under residential distillate supplies. However this protection is not without its cost. As already mentioned, during the last embargo, distillate production was increased at the expense of gasoline. If the public health is jeopardized once again the same tradeoff will be made.

> "The national and state plans fail to address the physical need for moving people to essential activities."

It is the resultant compounded reduction in gasoline supplies which poses the greatest threat to the personal and economic well being of the citizens of this state. North Carolina is basically a commuting state. Low residential densities make efficient (cost returning) mass transportation systems virtually impossible. Most larger cities have small bus systems but even these have serious financial problems, witness the Raleigh and Chapel Hill systems. Thus our main worry in a future substantial petroleum supply denial will be finding alternatives to private automobile use, now the life blood of our economic activity.

The national and state plans fail to address the physical need for moving people to essential activities. Whereas the focus of the national programs is on governmental regulation of the energy market, it is nevertheless entirely market oriented. It simply establishes new rules for market transactions. Fuel allocation is done by coupon, priority level, or mandated conservation rather than by price. The individual actor or "purchaser" in this market is still required to fend for himself, to do the best he can for himself under the circumstances. This is fine for national level programs, but state and local activities should go much further. However, the emergency plan of the state echoes this same orientation. Fuel is made less available by restricting sales or requiring certain conservation practices, and emergency allocations are made to special hardship cases, but the fact that many people will have to get to certain locations is ignored.

This focus on market regulation and reliance on individual action neglects the basic economic definition of the short term. It is in the short term that we are most restricted on the actions we can take, most committed to our present way of doing things. It is in the short term that individual action will be the most unproductive, especially in efficiently reducing gasoline use patterns, which are currently so vital.

State and local government planners must go beyond "encouragement" or "guidance" and propose concrete measures for moving people to essential activities during periods of substantially reduced gasoline supplies. Such measures might include emergency use of the school bus fleets which lie idle most of the day, a system for rewarding those who form car pools, emergency car pool information centers in town halls, radio stations, and industrial firms, and shifting to abbreviated 3-4 day work weeks, with extended work shifts. Particularly effective programs might be centered around large governmental and industrial employers. For instance, in order to encourage pooling, employers should be required to observe strict time schedules for all non-hourly employees. The luxury of flexible schedules is contrary to energy efficient automobile transportation. When it is necessary to require overtime or an extended work day, employees should be notified well in advance and work structured around car pool members who stay beyond quitting time to accomodate one who is forced to work.

Such simple measures should be specified clearly within any contigency program developed by state or local authorities. The market is impersonal. It is easy to say that we will all have to "conserve" more, "tighten our belts", but severe reductions in gasoline availability will strike particular individuals very hard, especially a sudden event like an embargo. To them personal security will be as important as national security. We have now addressed the latter, it is time to give some assurances of the former.

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Comment: The State is Prepared for a Short-Term Petroleum Crisis

In the preceeding article, Thomas LaPointe focuses his attention on "... short-term supply crisis management caused by an embargo or national catastrophe . . ." and its implications for state and local policy making.

After a detailed analysis of the current energy situation in the United States and North Carolina in particular, LaPointe concludes that North Carolina is relatively secure in the areas of electric power generation and home heating. However, he feels that North Carolina is particularly vulnerable in the transportation area, should another petroleum embargo strike the United States.

In effect, he seems to feel the national and state plans relating to an energy emergency are inadequate. Specifically, they ". . . fail to address the physical need for moving people to essential activities." He also feels energy crisis programs that are totally market oriented—that is, the emergency programs increasing governmental regulation of existing energy plans must go beyond government "encouragement" or "guidance," and "market regulation." State governments must "propose concrete measures for moving people to essential activities during periods of substantially reduced gasoline supplies."

It is our intention to examine North Carolina's energy crisis plans—specifically the draft Emergency Energy Program, to determine if LaPointe's comments about the Program, particularly in the area of transportation, merit further planning response.

Emergency Energy Program

A brief review of the draft Emergency Energy Program indicates that it consists of six major parts: an Energy Resources Overview; an Energy Outlook; Apparent Trends for North Carolina; Definition of an Energy Crisis; an overview of Emergency Energy Planning; and Administrative Procedures Pertaining to the Declaration of an Energy Crisis by the Governor.

The Energy Resources Overview reviews the historical context of our present national energy situation and the Energy outlook summarizes the major findings of the Federal Energy Administration's (FEA) 1976 National Energy Outlook.

The Emergency Energy Program draft states that the outlook on specific fuels in use in North Carolina is more uncertain than the national outlook. However, it appears likely that North Carolina can no longer rely on cheap energy in general, and particularly cannot rely on cheap natural gas or electricity which has fueled much recent growth outside of the transportation sector.

The Emergency Energy Program draft also states that natural gas will be the fuel most likely to be in short supply in the immediate future, and the effects of a severe natural gas curtailment during a "normal" or "colder than normal" winter on the demand and supply of alternate fuels are difficult to predict.

Should North Carolina face an energy crisis in the near future, the most likely situations appear to be: (1) natural gas curtailments in the area of 50 + percent, with attendant increased demand for propane, middle distillate and residual fuel oils, coupled with a cold winter; (2) spot shortages in the supply of petroleum products due to interruptions in the transportation and distribution infrastructure; e.g., localized pipeline malfunctions, labor actions, terminal fire, etc.; (3) spot increases in consumption in certain sectors. This may be brought about for example by an unseasonal period of cold weather; panic buying as a result of an announced or rumored impending price increase, etc.

In the longer term, crisis situations may develop due to: (1) possible withdrawal of large prime suppliers from the state upon termination of the mandatory allocation system; (2) imposition of another oil embargo; or (3) propane storage, distribution, or daily flow limitations at the Apex, North Carolina terminal and its associated pipeline.

Emergency energy planning entails the specification of certain actions to be taken to bring into balance the energy supply-demand equation. Generally, two types of actions may be considered to adjust an imbalance:

(1) Curtailment of demand, such as, conservation, etc.;
(2) Allocation of available supplies, such as, rationing or other allocation procedures.

The contingency measures outlined in the draft Emergency Energy Program are designed to reduce the demand for energy resources in short supply for the period of the shortage with the least amount of

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Gasoline management is a part of the short-term program Photo by Bruce Stiftel

"sacrifices." However, it is recognized that the basis of the state's overall welfare depends, to a large degree, upon maintaining maximum utilization of production facilities and income-generating activities. Thus, adequate preparation is the initial indispensable element of remedial action, should an energy crisis develop.

The nature of the remedial action required will depend on the seriousness of the crisis as judged by the Energy Policy Council, the Governor, and the Legislative Committee on Energy Crisis Management. The accuracy of any judgment or evaluation of the situation as well as the effectiveness of any action taken will depend entirely on the nature and accuracy of the information available to these entities, and on their ability to obtain that information in a timely manner.

In order to insure timely and equitable implementation of the contingency and emergency programs and to provide sources of information, coordination and arbitration at the local levels, six Area Fuel Councils should be established across the State. Additionally, three member County Energy Panels should be organized in each county. The major function of the Area Fuel Councils and the County Energy Panels will be to assist the Energy Policy Council to ensure equitable distribution of available fuels, coordinate support and assistance between wholesale purchaser-resellers, furnish timely information on the local supply situation, and coordinate assistance to wholesale purchaser-consumers and end-users. These groups will be the basic grass-roots organizations of the contingency programs. In the event of an energy crisis, the ability of the state to assist its citizens could be directly attributable to the quality of operations of these local bodies.

In general, the actions available to the Governor during an energy crisis are (1) appeals to the public and private sectors for voluntary conservation measures such as increased car pooling, reduction of heating thermostat temperatures, etc., (2) mandatory measures such as utility load curtailments, rationing plans, etc., and (3) some combination of both voluntary and mandatory measures as the situation might dictate.

The draft Emergency Energy Program recognizes that emergency orders, rules and regulations applied across the board on an equal basis may by their very nature cause individual hardship or discomfort disproportionate to that experienced by the state as a whole. Thus, the Program provides for appeals or review in such cases. Exemptions may be granted to individuals or firms that demonstrate unique circumstances or hardship.

Transportation and Essential Activities

LaPointe contends that some short-run solutions are needed to maintain essential activities if a future embargo arises. He states that the Emergency Energy Program "... fails to address the physical need for moving people to essential activities." He also contends that, "... fuel is made less available by restricting sales or requiring certain conservation practices, and emergency allocations are made to special hardship cases, but the fact that many people will have to get to certain locations is ignored."

It must be remembered that American society cannot be restructured in the short-run, nor can it be restructured by a single state's program. In the short-run, the best that any state can hope to accomplish is to utilize the existing structure to achieve its objectives—the ability to perform necessary activities with the least social disruption. While the short-term emergency program will cause some displacement, such as fewer trips to the supermarket, less dining out and an end to pleasure trips, a long-term response will require permanent alterations in our life-style. These alterations may be a function of inducements or rewards, price rationing, and curtailments or other mandatory measures. They will probably include the use of mass transit, more efficient cars, bicycles, and walking.

The various measures outlined in the Emergency Energy Program are designed to balance supply and demand for energy resources in the short-run with the least amount of sacrifice to the public.

In point of fact, the Emergency Energy Program does address the problem of moving people to essential activities. In a three phased approach to a declared energy crisis, the State's emergency energy planning contains sections concerned with transportation and gasoline-diesel rationing plans. The underlying assumption is that transportation is essential and can be accomplished through existing modes of transport. The phases of the Emergency Energy Program are detailed below:

Phase I

(a) *Voluntary Measures - Public and Private*

(1) *Transportation*

*— Encourage strict adherence to speed limits.

— Ask motorists not to drive at least one day per week.

— Ask motorists to combine several errands into one trip.

— Encourage carpooling, vanpooling, and utilization of mass transit systems.

— Encourage use of bicycles and walking.

— Encourage individual and corporate automobile and truck conservation in everyday driving through tuneups, properly inflated tires, avoiding excessive braking and less use of car or truck air conditioning. Check air filters and PCV valves and replace if it is necessary.

— Encourage motorists not to idle engines unnecessarily and not to race engines.

*— Ask for and encourage better use of turn-right-on-red law

— Encourage use of public transportation (bus and rail) for trips out of town. Encourage bus companies to provide additional pickup points for passengers.

— Ask for limiting unnecessary student driving to school.

(2) *Voluntary Gasoline-Diesel Rationing Plan*

*— Encourage service station operators to limit hours for the sale of gasoline.

*— Encourage closing service stations at least one day a week. Stations in the same general area should be encouraged to stagger the days they will close. This would not apply to stations in isolated areas or truck stops.

*— Enourage gasoline purchases be made on odd-even day of month as determined by the last digit of the license plate number. Odd number - odd number calendar day, even number - even number calender day. Personalized license plates with no number should be considered odd.

*— For those stations open, Saturday or Sunday will be open purchase day.

— Encourage business to investigate and develop plans for staggering work hours so that employees can utilize mass transit systems more effectively. Mass transit officials should be consulted.

— Truck stop dealers should be encouraged to limit sales to volumes that would be adequate for a reasonable distance depending on the severity of the supply situation.

*— Encourage volume or dollar limitations at the discretion of the dealer. It is suggested that where inventory permits, fillups be made to alleviate wasted fuel for the customer. (This should not include reserve tanks and supplementary storage containers.)

*— Gas cans should not be filled except where necessary to move out-of-gas cars to service stations.

*— Encourage adoption of flag system to indicate availability of various services at service stations. *Green flag* indicates sale of gas to all customers. *Red flag* indicates station is closed. *Yellow flag* shows station is open for service only.

*— If the situation warrents, priority at the pump should be given only to those classes of customers in the (100) percent of current requirements category as listed in the Federal Mandatory Allocation Regulations for gasoline and diesel.

(3) *Residential and General Public*

— Urge homeowners during heating seasons to turn thermostats down 6°F during the day and to 55°F at night. A six degree reduction in every home would save the equivalent of 600,000 barrels per day nationally or enough to heat three million homes.

— Encourage homeowners to use storm windows, heavy polyethylene sheeting, and weatherstripping.

— Keep fireplace dampers closed at all times when not in use. Use fireplace to supplement space heat.

— Leave draperies open on sunny days facing the sun. Close at night to protect against the cold.

— Close off rooms not in use.

— Reduce hot water temperature. Take shower baths instead of filling the tub. Operate dishwashers and clothes washers only at full loads to reduce number of washing needed. Use detergents designed for cold or warm water washing. Repair leaky faucets.

— Avoid letting hot water run constantly while washing dishes, shaving and similar uses.

(4) *Industrial and Commerical*

— Encourage reduction of space heat. Turn thermostats down to maintain 65°F during working hours and 55°F during non-working hours. Exceptions to these efforts may be necessary for protection and operation of specialized equipment, e.g., hospitals, greenhouses, and computers.

— Encourage reduction of hot water heater temperature to 105°F.

— Reduce the number of trips scheduled for corporate airplanes and other motor vehicles. Combine several trips into one.

— Encourage combustion efficiency of boiler and other process equipment.

- — Promote use of the communication facilities in lieu of travel.
- — Encourage industry to use rail shipments instead of trucks where fuel would be conserved. Improve intercity freight deliveries and service calls.

Phase II

In the event that Phase I does not improve the supply situation, the Governor, upon approval from the Legislative Crisis Committee should institute Phase II.

Phase II could include, on a mandatory basis, those items in Phase I marked with an *asterisk*. The Governor should continue to ask for voluntary compliance to all other measures.

The shortage situation in one type of fuel may be having an adverse effect on other energy resources at this point. The Governor may consider instituting voluntary and/or mandatory orders for other energy resources. In matters relating to electricity and/or natural gas, the North Carolina Utilities Commission is the regulatory authority.

Phase III

It is reasonable to assume that the crisis is of regional-national proportions if abatement of the shortage does not occur during Phase I and II after crisis declaration. Therefore, it is reasoned that national controls would be in existence at this point. However, the Governor may find it necessary to continue the mandatory controls for additional 30 day intervals, as approved by the Legislative Committee on Energy Crisis Management.

Termination

Termination of controls and orders implemented by the Governor will end 30 days after implementation unless renewed by affirmative action of the Governor and the Legislative Committee. Termination will be by public announcement.

Implicit in this phased approach to the embargo scenario is the fact that some gasoline will still be available for consumption. The U.S. may not be energy independent, but it still produces 60 percent of its own petroleum supplies.

If the next embargo leads to the "worst case" then Phase III will be in effect and state planning will be pre-empted by the federal program. In either case, both the state and federal programs are designed to provide the consuming public the gasoline they need for essential transportation needs. However, some inconvenience will probably be experienced by the consumer. An embargo will remove from the market some amount of previously available supplies. No amount of planning will replace this lost supply. There is no way you can remove 40 percent of the current supply of petroleum without incurring some social discomfort. However, this does not mean essential activities must be curtailed.

The measures suggested by LaPointe imply a massive logistics problem. How do you make efficient use of the school bus fleets if they are fully utilized during the peak hours, from 7 to 9 a.m. and 3 to 5 p.m., picking up and delivering children? This is also the time that most men and women are going to and coming from work. In addition, he has stated, ". . . low residential densities make efficient mass transportation systems virtually impossible." Why would the use of the school bus fleet be any more efficient?

Many of LaPointe's recommendations such as rewards for carpooling, vanpooling and the utilization of mass transit systems are also encouraged by the Emergency Energy Program. However, in an emergency situation, where gasoline is in short supply, the above measures offer the reward of increased gasoline for other personal needs rather than monetary rewards.

LaPointe also believes that, "State and local government planners must go beyond 'encouragement' or 'guidance' and propose concrete measures for moving people to essential activities during periods of substantially reduced gasoline supplies."

The question of whether ". . . state and local government planners must go beyond 'encouragement' or 'guidance' " or merely make ". . . new rules for market transactions" seems to be more a matter of value judgment than obvious fact. LaPointe's reassurance that proposed non-market measures will affect more efficient (cost returning) results than a controlled market oriented program as proposed by the Emergency Energy Program is speculation. Realistically, political and economic considerations cannot be ignored. Any circumventing of the existing market structure would require a new, costly and cumbersome, bureaucratic structure. For any proposed program to be effective, it must be acceptable to both the North Carolina General Assembly and more importantly to cost conscious North Carolinians.

Conclusion

In sum, it is not at all clear that North Carolinians are secure in the areas of electrical generation, home heating, or transportation in the event of a renewed petroleum embargo. At the same time, considerable effort has been given to designing emergency plans that will help to obviate these problems during an energy crisis.

North Carolina's Emergency Energy Program is a group of contingency measures designed to reduce short-term energy supply problems. LaPointe's conclusion that, ". . . our main worry in a future substantial petroleum supply denial will be finding alternatives to private automobile use . . ." is a long-term and a costly problem that will have to be addressed by the federal government, since no state will have the resources to obviate the hardships of a substantial long-term embargo.

It is the belief of the Energy Division that the proposed Emergency Energy Program is capable of handling short-term supply problems, with a minimum of personal sacrifice and bureaucratic cost.

Miles Bidwell and Jean M. Bonnes

A Peak Load Pricing Policy for North Carolina Utilities

In the early 1970's North Carolina electric utility companies planned to embark on construction projects for new plants costing billions of dollars. But, for the first time in the history of the state, power firm policies fell upon turbulent waters. Soaring electric rates had resulted in a tide of consumer outrage. Legislative efforts delayed the companies from sailing their original courses. Questions were being raised about utility pricing policies.

In 1975, the North Carolina legislature adopted a measure by Senator McNeill Smith to require the state Utilities Commission to hold public hearings on peak load pricing and the future needs for electricity in the state. After the December, 1975 hearings, the Commission ordered the utilities to submit plans to implement this form of pricing.

With peak load pricing, a consumer is charged a rate based upon the time of day he uses the electricity. This system charges a lower rate for off-peak use to encourage electricity consumption at off-peak periods. Advocates of peak load pricing, sometimes called time of day or marginal cost pricing, claim there could be an immediate reduction in average monthly bills and that construction programs for new generating capacity to meet peak demand would be delayed for a significant period in the future.

"With peak load pricing, a consumer is charged a rate based upon the time of day he uses electricity."

The present rate structure is left over from the past when average costs for generating electricity were declining. Back then, people never used to worry whether they turned off lights in empty rooms or tried to conserve electricity in other ways. Most people did not question or understand the reason for the rate structure, because as their use increased, they got a cheaper rate, something like a bulk rate. They felt it was not worth the effort to conserve energy because it did not lower their monthly bill very much.

People were behaving exactly as the economic text books predicted. The declining block rate structure lowered the unit cost as more electricity was consumed. This meant that the last unit cost less than the average price. Even though electric bills rose with increased consumption, the added cost of using one more unit was small.[1]

Why the Increase in Electrical Rates?

In 1973, the oil embargo by the Organization of Petroleum Exporting Countries (OPEC) and the ensuing "energy crisis" raised our consciousness about a phenomenon that had begun several years earlier. Energy prices were rising. In North Carolina in 1961 the average price for one kilowatt* hour of electricity was 0.0125 dollars. In 1967, that price had dropped to 0.011 dollars. But by 1975, the average price had climbed to 0.0265 dollars and is still climbing.[2] There were several reasons for this change.

In the 1950's and 1960's the electric companies took advantage of economies of scale as they built larger and larger generating plants. The price of various fuels was nearly constant and these two factors combined to cause a decreasing cost of electricity generation. The only rate cases heard by the Utilities Commission were requests by the utility companies for decreases in rates. Meanwhile, the public enjoyed a substantial increase in real income, making it that much more difficult to get excited about the technical aspects of efficiency in electricity generation.

Electric power generating plants continued to expand. But, sometime in the early 1970's the electric utilities industry ran out of economies of scale and the costs of electricity and of additional generating plants began a rapid rise. This phenomenon, coupled with the sudden increase in oil and coal prices has spurred the abrupt jump in electrical rates.

Is the Existing Rate Structure Part of the Problem?

The present rate structures were drawn up in the old days. Since large generating plants were more efficient and had smaller average costs than the small

**A kilowatt is an amount of electricity used at any moment. An electric toaster might have a demand of 1,000 watts or one kilowatt. The same toaster if operated for an hour would consume one kilowatthour (kwh) of electricity.*

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Duke Power's Belews Creek Plant

Photo courtesy Duke Power Co.

plants, it seemed clear that if people could be induced to use more electricity, more efficient plants could be built and everyone would benefit from lower average electric rates. Therefore, the declining block system became the traditional way of pricing. The power company calculated the total expected cost of producing the electricity which included a "fair" rate of return on its capital, and divided by the number of kilowatt hours it expected to generate. This way it arrived at a price per kilowatt hour. This average price was then modified to charge a higher rate for the small user and a lower rate for the large consumers. Consumers were rewarded with lower rates if they used devices that consumed large quantities of electricity, like hot water heaters and electric heating for houses.

The result today, however, is not a lower average cost for generating electricity, but a higher cost, revealing the relation between cost and output. This cost of new expensive generating capacity, encouraged under the present system, is spread to all consumers in the form of higher average electric bills. It is one source of inefficiency in electricity generation.

A second inefficiency results from having prices and costs not directly related to each other. Under existing conditions, the cost of generating electricity increases with the amount being generated, because the most efficient generating plants are brought in first. In 1974, the fuel cost alone varied from 0.00186 dollars to 0.02768 dollars per kilowatt hour in the Duke system.[3] Average costs in the system are increasing with total use. Therefore, the cost of generating electricity at periods of peak demand is greater than the cost of generating it at times of low use. But people pay the same amount regardless of when they use it. Since this rate is charged at all times, the consumer has no incentive to plan to select the time of his use. The result is a greater demand at peak times, which requires the power companies to maintain additional expensive generating plants. The consumer is caught in a precarious position within an inefficient pricing system—a pricing system that encourages greater total use and greater peak use. What are the alternatives? What would be the effects of using a different approach? A good starting place to look for these answers is to examine the way other goods are distributed and priced.

The Competitive Model

In a competitive economic system, the consumers ultimately decide how a nation will allocate its scarce and limited resources by casting dollar votes in the market place. Consumers decide, for example, if the nation is to have an abundant supply of automobiles, rather than a well developed mass transit system.*

In all cases, the individual consumer decides whether or not to buy something by comparing the expected benefit with the price. In any competitive market, the prices of manufactured commodities reflect the marginal cost of producing the commodities.

The electric utilities industry is not a part of the competitive system. In the past, the first company to supply electricity to an area became the monopoly supplier. To protect citizens from monopoly power, states established commissions to regulate these industries.

On the one hand, the commission has a chance to set electricity prices in any way it chooses. On the other hand, the commission has the very difficult task of performing the functions that occur automatically through the interaction of producers and consumers in the competitive sector. The commission faces the problem of making the interrelated decision of how much electric capacity to have, and how to set the price signals that consumers use to decide how much electricity they want and when they want it.

There is an important distinction between a competitive market and a monopoly or non-competitive

**John Kenneth Galbraith would argue that in the real world of giant monopolies, corporations are able to cajole, coerce, and deceive the consumer into buying what the corporations want to sell. Barry Commoner in the Poverty of Power argues that the demise of public transit in the U.S. was helped along by General Motors buying up municipal trolley systems and shutting them down.*

system. The price is always a signal to the consumer for deciding how much of each item to purchase in both systems, but only in a perfectly competitive system must the price represent the marginal cost to the society of producing each item.

Marginal Cost Pricing

In a competitive market a producer does not set the price. The market determines the going price and the producer decides how much of this item to produce by comparing the price with his marginal cost.

The marginal cost is the cost of producing an extra unit or the difference in his total costs now and his total costs when he produces one more unit. If the marginal cost to produce a pencil, for example, is only two cents, but the market price is three cents, the manufacturer will continue to produce pencils and expand his output. When the marginal cost to produce the pencil equals the market price of three cents he will not produce beyond this quantity because the addition to cost would be greater than the increase in revenue which is market price. He will not, for example, want to expand production to a point where the marginal cost of that pencil is three and a half cents, half a cent above the market price. In a competitive system, all production will be such that the price of each good is equal to its marginal cost.

In the above case of pencils, this is a readily applied concept. In the case of electricity production and throughout this paper, however, the large scale and expense of generating plants make it appropriate to consider Long Run Marginal Cost (LRMC). The marginal cost is always the cost of producing another unit; however, when producing another unit involves building a new multi-billion dollar plant, this new capacity cost must be considered in calculating the marginal cost at levels of output which press against capacity. Since the cost of each new plant is greater than the last one, and it does not matter why the costs are increasing (it might be due to construction or capacity or pollution controls etc.), the appropriate long run marginal cost must reflect the cost of increasing the output. This is necessary if the optimal amount of generating capacity in the system is to be determined. In the long run, the desired amount of new capacity can be determined only by seeing how much electricity people want to use at a price that includes the potential cost of new capacity.

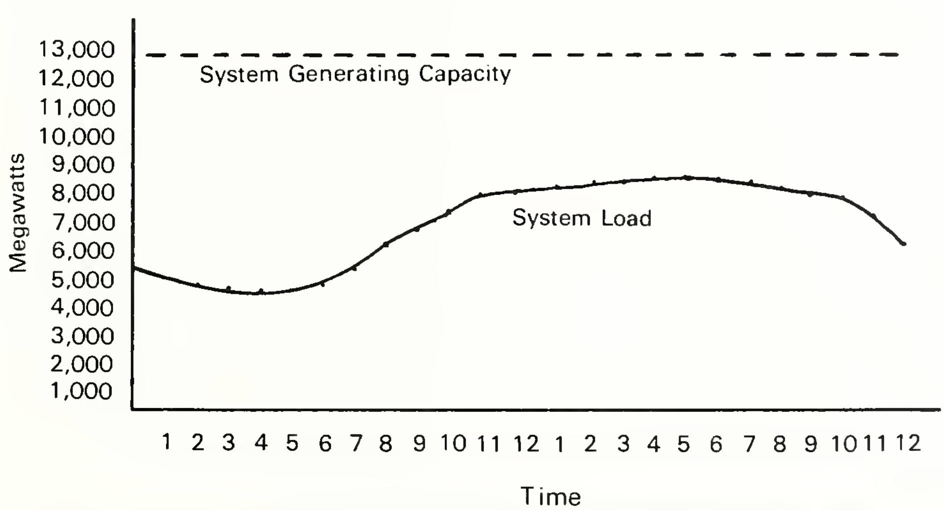
Because marginal cost pricing means setting the price equal to the cost of producing one more unit, it is irrelevant that some of the peaking electricity comes from hydro plants which have low marginal costs until they are fully used. The appropriate price is the cost of another KWH to the system. The general theory tells us that incremental capital costs should be included in the prices attached to the time period in which use presses against capacity. This is fair since it allocates the new construction costs to those who demand electricity during peak periods, and who, therefore, are making the new construction necessary.[4] On the other hand, including the cost of new construction might well decrease demand, and make construction of new generating plants unnecessary. "Both the British and the French electricity industries have reported improvements in system load factors of between 10 and 20 percent."[5] At the present time in the Duke system, which recorded 44 per cent reserves during its greatest peak, this would not have a matter of practical importance in rate setting. However, if and when the system demand does increase enough to approach capacity, then the marginal cost prices will reflect this marginal construction cost, and should result in equitable and efficient distribution of the costs.

The Present System is in Conflict with the Competitive Model

Regulatory commissions now set a price for electricity that has no relationship to the marginal cost of generating it. The price of electricity, though, still remains the signal on which the consumer bases the decision to purchase or not to purchase. But that price has no direct relationship to the cost to society of producing it. *The present pricing system leads to less*

Figure 1

Duke Power Company System Load for Day of Greatest Summer Peak, Monday, August 25, 1975



use of cheap off-peak electricity and more use of the expensive peak electricity. Therefore the average cost of all electricity generation is increased.

If the consumer were charged for the average costs of the products he used, the market place would be chaotic, like the supermarket described by Columbia University economist William Vickery, at the peak load pricing hearings before the North Carolina Utilities Commission during December, 1975.

To eliminate the bother of checkout counters, the supermarket would do away with the present marginal cost pricing system and institute an average price for all the goods based only on the weight of the purchase. For example, an economist might find the average price per pound by weighing all expected purchases at the grocery stores and dividing the entire weight into the desired revenue.

This pricing system would facilitate matters at the checkout station and probably eliminate lines. A simple scale would weigh each consumer's purchase and the bill would be based upon a fixed price per pound.

The result of this pricing scheme is predictable, said Vickery. The consumer would buy considerably more steak and less potatoes, and the supermarket would go broke. If this were a monopoly situation with no competing stores, then it could stay in business by substantially raising the average price.

Illustrative Examples

Figure 1, the August 25, 1975, daily pattern for the Duke system, illustrates the variation of demand over a 24-hour period for the day of the highest summer peak demand. The lowest demand was 4,503 megawatts at 5 a.m. The average demand for the day was 6,834 megawatts and was reached between 9 and 10 a.m. The greatest peak demand was over 8,400 megawatts and occured between 5 p.m. and 6 p.m.*

In Figure 2, MC shows the relationship between the marginal cost of generating the electricity and the amount being generated. This curve starts at a low level, corresponding to the use of the least expensive base load generating plants, then increases as the intermediate plants are brought in, and finally increases sharply as the "peaking" plants are added. As the limits of capacity are reached, this curve includes the cost of building new generating capacity to satisfy a further increase in demand and rises even more steeply. Graph (1) represents the demand shown in

**At this same time Duke Power had over 12,400 megawatts of installed generating capacity. About 40 per cent of capacity was idle at the time of greatest use. This level of reserves is more than double the amount considered desirable in the industry. In general, utilities like to have between 15 and 20 per cent reserves. This amount should be computed considering the possible purchases from neighboring systems. It should be added that the reserve is needed only as long as prices are not flexible so that there is no way to discourage use during a temporary shutdown of a plant.*

Figure 2

Different Pricing Systems and the Effects on Electricity Use

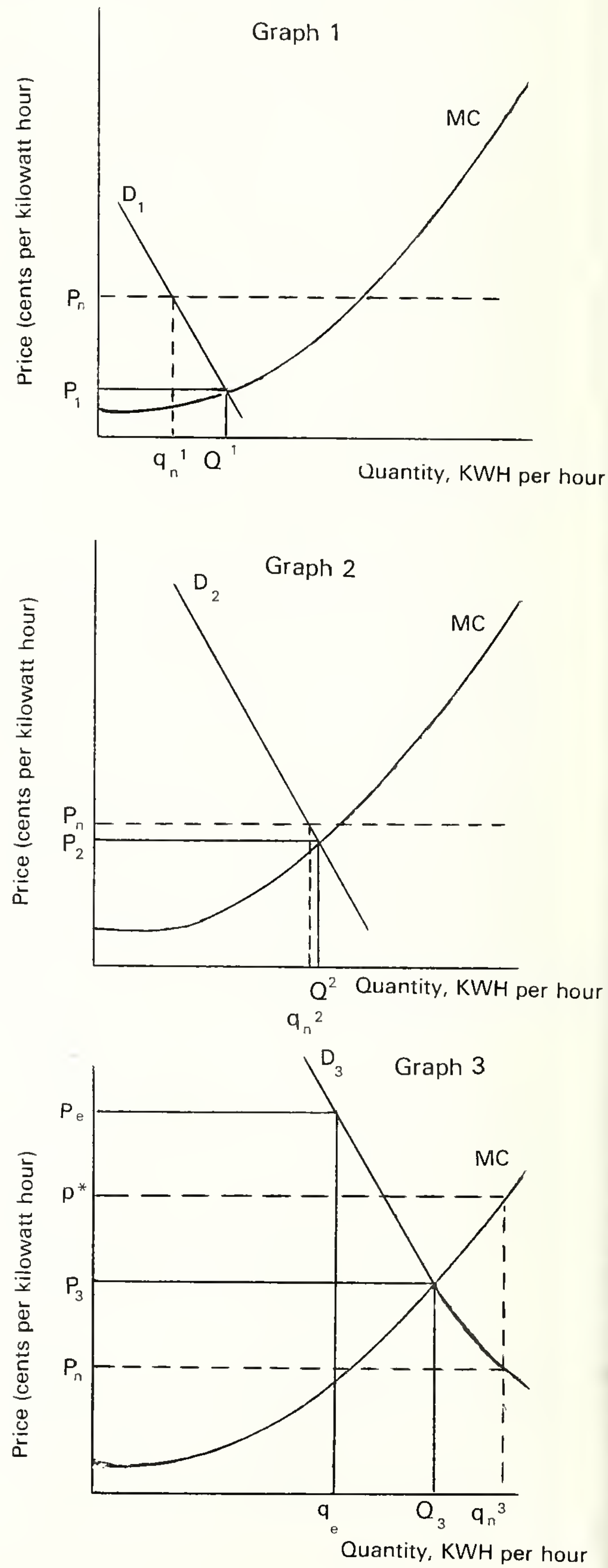


Table 1
Generating Capacity and Total Sales of Class A Electric Utility Companies in North Carolina
1970-1975

Generating Capacity[1] (KWH in 1000's)	1970	1971	1972	1973	1974	1975	Average Yearly Change
Duke	56,932,821	60,059,756	66,510,270	76,927,801	99,631,733	111,303,877	14.34
Vepco	46,147,680	48,013,560	55,179,240	67,162,920	74,889,240	81,035,130	11.92
CP&L	29,522,560	40,121,404	44,317,276	50,609,096	55,750,240	64,388,087	16.88
Nantahala	876,000	898,898	950,327	988,521	1,017,033	957,265	1.79
Total	133,479,061	149,093,618	166,957,113	195,688,338	231,288,246	257,684,359	14.06
Sales (including Resale)[2] (KWH in 1000's)							
Duke	35,287,995	36,912,737	39,688,068	43,158,623	42,343,600	42,137,670	3.61
Vepco	23,505,825	24,686,096	26,910,710	30,044,018	29,872,991	31,488,319	6.02
CP&L	17,547,500	19,656,673	22,101,472	24,081,319	24,076,446	24,118,233	6.57
Nantahala	374,735	415,173	414,278	445,685	474,269	412,891	1.96
Total	76,716,055	81,670,679	89,114,528	97,729,645	96,767,306	98,157,113	5.05
Ratio (Sales/Generating Capacity)							
Duke	.6198	.6146	.5967	.5610	.4250	.3786	
Vepco	.5094	.5141	.4877	.4473	.3989	.3886	
CP&L	.5944	.4899	.4987	.4758	.4319	.3746	
Nantahala	.4278	.4619	.4359	.4509	.4663	.4313	
Total	.5747	.5478	.5338	.4994	.4187	.3809	
Average Price[3] (¢/KWH)	1.34	1.43	1.49	1.60	2.04	2.65	

[1]Total installed KW capacity (FPC Form No. 1 p. 432-434) x 8760hours/year + KWH purchased (FPC Form No. 1 pg. 431, L. 10)

[2]FPC Form No. 1, p. 409, L. 12

[3]FPC Form No. 1, p. 409, L. 10, col. (b)/col(d): does not include resale

Figure 1 between 4 a.m. and 5 a.m., Graph (2), the demand between 10 a.m. and 11 a.m., and Graph (3), the demand between 5 p.m. and 6 p.m.

Under the present system, a customer is charged the same price per KWH whenever the electricity is used. The present average price is represented as Pn and was about 2.65 cents per KWH in 1975. At this price, consumers used $q_n 1$ between 4 a.m. and 5 a.m. as shown in graph (1). Later in the day, they used $q_n 2$ as shown in graph (2), and during the peak time with the price still at P_n consumers used $q_n{}^3$ as shown in Graph (3).

These same graphs also illustrate the effects of changing to a marginal cost, flat-rate (no block rates with variable time of day pricing) pricing system. A marginal cost pricing system would set prices equal to the marginal costs. Setting marginal cost prices consists of determining where the demand curve intersects the *MC* (marginal cost) curve in each diagram. An optimal set of prices is shown by P_1 in Graph (1), P_2 in Graph (2), and P_3 in Graph (3). Comparing the different prices, it is seen that the marginal cost price would be lower than the existing price at the times represented by Graph (1), and since the price was lower, people would use more electricity at this time, an increase from $q_n{}^1$ to Q^1. Much of this increase would come from people installing automatic timed switches on water heaters as is done in countries where time of day pricing is used.[6]

The price and quantity during the period represented by Graph (2) would be quite similar to the present for most residential users. The second big difference would occur during period (3). During this peak time, the electricity would be priced at its marginal cost instead of being subsidized. The price would be set at P_3. Because of the higher price, people would want to use less at this time and quantity would fall from $q_n{}^3$ to Q_3.

It is obvious that a substantial saving would be incurred. The people who now use $q_n{}^3$ of electricity at the time of peak do so because they are charged only P_n. However, the real cost of this electricity is p^*. The difference between these prices can be classified as a subsidy, financed by charging everyone more for their electricity at other times. The difference in these costs at different times of day increases as the system peak is reached, and has been estimated to vary by as much as from a low of about one cent per kwh at late night to over 11 cents per kwh at peak.*

Table 1 shows the relation between electric price and output and generating capacity. It was prepared by the office of Senator McNeill Smith whose bill established the hearings on electricity pricing.

The table shows that in the face of decreasing demand, utility companies have continued to expand generating capacity. Profits from electric utility companies are established as rates of return on capital base. This means that the more capital there is, the more profit there will be. But profit comes from higher electric rates.[7]

In 1970 Duke Power's ratio of output to capacity was 61.98%; by 1975 this had fallen to only 37.86%. This means that generating capacity has been increasing much faster than sales. As the percentage of excess capacity increases, the rate per kilowatthour increases.

Benefits

Possibly the largest savings from marginal cost pricing would be gained in the long run because the higher price and lower use at peak times could decrease the need for new construction. If some time in the future, some customers showed by their willingness to pay a high price at peak, that using electricity at the time of peak was worth to them as much as it cost to produce the electricity, then peaking plants could be added. But, they would be paid for only by the people using the electricity at the time of peak, rather than by all customers.

When marginal capital costs are included in the peak period marginal cost, the discrepancy between peak and off-peak costs becomes greater as the cost of generating plants increases. For example, Duke Power estimates the cost of its proposed Perkins nuclear plant at *more than* 632 dollars per kilowatt of generating capacity.[8] If a pricing system could eliminate or reduce the need for excess capacity then expensive construction programs could be eliminated at a great savings to the consumer.

A peak load pricing system should also provide benefits to lower income utility users. If a marginal cost pricing system was implemented in North Carolina, the total revenue collected by the utilities would be likely to exceed the total costs for production. To keep consumers bills equal to average generating costs, a rebate of the difference between the total revenue collected and the total cost should be offered to the customer. The rebate would be computed by determining the difference between the total revenue collected and the total costs of operating the system, and dividing this by the number of customers served. Since electricity use increases directly with income (Recent federal studies show an income elasticity of electricity use of about 1 by cross section.[9] Most studies show in time series analysis the income elasticity is about .5[10].), this would cause a relative decrease in the electric bills of low income people. Therefore, a peak load pricing scheme should have positive distributional effects.

**Differences this large probably only occur when a system is being used almost to capacity and the marginal capital cost of new construction are therefore included in the marginal cost calculation. At the present rate of utilization in the electric systems in North Carolina, the price difference would be much less because there is much unused capacity even at the times of peak usage.*

Why Three Instead of Two Prices?

With a peak-load pricing system, at least three prices are needed over a 24-hour period, plus one or two emergency prices. The time of highest price would be a three to four hour period during the heaviest demand. A second period would include most of the remaining waking hours and would be similar to the existing price. A third rate, for late night hours, would be much lower prices to reward off-peak users.

"Possibly the largest savings from marginal cost pricing would be gained in the long run because the higher price and lower use at peak times could decrease the need for new construction."

During the hours of greatest demand and highest price, a consumer might choose to wait a few hours before turning up the air-conditioner, or save even more electricity by turning off his hot water heater. At off-peak hours when the price is very low, the customer might take advantage of the low rates by using a timer on his water heater, freezer, etc. Because time of summer peak coincides with the time when solar energy is most available, a peak pricing system would encourage development and use of solar technology.

A two price system is not considered appropriate because the object is to set prices that reflect marginal costs and the variation in marginal cost is so great that a two price system could only approximate the marginal cost part of the time. The rest of the time, the price would be either greater or less than marginal cost, and much of the present inefficiency would still persist with the addition of a more expensive metering system. A related problem is that if only two prices are used, the change in price from one to another must be substantial. Any sudden change in prices could cause a shift to the other side of the high priced period and shift the peak. A three or more price system is necessary so that changes from one price to the next can be sufficiently small. The optimal system would have very many prices. The use of three or four is a compromise between efficiency in pricing and the costs of metering.[11]

How should such a system be implemented? Inexpensive metering systems have been developed in Europe and could be used, or existing meters could be modified to provide multiple price capacity. In addition

Duke Power's McGuire Nuclear Generating Station is about 75 percent complete

Photo courtesy Duke Power Co.

to the three time of day prices, one or two emergency prices should be added. An emergency high rate would substitute for excess capacity. If a large plant broke down at a time of heavy use, the system would switch to an emergency rate such as the one shown as price= P^e on Figure 2, graph 3. As explained previously, the resulting difference between the power companies' total costs and the total revenue collected would be rebated equally to customers, so that only the people who used more than the average would wind up paying more. A low income, small user could conceivably wind up receiving a payment from the company instead of a bill at the end of the month.

What Choice...

In the long run, the choice facing consumers and Utility Commissions is between building new generating facilities or marginal cost pricing. As Carolina Power and Light said in an advertisement in the *Raleigh News and Observer*, "...the less you use at hours of peak demand, the less generating capacity we'll have to build. And the less your electric bill will have to go up in the future."[12]

After the decision is made to commit sums of capital for construction of new plants, all consumers of electricity are strapped with the economic burden. (Duke Power's proposed Perkins Nuclear Station will cost about three billion dollars, or the equivalent of the net worth of Duke Power's total assets in 1975.)

Many people seem confused by the concept behind peak load pricing. But, these same people have lived with peak load pricing for other commodities for most of their lives. The telephone company has special rates for time of day use to reward callers for using the lines during off-peak hours. This redistributes the demand for services. Without a marginal cost or time of day pricing system, the telephone customers would have no incentive to wait until evening to make calls. The telephone company would need to build more facilities and transmission lines to accomodate the peak hour demand,and the rates would have to increase to pay for building this "needed" new capacity.

Under an average pricing system, rates would skyrocket as the telephone company scrambled to keep up with a new construction program. Since the consumer would have no incentive to be selective of the time of day he phoned long distance, the wires would be flooded daily and the lines hopelessly tied up, resulting eventually in "ring out" (comparable to a brown or blackout). This would be followed by more construction programs and more rate increases.

There is no dispute among conservative or liberal economists that peak load or marginal cost pricing is the most efficient way to allocate any resource, including electricity. Marginal cost pricing is a method of pricing followed by electric utilities in nations around the globe. Marginal cost pricing is followed by business operations throughout the United States. It would seem such a system should be used by North Carolina utilities.

Footnotes

1. For a discussion of increasing costs and decreasing economies of scale, see: Leonard W. Weiss, "Antitrust in the Electric Power Industry," in *Promoting Competition in Regulated Markets,*. The Brookings Institution, Washington, D.C. 1975.
2. Federal Power Commission, *Form 1*, p. 409.
3. Duke Power Company and the Federal Power Commission, *Form 1*.
4. The traditional theory of peak load pricing is that the peak users pay the marginal capital cost as well as marginal operating costs. See Berlin, Cicchetti, and Gilen, *Energy Policy Project*, Chapter 3, 1974, also Alfred Kahn, "Between Theory and Practice", *Public Utilities Fortnightly*, January 2, 1975, pp. 29-33.
5. Paul L. Joskow and Martin L. Baugham, "The Future of the U.S. Nuclear Energy Industry", *Bell Journal of Economics*, Spring 1976, p. 17.
6. An extensive discussion of peak load pricing methods used in France and England appears in P. L. Joskow, et al., "Symposium on Peak Load Pricing", *Bell Journal of Economics*, 1976, pp. 197-240.
7. Commonly called the A-J effect, this phenomena is explained in Averich, H. and L. Johnson, "Behavior of the Firm under Regulatory Constraint", *American Economic Review*, December 1962.
8. United States Nuclear Regulatory Commission, *Final Environmental Impact Statement*, October 1975, Table 9.1
9. Bureau of Labor Statistics, *Consumer Expenditure Survey*.
10. Lester P. Taylor, "The Demand for Electricity: A Survey", *Bell Journal of Economics*, Spring, 1975, pp. 74-110.
11. A discussion of how to best allocate marginal capacity costs to prices at different time periods are discussed by John T. Wnders, "Peak Load Pricing in the Electric Utility Industry", *Bell Journal of Economics*, Spring 1976, pp. 232-241. He argues some marginal capacity costs should be included at all times.
12. Advertisement, *Raleigh News and Observer*, October 12, 1976.

The Other Arms Race: The Liquid Metal Fast Breeder Reactor and the Plutonium Safeguards Problem

The development of breeder reactors that produce more fuel than they consume should be accelerated as a means of reducing the costs and hazards of nuclear power.

-Southern Governor's Task Force for Nuclear Power[1]

The plutonium breeder reactor is a government financed moloch, plagued by catastrophic dangers, massive cost overruns and questionable economic value, which the government technocrats are building for the private utilities . . . .lemon socialism.

-Ralph Nader[2]

Since its inception, controversy has surrounded the development of the Liquid Metal Fast Breeder Reactor (LMFBR) program. Why? The LMFBR presents significantly higher risks than the current generation of conventional Light Water Reactors (LWR), due mainly to the safeguards problems associated with the breeder's plutonium fuel cycle. Plutonium creates hazards to human welfare for several reasons. It is an extremely toxic substance. Furthermore, it is relatively easy to construct a nuclear bomb out of an quantity of plutonium the size of a softball and small amounts of plutonium can be used directly as radiation dispersal weapons. These potential dangers are accentuated by the breeder fuel cycle, which requires large amounts of cross-country transportation of nuclear materials. Shipments in transit are especially vulnerable to theft and sabotaged induced disasters. Nuclear black markets for terrorists and hostile governments may develop.

In the midst of this controversy, the LMFBR has been given the highest priority in recent federal energy expenditures. During fiscal year 1973, out of the total energy research and development budget of 0.7 billion dollars, the breeder received 0.3 billion dollars and "other nuclear" was allocated 0.2 billion dollars.[3] Through 1974, the LMFBR has consumed 1.8 billion dollars, and the Energy Research and Development administration (ERDA) conservatively estimates an additional 8.9 billion dollars, (omitting operating subsidies to early commercial breeders and private capital) will be needed to bring the project to fruition. ERDA hopes the first commercial models will be available in 1987 and "optimistically" projects 186 operative LMFBR's by the year 2000.[4]

Why has the breeder reactor been emphasized? Proponents cite national security, lower long-run energy generation costs, and a somewhat lower thermal pollution capacity. It is true that the breeder technology offers an advantage in meeting a short-term energy independence goal because of the relative scarcity of uranium 235 for the LWR. Dale has shown that "taken by itself, U-235 makes only a minimal contribution to overcoming oil scarcity."[5] Only 0.7 percent of mined uranium is in the U-235 form; most is U-238 which cannot be used in the LWR but can be converted into plutonium 239 for use as LMFBR fuel. In addition, the breeder reactor actually produces more fissile Pu-239 than it consumes. Nevertheless, the relevant questions are whether health and safety standards will be constraining factors and whether solar power, fusion, or alternate nuclear cycles might be more economical alternatives when all the costs are included.

Opponents of the LMFBR have produced counter-

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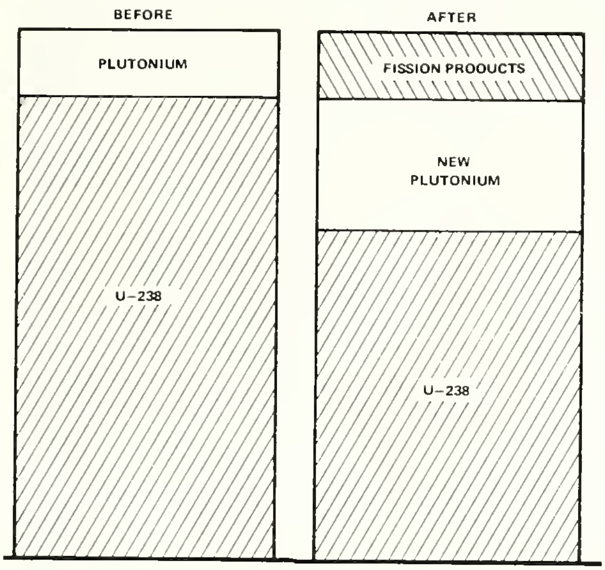


The breeder produces more plutonium than it consumes out of non-fissionable uranium 238.

Source: General Electric, "Our Only Reasonable Alternative"

studies showing the breeder cannot be justified from an economic point of view when more conservative assumptions of future energy demand, uranium supply, the rate of time discount, and the date of commercial introduction are made.[6]

However, the LMFBR does not produce higher levels of routine radiation emissions than conventional reactors, and under ordinary conditions, these levels will be below natural background concentrations. Core Disassembly Accidents are no more likely for the LMFBR than the LWR. There is, though, one area of additional hazard for the LMFBR fuel cycle. A National Science Foundation survey of scientists pinpointed a high degree of concern over nuclear material safeguards. This is where the breeder carries extra risks.[7] Nobel laureates line up on both sides of nuclear power issues. The average citizen is not sufficiently informed.

The purpose of this study is to examine the safeguard risks associated with the breeder reactor. First, the safeguard problem is defined. The safeguard risks of the breeder reactor are compared in relation to the other types of nuclear reactors considered for use in the United States. (These reactors operate on different fuel cycles and safeguard risks depend on the fuel cycle.) This is followed by a discussion of the safeguard risks, and the methods and costs of assembling a safeguards system. The article concludes by emphasizing the conflicting array of opinions and policy implications for the breeder program.

The Safeguards Problem

Safeguard risks are narrowly defined as one subset of nuclear power safety risks. *Safeguard risks are man-made in origin; they include nuclear theft and subsequent use of Strategic Nuclear Material* (SNM) for bombs or radiological dispersal weapons as well as acts of sabotage which may induce accidents in operation or transportation.* ERDA's second environmental impact statement on the breeder program discusses the safeguards issue but does "not attempt to quantify the risk on the rationale that the frequency of such occurrences cannot now be estimated."[8] Uncertainty is large because society is facing a new problem and firm safeguard methods and policies have not yet been established.

Plutonium and Radiation Risks

Even though safeguard risks have not been quantified, they are real, and could prove damaging to human welfare. There are four broad categories of radiation danger: somatic, genetic, teratogenic, and carcinogenic. It must be emphasized that the effect of radiation is cumulative; the total body burden is important.

Somatic effects refer to physical damage to body cells and tissues. The immediate result of exposure of human tissue to radiation is the removal of electrons which are then free to ionize other molecules. Chemical bonds split and cell structures become disorganized. Plutonium 239, the primary fuel used in the LMFBR, is a heavy emitter of alpha particles which cannot pentrate through the skin. Inhalation is the primary mode of contact because most forms of plutonium are relatively insoluble. This does not mean that somatic effects are confined to the respiratory system because the lymphatic and circulatory systems transport the dose throughout the body. Much of the non-lung body burden of plutonium is stored in the skeletal system. Possible results of somatic damage are death, growth impairment, mental retardation, cataracts, and sterilization.

However, the immediate somatic effects of plutonium exposures may be the least important. A dose may have deadly future ramifications to the exposed individual and to future generations. According to Russell, a dose of sixty rads* per generation (30 years) delivered continuously would double the mutation rate.[9] The United Nations Scientific Committee on Effects of Atmospheric Radiation suggests that there is no threshold for genetic effects and "the frequency of mutation is proportional to dose, but is not independent of dose rate."[10] Genes have somatic implications as well. Lederberg, a Nobel laureate in Genetics, writes, "It is generally accepted that there is a genetic component in much, if not all disease."[11]

Radiation is also teratogenic; it has the ability to cause birth defects.

* *Strategic Nuclear Material consists of material that can be fabricated into a fission bomb. A strategic quantity is the amount of material needed for the construction of one bomb. Substrategic quantities of plutonium are also dangerous due to its toxicity.*

***The rad is a dose corresponding to the absorption of one hundred ergs of energy per gram of body tissue.*

A fourth possible result of radiation exposure is carcinogenesis. The exact process of how injury initiates cancer is not known and there are long and variable periods. One ten millionth of an ounce of plutonium injected subcutaneously in dogs produces bone cancer.[12] The National Academy of Sciences Commission on Biological Effects of Ionizing Radiation (BEIR) estimates the lung cancer risk at 1.3×10^{-6} per year-man-rem* for adults.[13]

Gofman and Tamplin take a more extreme view. They claim the cancer risk factor is 1800 times greater than the BEIR estimate. "If the average exposure of the U.S. population were to reach the allowable 0.17 rads per year average, there would, in time, be an excess of 32,000 cases of fatal cancer plus leukemia per year, and this would occur year after year."[14]

Plutonium may also present special dangers. The International Commission on Radiological Protection has warned that, "In terms of amount available, projected usage, extent of anticipated accidental human exposure and radiotoxicity, plutonium is the most formidable radionuclide in the periodic table."[15]

> "Terrorists frequently attack their single-minded goals with fanaticism and ruthlessness."

Plutonium burns spontaneously when exposed to air, forming intense insoluble plutonium dioxide particles. One ounce of plutonium can yield 10 trillion small aerosols which may be suspended in the atmosphere. Some scientists have reported that plutonium emits a special type of alpha particle known as a "hot particle" because of its intensity and small size. These small radioactive aerosols may penetrate deeper into air sacs and remain embedded in respiratory tissues. It has also been suggested that "Energy dissipated in a limited volume may be far more carcinogenic than if the same type of radiation were to dissipate its energy over a much larger mass."[16] According to Geesaman, plutonium "hot particles" pose a carcinogenic risk between 100 and 10,000 times greater than the National Commission on Radiological Protection (NCRP) calculation. The British Medical Research Council and the U.S. NCRP have rejected the "hot particle" hypothesis as unfounded. ERDA has not taken a formal stand on the matter, awaiting the results of a study to be completed in 1985. Hardly anything is known about the total long-run effects of radiation in the biosphere.

Nuclear Terrorism and Theft

Radiation could be released from a variety of terrorist activities following a theft of nuclear materials. Terrorists frequently attack their single-minded goals with fanaticism and ruthlessness. Westinghouse Corporation "clearly recognizes that the threat of exposure, hijacking, and theft increases as more light water and breeder reactors are placed in service." However, Westinghouse does not appreciate the nature of a terrorist when it claims that "spent fuel has too high a level of penetrating radiation to be a target of theft or diversion."[17] Terrorists have been known to take health risks and often wish to die as martyrs to their cause. Hostile governments may also be a threat.

What are the risks of nuclear theft? Opinion varies. The impact statement prepared by ERDA states that "to obtain significant quantities, a large number of thefts must be committed with a concomitant high risk of detection."[18] Former Congressman Hosmer, a nuclear power advocate and ally of the Atomic Energy Commission (AEC), warns that, "Liberating a half gram of plutonium at a time might be so small an amount as to be relatively undetectable even by the best black boxes and the sharpest eyed inspectors."[19]

Where is nuclear theft most likely to occur? Fresh fuel assemblies are prime targets because they contain SNM in large quantities and are pre-packaged for safe handling. Also, there are fewer physical barriers to cross in transit than at a nuclear facility. Willrich and Taylor downgrade the possibility of plutonium theft in stages when it is mixed with intensely gamma radioactive products. The most susceptible areas are then

> . . . the output of reprocessing plants, plutonium storage facilities, fuel fabrication plants, fresh fuel storage facilities, and the transportation links . . . Among these the places that would be most vulnerable to attempted thefts would be the plutonium load-out rooms at reprocessing plants where an employee might pour out very small quantities of plutonium nitrate into a container for surreptitious removal; or at fuel fabrication plants, where an employee might steal a few fuel pellets or a plutonium-bearing fuel rod or fuel pin.[20]

What will happen to stolen plutonium? Employee-related thefts will probably enter a black market since employees with clearances are rarely members of subversive organizations. Hijacked-transportation-related thefts are probably placed directly in the hands of terrorists or organized crime. The profit potential is tremendous. Plutonium is valuable as a legitimate fuel source. One kilogram "can produce as much energy in a power station as 1,700 tonnes** of oil."[21] Its black market value will be much higher as

**The estimated biological effect of a radiation dose is measured by the rem. For example, a dose of 0.1 rad from neutrons or high energy protons is approximately equal to one rem. One rem is also equivalent, roughly, to one rad of X-Ray or beta radiation and a mere 0.05 rad from particles heavier than protons.*

***One metric tonne equals 1000 kilograms or 2200 pounds.*

an instrument of death and destruction capable of bringing about land conquest, religious, racial, or national genocide, coups d'état, and international income redistribution. In 1970, a fourteen year-old honor student in Orlando, Florida bluffed a nuclear bomb threat and almost succeeded in gaining one million dollars of ransom money.

Taylor, in congressional testimony, insisted that present safeguards are "not adequate to prevent theft by heavily armed groups with resources and motivation comparable to the Brinks gang and other groups of professional criminals".[22]

Three Nuclear Fuel Cycles

In order to evaluate the likelihood and places of origin of potential safeguard risks in the breeder reactor, an examination of its nuclear fuel cycle is crucial. Determining the relative risks involved requires a comparison with the two other major types of nuclear reactors. The three types of fission reactors considered serious contenders in the upcoming U.S. energy picture are the Liquid Metal Fast Breeder Reactor (LMFBR), the conventional Light Water Reactor (LWR), and the High Temperature Gas Reactor (HTGR). Each operates on a different nuclear fuel system.

The LMFBR* releases energy as it converts uranium 238 to plutonium 239. Occasionally, Pu-239 captures an extra neutron without undergoing fission. The product, plutonium 240 poisons chain reactions in the reactor. Therefore, when the 240 isotope content builds up to 10 percent to 20 percent of the total plutonium content, the fuel rods have to be removed. At that time, there is also more Pu-239 than existed originally in the fuel assembly. Economic factors encourage separation of the Pu-239 from the Pu-240 and subsequent reprocessing for re-use as fuel for either the LMFBR or the LWR. After reprocessing, the material is then transported to a fuel fabrication plant. From there, it is ready to be sent to a reactor.

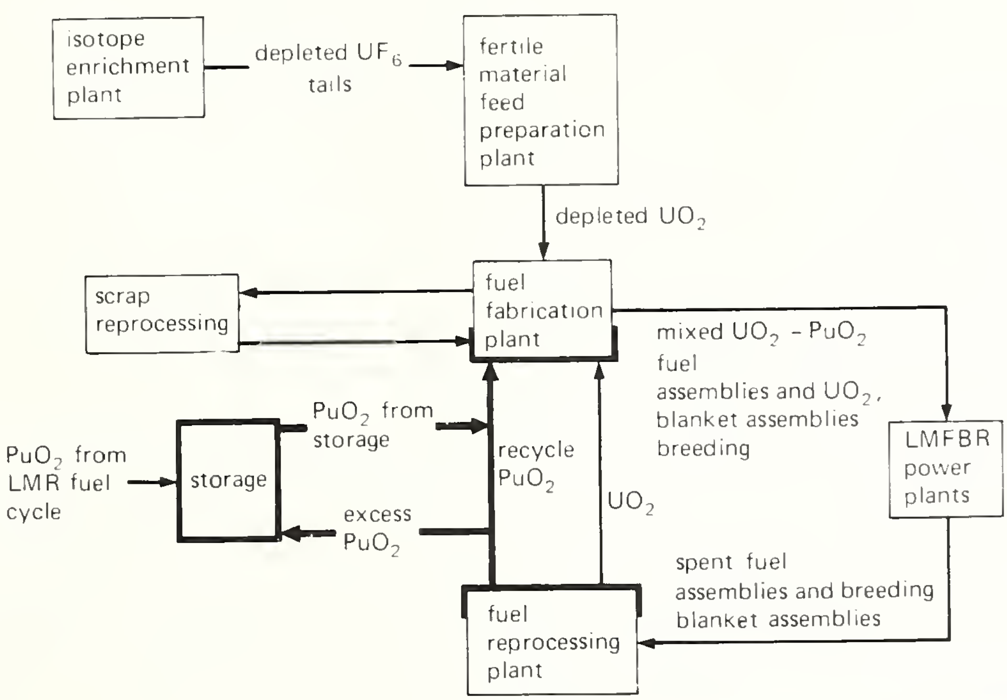
Plutonium 239 poses most of the safeguard problems because it can be used to construct a nuclear bomb. The 240 isotope is useless to potential bomb makers. However, both isotopes are strong alpha emitters and can be used in radiological dispersal weapons. Large quantities of plutonium 239 are available in forms relatively safe to handle after reprocessing up until the new fuel rods are inserted into a reactor core. Spent fuel rods** are less of a problem since detection and recovery is simplified. (The gamma radioactive fission products can be more easily identified by Geiger counters.) The size of the nuclear material flows is indicated by the example of the Clinch River Breeder Reactor. This small government demonstration LMFBR located in Oak Ridge, Tennessee will require 20 tons of plutonium and 210 tons of uranium during its 30-year plant life. One third of the fuel core will be replaced annually.[23]

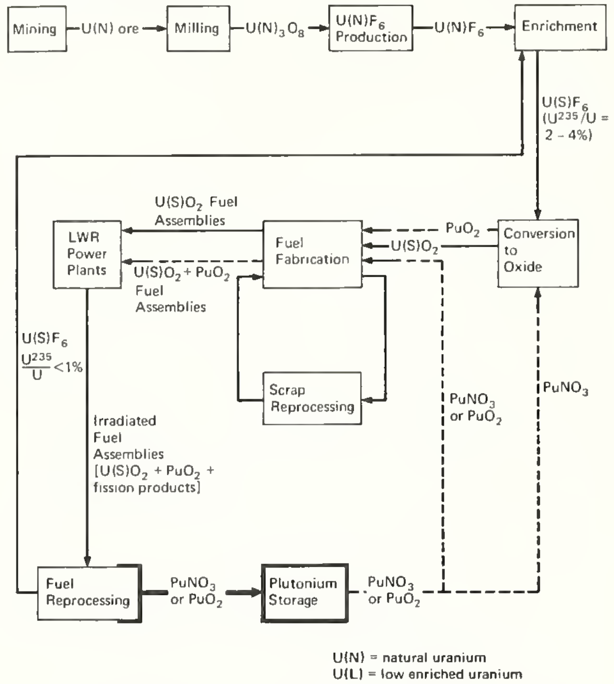
The current generation of nuclear power plants, the LWR, splits uranium 235. During the process, some plutonium is produced as a by-product. Since it is possible for an LWR to operate on recycled plutonium when certain modifications in plant design are made, spent LWR fuel may also be shipped across country to

The term "liquid metal" refers to the sodium coolant in the breeder reactor; the nuclear material is in the solid form.

***Spent fuel is the depleted nuclear material left over after fission.*

The Liquid Metal Fast Breeder Reactor (LMFBR) Fuel Cycle





The Light Water Reactor (LWR) Fuel Cycle

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capital-intensive reprocessing facilities.* The magnitude of safeguard risks is much lower in the LWR than in the LMFBR for several reasons. First, *the LMFBR involves approximately six times as much plutonium overall and two to three times as much in fresh fuel assemblies, when compared to the LWR with plutonium recycling.*[24] Second, LWR fuel rods are much less concentrated than the LMFBR rods. A thief would need only 50 to 100 kilograms of rods to be able to build a bomb from LMFBR fuel rods at this stage.[25] The uranium in LWR fuel requires extensive processing before it can be used in a bomb and much more material must be stolen to acquire enough plutonium for a bomb.

The third major nuclear reactor type, the HTGR, converts relatively abundant thorium 232 to uranium 233. Like the LWR, the HTGR is not a breeder, although the HTGR has a higher efficiency and may be a partial solution to the problem of U-235 scarcity. After fabrication into fuel particles, the HTGR fuel is relatively dilute and large amounts of nuclear materials are transported in this fuel cycle and shipments appear especially vulnerable.

**The first reprocessing facility ceased operation in 1974 with the intention of resumption after enlargement of the West Valley, New York plant. Plutonium has been stockpiled at the facility. Recently, the plant was abandoned by the parent company leaving the plutonium disposal problem in the hands of the State or Federal government. At the present time, there is no LWR plutonium recycling operation in the United States, but another facility is planned in Illinois.*

In assessing the safeguard ramifications of these three nuclear fuel cycles, Willrich and Taylor have developed scenarios relating annual production rates for strategic nuclear materials to nine combinations of reactor types in use. Quantities are highest when the breeder is the predominant reactor and LWR plutonium is recycled. Potential bomb equivalents range from a low of 7,000 annually in 1980 to a year 2000 high of 250,000. The estimated number of plutonium truckloads to fuel fabrication plants varies from 300 to 3000 annually depending on the amount of plutonium recycling in the scenario. For all cases, Willrich and Taylor project 1000 American nuclear reactors, five to fifteen uranium enrichment plants, twenty fuel fabrication plants, and twenty fuel reprocessing plants in the year 2000.[26]

Cochran estimates that 100 million kilograms of plutonium will be in use by the year 2000.[27] He assumes a hypothetical figure of plutonium residuals to the environment from all sources including core accidents, nuclear theft, transportation losses, and natural disasters at a millionth of the stock in use. Placing the cancer risk at 0.05 per person per microcurie of plutonium 239 inhaled, Cochran estimates that 10^8 cancers would result. He admits that his estimate may be high or low by a factor of one thousand since the biosphere may provide a sink for some plutonium, but food chain cycling may countervail the effect.[27]

Types of Safeguard Problems

Once nuclear material has been stolen, there are three basic types of potential safeguard problems: the construction of nuclear bombs, radiation dispersal weapons, and the sabotage of nuclear facilities and transportation shipments.

One of the frequently mentioned complications of nuclear theft is the highly emotional issue of illicit nuclear bombs. Can a bomb be constructed from stolen SNM? How does the relative difficulty of fabrication compare for the LMFBR and alternate fuel cycles? How much material must be stolen to build an explosive? Not surprisingly, these questions have not been resolved.

Conflicting opinions abound. ERDA maintains, "While it does not theoretically take extremely large quantities of plutonium to manufacture a nuclear explosive, the process is not an easy or sure one to accomplish. The possibility of harm to the weapon maker is high, as is the possibility that the potential weapon would detonate prematurely with very minor results."[28]

Terrorists are interested in crude fission bombs, and therefore do not need to construct efficient, lightweight missile warheads. Taylor suggests that one person working alone could design and build a bomb equivalent to 100 tons of explosives from ten kilograms of reactor grade plutonium oxide. Such a bomb could kill 100,000 people in an urbanized area.[29] According to Kinderman, "the equipment requirements would not be large . . . a few tens of thousands of dollars of equipment properly installed."[30]

Terrorist groups able to accumulate strategic quantities of plutonium but lacking explosive fabrication expertise could conceivably kidnap or bribe someone to help them. Classified information and underground handbooks on bomb construction are already reputedly in circulation.

How risky is bomb fabrication to the terrorist? Because of the toxicity of plutonium, it would be wise to work with it behind an air-tight barrier to prevent inhalation. Heavy shielding is not necessary because most of the emissions are non-penetrating alpha particles. A bomb maker working with U-233 stolen from an HTGR fuel cycle facility would face larger health risks from penetrating gamma rays.

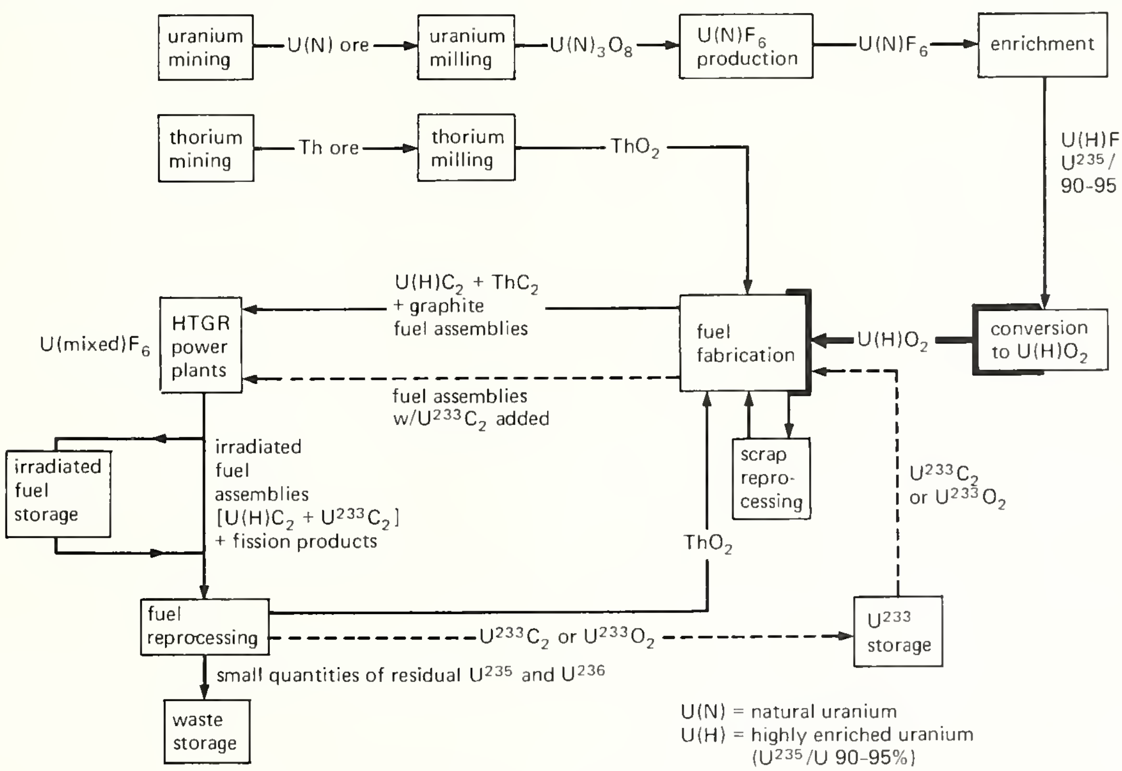
How much nuclear material is needed to build a bomb? One kilogram of plutonium 239 will not explode. A few neutrons will be undergoing fission, but they will generally escape the surface of the material without initiating further fissions. The amount of SNM that must be present for explosive fission is called the critical mass. It is sixteen kilograms for plutonium 239 (delta phase) and fifty kilograms for U-235.[31] Reflective metals such as beryllium can reduce the required critical mass substantially.

Plutonium will be present in many different forms in the various stages of the LMFBR cycle. Metallic plutonium is best for bomb-making. The Nuclear Regulatory Commission (NRC) has issued guidelines that in-transit plutonium should be in the oxide form to minimize damage in case of a transportation accident. The oxide form requires no special processing before use in a bomb core, but conversion to the pure metal increases the efficiency of a bomb and is not difficult. When plutonium is produced from U-238 in a breeder or conventional reactor, it is reprocessed into the nitrate form. Plutonium nitrate fissions too slowly to be directly usable in a bomb; however, it is a simple matter to transform it into the oxide form.

Spent breeder fuel assemblies contain relatively large proportions of plutonium 240. If the 240 isotope content is too high, the bomb may not fission or it may predetonate, fizzling out without suddenly releasing large amounts of radiation and energy. Yet, technology is now being developed to separate Pu-240 more easily.

In contrast, LWR fuel is enriched to only two or five percent U-235 and it is not directly usable in a nuclear bomb. U-238, the bulk of LWR fuel, will not sustain a chain reaction in a bomb. Currently, the technology for uranium enrichment is classified and complex. The processes require huge amounts of electricity and extensive facilities. Technology is in a constant state of change and research is being done on a laser method of uranium enrichment.

Another possible alternative, the HTGR, is susceptible to nuclear theft for bomb construction purposes at only two stages in its fuel cycle; during oxide con-



The High Temperature Gas Reactor (HTGR) Cycle

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version and fuel fabrication.

At the oxide conversion step, a thief would have to accumulate "125 kilograms of material to have enough uranium, after separation from the thorium, for a crude fission bomb."[32]

At fuel fabrication, HTGR uranium is enriched to 90-95 percent U-235. Despite the high enrichment level, once this material has been fabricated into fuel particles, it is not optimal bomb material. The U-235 is considerably diluted by thorium; requiring extensive chemical separation the HTGR fuel particle coatings also impede exploitation. The graphite must be burned off; silicon carbide will not burn and is not acid soluble. It must be crushed between rollers. A nuclear theft of four tonnes of HTGR fuel would provide fifteen kilograms of usable high enriched uranium. Before graphite coating and thorium combination, a thief would still need 1500 kilograms of particles.[33]

Radiation Dispersal Weapons

Stolen nuclear material, especially plutonium, can be very useful to terrorists lacking sufficient quantities for bomb construction. Plutonium could be scattered in the wind in populous areas, thrown into the water supply, or spread through buildings. Dispersal would claim a heavy toll in human life, property damage, and land contamination. A timing device could be used to release finely divided radioactive particles from containment.

Decontamination costs would run in the millions of dollars for a skyscraper. Outdoors, plutonium would be diluted by fresh ambient air and swept away by turbulence. However, it would be harder to contain the pollutant, and environmental damage may be more persistent outside. After settling on the ground, particles may re-enter the air or leach through the soil to ground water. For rational or irrational reasons, society may shun places victimized by radiological dispersal, incurring opportunity costs. Microgram quantities of plutonium could be placed in seemingly empty envelopes and mailed as inhalation letter bombs. Inhalation of uranium is relatively less harmful. "Plutonium 239 in equilibrium with its daughters has a direct radiological hazard about 10,000 time that of natural uranium in equilibrium."[34] Still larger quantities of the U-233 isotope product of HTGR's would be needed to match the dispersal hazard potential of plutonium.

The environmental impact statement on the LMFBR discounts the danger of radiological weapons, terming their use possible, but speculative. "Although the potential consequences could be significant, they would not approach the severity of a nuclear explosive. The use of radiological weapons does not appear to be consistent with the observed behavior of terrorists or extortionists."[35]

In fact, although not quite as dramatic as a nuclear bomb, radiological dispersal may have as much emotional impact. Foreign nations are probably less interested in radiological weapons because they can be self-defeating if the desired objective is conquest of agricultural land or special resources. Purely political or ideological wars can be fought with dispersal weapons, but many other biological warfare toxins are available and easier to use.

Nuclear Sabotage

Nuclear terrorism can take place without nuclear theft. Sabotage is derived from the French word *sabot* meaning a wooden shoe. A *sabot* strategically inserted in factory machinery very effectively gums up the works. Successful nuclear sabotage is far more worrisome. Armed groups could take over a reactor and cause a deliberate malfunction. A sabotage-induced incident would entail expensive repairs during a long shut-down period with additional costs in foregone output. Although the accidental Brown's Ferry reactor fire was not a safeguards-related event, it demonstrates the size of possible losses. Economic cost exceeded £50,000,000 (one British pound is approximately equal to 1.6 American dollars).[36]

During a LMFBR core accident, released energy may cause the liquid metal (sodium) coolant to boil.

"Plutonium could be scattered in the wind in populous areas, thrown into the water supply, or spread through buildings."

Normally, sodium lowers the temperature, decreasing the fission rate. Boiling sodium bubbles leave voids or areas of open space where heat and neutrons are not absorbed. This *positive sodium void coefficient* propagates the uncontrolled chain reaction. Released energy can further vaporize sodium, cause melting and relocation of the cladding and fuel core, and break apart mechanical reactor features. Webb estimated that because of runaway reactivity, a nuclear reactor explosion may be equivalent to as much as 20,000 pounds of TNT.[37]

Ralph Nader disputes ERDA's Rasmussen report findings on accident results. He quotes the American Physicist Society's projection that, "A reactor accident would cause 10,000 to 20,000 deaths, 22,000 to 350,000 injuries, 3,000 to 20,000 genetic deaths, plus widespread and enduring land contamination."[38]

Willrich and Taylor are less pessimistic on the sabotage issue because reactor safety designs are inteded to minimize susceptibility to natural and man-made disasters and to contain any accidents that might occur. They conclude that bombing a reactor core to destruction would be less dangerous than constructing a low yield fission bomb.

Transportation and the Safeguard Issue

Transportation may be the most vulnerable link in the chain of safeguards. Scenarios dependent on the LMFBR, or to a lesser extent the LWR with plutonium recycle, mandate the shipment of large amounts of strategic nuclear material. Projected data on the number of shipments and their contents is available for the Clinch River prototype breeder. There will be 84 to 106 annual shipments directly attributable to this single reactor operating at sub-commercial levels. 1250 kilograms of plutonium oxide, enough for 100 fission bombs will be shipped each year from the Clinch River prototype. NRC estimates shipping distances at from 500-1000 miles.[39] ERDA's risk determination for transportation in the LMFBR impact statement was based solely on assumptions and judgment. The EPA was unable to conclude that existing transport cask designs are adequate under actual accident conditions. ERDA made no attempt to predict risk from theft or sabotage of shipments.

The Nuclear Regulatory Commission has no jurisdiction over common carriers to avoid entering the domain of the Department of Transportation and the Interstate Commerce Commission. NRC can only directly set standards for nuclear facilities. It would be difficult to require secruity clearance for employees of common carriers.

Truck shipments are the most susceptible to diversion of SNM. Trucks are allowed to carry non-nuclear cargo along with SNM shipments, provided that no extra stops are made before discharging the nuclear cargo. Trucks should be monitored closely to insure adherence to the planned route.

Railroad cars are more difficult to hijack. On the other hand, no special design requirements pertain to trains and there are no restriction on stops and storage methods. It is difficult to plan ahead against theft conspiracy by railroad employees.

As for air transport, we must be prepared to prevent skyjacking and theft by employees or agents disguised as employees. There are currently no special regulations for the physical protection of air shipments or for guard-escorts. The Institute of Nuclear Materials Management notes, "The inability of the air industry to properly handle the cargo handed to it for air carriage now approaches a national scandal."[40] Air shipments are often combined with trucking of SNM from the airport to the destination.

"Transportation may be the most vulnerable link in the chain of safeguards."

Places of transfer or mode changes as well as warehouses must be carefully safeguarded. So far, there have been 300 reported accidents in transportation of radioactive materials. NRC claims no deaths or injuries resulted. "Accidents" can also be made to occur deliberately by intentional destruction of mechanical parts. A terrorist could also attack or bombard a shipment of nuclear materials. Transportation modes do not have the sophisticated design containment devices and barriers which help protect nuclear facilities. Although the quantity of SNM at stake is smaller, for a given shipment, the amounts are not strategically insignificant. The AEC projected 9,500 *spent fuel* shipments in the year 2000, with a mean distance of 500 miles or a total of 4,750,000 vehicle-miles. Fifty percent of these would be from LMFBR fuel cycle needs. Weinberg's counter-estimate is 12,000,000 vehicle miles traveled.[41] Nuclear shipments by any mode should be protected by armed, trained guards. Travel routes and speed should be carefully observed and back up force available.

What are the effects of a transportation "accident"? NRC's estimates are based on their expectation that the fuel cladding on unirradiated fuel assemblies will remain intact should the inner and outer containers be breached. Even a small break in the inner container could cause coolant loss spilling the entire contents of fuel rods as further breaks open up. NRC admits the severity of such an event, but considers the probability "incredible".

Safeguard Lapses

Industrial and governmental advocates of the LMFBR program who cite the generally good safety record of the nuclear industry in the past are naively attempting to justify extrapolations into the future. Nuclear power is becoming de-mystified as knowledge about its capabilities and limitations becomes more widespread. In a future predicated on a plutonium fuel cycle, vastly increased amounts of this element not found naturally on earth will be circulating across the country. Criminals and terrorists will gain awareness of their opportunities to take advantage of new technology.

Overall, the past record of the nuclear industry has been satisfactory. Nevertheless, there have been a number of serious lapses in nuclear safeguards. Most have not been given wide publicity. Edward Teller commented, "So far we have been extremely lucky. But with the spread of industrialization, with the greater number of simians monkeying around with things they do not completely understand, sooner or later a fool will prove greater than the proof even in a foolproof system."[42]

Carl Walske, former Assistant Defense Secretary for Atomic Energy Matters in 1974 Congressional testimony, stated that, "3600 employees with access to nuclear weapons or materials were replaced in one year because of alcoholism, mental illness, drug abuse, and disciplinary problems."[43]

Can the human element ever be eliminated as a risk factor? A serious lapse in safeguards occurred at the Kerr-McGee fuel production plant in Oklahoma. Large quantities of plutonium were reported missing and one employee, Karen Silkwood, died under mysterious circumstances. The Nuclear Energy Liability-Property Insurance Association is one of two pools underwriting nuclear policies. It has made 30 claim payments since 1957. None of these accidents occurred at power plants; most were transportation-related. The incidents include a $300,000 settlement to the estate of a cancer victim who was contaminated by plutonium at a truck terminal in 1963 and the 1975 loss of contaminated reactor filters after the boxes fell off a truck. The filters later turned up in a police "lost and found".

Safeguard Methods

There are four main purposes of a safeguards program: 1) to prevent diversion of nuclear material, 2) to detect deversion after its occurrence, 3) to recover lost material safely, and 4) in the event of a failure in the first three objectives to establish a scenario for protection of human welfare and minimization of environmental damage.

The Federal government and the nuclear power industry should work together with the scientific community and the public to develop a comprehensive safeguard system. Federal authority is currently fractionated. EPA urges a more clear-cut delineation of responsibility between ERDA and NRC. The AEC admitted in 1974, "Almost no standards exist in the materials protection area and in many cases the basic data needed to develop such standards have not been developed."[44]

We are now spending less than 10,000,000 dollars a year on safeguards. Hardly any research has been done in the area of stolen material recovery. ERDA is conducting a threat definition study to examine the uses of stolen nuclear material and the characteristics of possible perpetrators. The study should be complete in 1978. ERDA is also funding a small amount of research in computerized material monitoring. The agency will make a decision on the safeguards-acceptability of commercial LMFBR's in the early 1980's.

What are some of the methods used in a safeguard system? Strategic Nuclear Material accountancy is supposed to show if safeguards are working properly. It cannot prevent nuclear theft, but in the ideal case it serves as a deterrent by increasing the possibility of apprehending the culprit and capturing the material. In reality, there is a long time lag between theft and discovery. The acceptable limit of error in measurement for SNM at a reprocessing plant will represent a large amount of unaccounted for material. There is also a large amount of material located in the inaccessible parts of machinery and reactor cores. Edward Teller is concerned, *"I don't think anybody can foresee where one or two or five percent of the plutonium will find itself."*[45] The nuclear industry hopes for some improvements in on-line nondestructive assay techniques so that lag times can be reduced.

Many measures serving as safeguards are designed for routine physical protection. These safety methods include radiation shielding, containment to prevent criticality and allow heat dissipation, entry and exit controls, storage vaults, and foundations and barriers designed for maintaining stability in the event of earthquakes and other natural phenomena.

Other measures have been developed for security purposes. Security plans are not available to the public for obvious reasons. The development of portal radiation monitors and conventional explosive monitors could greatly improve a safeguard system. An alarm system could be coordinated with mechanized physical barriers and could alert the security force. A security force in conjunction with the rest of a safeguard system should be designed to control the "maximum credible" set of adverse circumstances. The question of government versus private responsibility for safeguard controls and costs has not been settled. ERDA is studying the possibility of a Federal nuclear guard force.

Alvin Weinberg urges creation of a "nuclear priesthood", a technocratic elite, which may be governmental or private, dedicated to the maintenance of security. Ordinary police forces may not appreciate the danger or may be unable to cope with system complexities. A "nuclear priesthood" may have some undesirable consequences. The FEA warns that, *"There should be consideration of the impacts on society . . . since safeguarding against plutonium theft is basically an insoluble problem without putting the whole nuclear energy system under military controls."*[46]

Britain's Royal Commission on Environmental Pollution warns that the "use of informers, infiltrators, wiretapping, checking on bank accounts, and the opening of mail . . . are highly likely and indeed inevitable" in an LMFBR economy.[47]

Finally, if society were willing to pay the price of possible loss of democratic values, how effective would the safeguard system be? According to Willrich and Taylor, "The quality of effort would be well beyond what the public normally expects from the law enforcement authorities in crime prevention, or even in the theft of large amounts of money."[48] Some serious lapses will undoubtedly occur.

Changes in fuel composition also have a large bearing on nuclear safeguards. The "cooldown" method is a way to change the composition of spent nuclear fuel without altering the fuel input. The LMFBR burns fuel at high specific power* favoring the formation of intense, short-lived radionuclides. For this reason, dispersal of spent LMFBR fuel carries a larger danger. Certain of these radioactive elements with high biological potentials decay to significantly lower concentrations with the passage of time. Weinberg suggests cooldown for a 360 day period before shipment to cut heat generated in shipping casks of spent fuel by a factor of six. By comparison, ERDA cost calculations in the environmental statement are based on a 30 day cooldown period. Cooldown is costly; it decreases the plutonium doubling time. It has been estimated that there is a loss of usable radioactive material of eighteen dollars per kilogram per month of waiting time.[49] That does not include additional costs associated with storage and inventory.

It is also possible to increase the danger to nuclear thieves by adding gamma emitters to fresh or spent fuel. Unfortunately, that may backfire and increase

** Specific Power equals watts per pound.*

the risks to the public. ERDA is also studying the possibility of poisoning unauthorized fissioning by the addition of isotopes which make it more difficult to construct bombs with large explosive potentials. Alternately, the chemical or physical forms might be altered to reduce toxicity in the event of dispersal. The most drastic fuel changes would be to reject the LMFBR fuel cycle and to avoid LWR plutonium recycle despite the economic incentives.

Safeguard risks may also be reduced by siting techniques. For example, co-location of some or all stages of fuel cycle facilities is recommended by EPA as a way to "greatly reduce the risk that a nuclear shipment between two facilities might be hijacked and also results in substantial savings in transportation costs to the enterprise."[50] A clustering of facilities into nuclear "parks", would also concentrate the problems of thermal pollution and susceptibility to natural and man-made disasters. Co-location is expensive in terms of foregone economies of scale since there would be a larger number of smaller fuel cycle facilities. Teller suggests location of reactors and facilities underground or underwater.

The Costs of Safeguards

Fortunately, the costs of pre-planned safeguards may not be unreasonable. Willrich and Taylor, critics of the meager controls originally anticipated, are optimistic. "It may appear . . . that the development and application of a system of safeguards that will keep the risks of nuclear theft very low indeed will result in enormous costs . . . this is not the case for a safeguard system which employs the best available technology and institutional mechanisms."[51]

Spokesmen from ERDA, NRC, the Joint Congressional Economics Committee, Westinghouse, and General Electric concur that the marginal cost of preplanned safeguards will be small relative to nuclear power expenditures, on the order of 1 percent to 2 percent of total nuclear costs. The exact magnitude is a matter of guesswork until firm regulations and requirments are set.

Because people are not currently aware of the magnitude of the problem, the political centers of power are not moving very quickly on the safeguard issue. In a 1976 report, the Government Accounting Office (GAO) found many safeguard deficiencies at ERDA contractor facilities and pointed out the need for "additional guards, alarms, doorway detectors, night vision devices, and improved communication equipment." But Congress appropriated less than half of the administration's 1976 request to upgrade contractor safeguards. ERDA has been allocated only 2.1 million dollars in fiscal 1976 to improve instruments measuring nuclear material.[52]

Conclusions

The safeguards issue is by no means resolved. Many questions are still unanswered. The probability of safeguard circumvention is very real, although as yet undertermined, due to uncertainty and the inchoate nature of safeguard planning. Various groups and individuals have expressed their own opinions about safeguard feasibility and the proper course of action for the Liquid Metal Fast Breeder Reactor program.

EPA was unable to conclude "on the basis of the information presented in the PFES* that commercial development of the LMFBR program can be accomplished without causing future unacceptable environmental impacts."[53]

The Scientist's Institute for Public Information denigrates the role of future technological improvements, "The advance of knowledge does not necessarily show the risks of LMFBR's to be smaller than ignorance or prudence would have thought them."[54]

The Rand Corporation concludes that due to the large amount of uncertainty surrounding the program, the LMFBR should be developed in an "austere, incremental sequential" manner, "with adequate time for testing and evaluation."[55]

A number of observers urge greater flexibility in an energy program to avoid excessive dependence on any single generation method. Edward Teller allows for the possibility that the "LMFBR will become the most useful reactor," but he stipulates that, "Claims to the effect that sooner or later the LMFBR will become unavoidable are unproven."[56] *The Royal Commission on Environmental Pollution urged postponement of the plutonium fuel economy for as long as possible while other alternatives are being developed.* Willrich and Taylor are concerned, yet more optimistic, "Obviously, there is no perfect solution to the problem of nuclear theft any more than there is a final solution to the problem of crime. But there are safeguards which if implemented, will reduce the risk . . . to a very low level, a level which, in our opinion, is acceptable."[57]

What should be done? Decision criteria and assumptions should be chosen conservatively because of the magnitude of potential risks and the lack of scientific consensus. Impartial research should be stepped up and public participation and debate should be encouraged. The Nuclear Regulatory Commission has two major efforts underway, a "Special Safeguards Study" on requirements and a report on the possible creation of a quasi-autonomous agency within NRC, the "Security Agency Study". ERDA is concentrating on threat definition and experimentation and demonstration of safeguard procedures.

These studies will not be complete until 1980-1982. It would therefore be reasonable for the government to hold down LMFBR operational development funds until these other issues are resolved. At any rate, some action should be taken now. Answers cannot be pushed off into the vague future: planning is preferable to procrastination.

Critics hope that ERDA will be able to live up to its promise that the "safeguards program will be designed to attain a level of protection to the public which

**Proposed Final Environmental Statement* would not increase significantly the overall risk of death, injury, or property damage from causes beyond the control of the individual."[58]

Likewise, it would be a futile self-fulfilling prophecy if other energy forms do not become feasible simply because the lion's share of research and development are channelled to the LMFBR, locking us into a single technology.

The plutonium safeguards problem has received little public attention. Few people are even aware of what an LMFBR is. Because this is an important public policy issue, the social decisions should be made by an informed populace.

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The Economics of Solar Technology in the Carolinas

Editor's Note: These articles discuss the economic viability of two types of solar energy technology using cost and weather data from Piedmont, North Carolina. In Single Family Home Solar Heating and Cooling, *a simple system for the solar powered space conditioning of a single unit residence is compared to conventional methods of space conditioning. The conclusion that the solar alternative is lower in lifetime costs is underscored by the increases in the costs of electricity and fuel oil which have occurred since the cost data for this article were gathered in 1975. In* The Feasibility of a Multi-Residence Total Solar Energy System, *a solar powered electrical generation and space conditioning system for a twenty unit residential development is compared with and found to be of higher cost than conventional methods of servicing such a development.*

Solar heating and cooling for single family units is economically feasible

Photo by Bruce Stiftel

Single Family Home Solar Heating and Cooling

It is impossible to deny we are rapidly depleting the world's conventional energy supplies. In addition, the use of conventional energy results in billions of dollars in pollution costs each year.[1] Household and commercial requirements account for about one-third of United States energy use and over one half of electricity demand.[2] Over 70 per cent of the energy consumed in these sectors is for heating, cooling, and water heating.[3] All three of these usages can be provided by existing solar technology. Implementation of that technology in North Carolina would result in a monetary savings to the individual homeowner and environmental savings to the public.

Solar Technology

Solar heating is simple. It usually involves pumping water or air over a solar heat collector and then storing the heat in rocks or water for circulation through the house. A design which has been utilized for over 18 years in three Washington, D.C. homes involves pumping water to the rooftop, allowing it to flow over a black sheet metal roof heated by the sun and into the basement to a storage tank which is surrounded by fist-size stones. A small blower activated by a thermostat circulates air through the stones and into the house. The solar heated water on the way to the storage tank is used to give a pre-heat boost to the domestic hot water supply.[4]

Solar housing technology involves only conventional materials such as sheet metal, glass, tubing, and rock. Construction includes steps which are unusual (e.g. installing a 1500 gallon tank in a basement), but it involves no special knowledge or equipment not possessed by most builders.

Although it is technologically feasible, solar air conditioning probably will not be economical until after 1980. Until that time there exist two cooling methods which have been associated with solar heating and which utilize less energy than conventional air conditioning. One is rooftop cooling which involves pumping water to the roof on cool nights,

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allowing it to flow over the roof, and storing "cold" in the storage tank used in the heating process. This is effective only in areas with cool dry summer nights. The second method involves the use of a conventional central air conditioning unit which operates at night, drying and cooling outside air and blowing it over the stones.

In both of these methods, during the day the same blower used during the winter heating cycle circulates the household air through the stones and thus cools and dehumidifies the house. Since the compressor only runs at night, when temperatures are lower, it should operate at higher efficiency than conventional central units.

Given this brief introduction to existing solar technology, we shall proceed to look at private sector feasibility of the solar heating and cooling alternative. First what are the parameters of construction costs, alternative fuel costs, discount rates, and system lifetime that will allow a solar system to "pay for itself" in fuel savings? Second, what are the implications of increasing energy costs with respect to solar desirability? Third, how adaptable is solar technology to different locations, housing patterns and design tastes?

A Framework for Cost Comparison

In order to determine with some precision both construction costs and energy use of a solar heating and cooling system, it was necessary to describe the size, design, location, and other details of a particular hypothetical house. Three builders were provided with an explanation of the principles of solar heating and cooling, and a plan similar to one circulated by Thomason,[5] including design specifications from "typical" houses used, by the North Carolina Oil Jobbers Association for energy cost comparisons, by Duke Power Company for insulation standards and energy savings estimates, and by the U.S. Environmental Protection Agency for energy conservation studies.

The house was to be a wooden frame structure facing North on a unshaded lot, with 1500 square feet of finished space, a full unfinished basement, and an attached enclosed unheated garage on slab. A side cutaway view of the house is shown in Figure 1.[6] The back side is covered by a solar collector extending from the crest of the roof to the ground. The front roof is less slanted, and as shown, may be equipped for summertime rooftop cooling. About one third of the basement is reserved for the solar storage tank and apparatus. All insulation standards were those required for FHA homes. The house was to be equipped with central cooling.

Conventional heating capital costs vary with type and locale. An oil, forced air system costs up to 2000 dollars installed with a usual price of about 1500 dollars.[7] Of the 1500 dollars, about 650 dollars is furnace cost, and 850 dollars is the cost of ductwork.[8] Electric furnaces installed run about the same price. The cheapest heating system to install is electric ceiling or baseboard heat which costs around 500 dollars.[9]

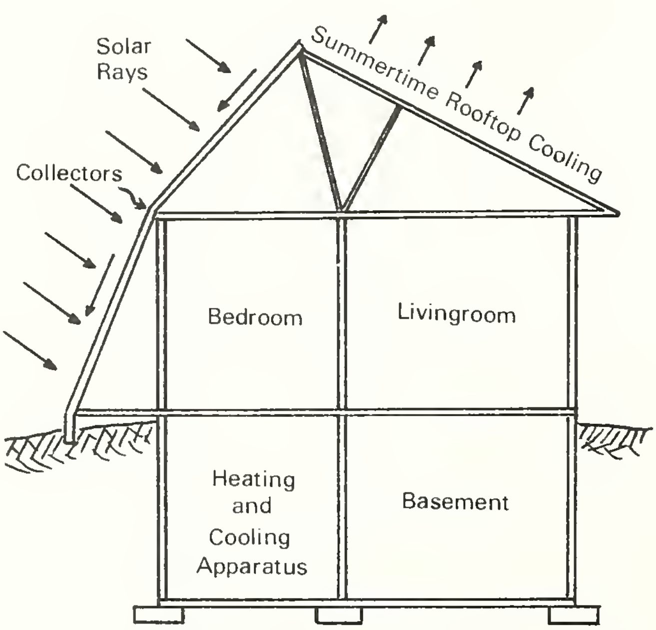
The differences in capital costs disappear to a great extent when central cooling is used. Ductwork must be added to the electric ceiling or baseboard heated home. This adds another 850 dollars to cooling capital costs of about 300 dollars per ton of refrigeration. (1 ton refrigeration = 200 BTU/min). This raises the total heating-cooling (3 ton load) equipment and installation costs to at least 2300 dollars for our "typical" house.[10]

The estimated costs of the solar system varied considerably. A piedmont Virginia contractor gave an estimate of about 6550 dollars for the solar heating system with off-peak cooling which included an auxiliary oil furnace.[11] A Chapel Hill independent builder gave the lowest estimate at about 4400 dollars.[12] This incorporated a lower cost method for auxiliary heating. The third estimate was 5450 dollars.

If the cheaper booster idea is substituted for the complete auxiliary heating in each estimate, an initial capital cost reduction of 550 dollars is realized. Thus, the estimates stand at 4400 dollars, 4900 dollars, and 6000 dollars. A cost estimate of 7300 dollars, proposed by Doolittle of North Carolina State University for a completed solar heated housing system with auxiliary for Raleigh, North Carolina was used for the high cost extreme.[13]

Figures 2 and 3 depict fuel requirements of the solar house and ensuing costs under 1975 electric rates in the region. This includes Thomason's finding that the off-peak cooling permits the same amount of electricity to produce 45 percent more cooling due to

Figure 1
A cutaway view of the "typical" house using solar heating and preheating of household hot water with off-peak cooling.



Drawing by Dan Fleishman

Figure 2

Energy Consumed by the Solar System

(KWH/yr = horsepower x 746 watts/hp x 1 KW/1000watts x days used/year x hours/day x 1/e)

	Heating		Cooling			
Variables	Warm Air Blower	Water Pump	3 Ton Compressor	Cooling Blower	Hot Water Heater	Misc. Electricity
power	.17 hp	.25 hp	3 hp	.5 hp	Solar elect.	——
daily use	20 h/d	3 h/d	9 h/d	9 h/d	——	——
duration of use	120 d/yr	120d/yr	150 d/yr	150 d/yr	——	——
efficiency	.75	.75	.85	.75	——	——
KWH/yr	406	90	3554	671	3400	9750

increase compressor efficiency at lower nighttime temperatures.[14] This is equivalent to getting the same cooling from about 68 percent of the amount of electricity required by conventional central cooling systems.

Assumptions necessary to the prototype situation are as follows: domestic hot water - 80 gallons per day; miscellaneous electrical use - 750 kwh per month; annual heating demand - 4380 degree days (at 65°F inside temperature); annual cooling demand - 900 hours. The last two estimates are based on a "typical" house studied by the N.C. Oil Jobbers Association in 1972.[15]

1975 electric rates plus the fuel escalator bring costs per kilowatt hour (KWH) to 4.06 cents for the first 250 KWH per month and 2.42 cents from then on.[16] For the total 17,871 KWH per year estimated for the solar house, the average cost is 2.44 cents per KWH. This yields a total annual cost of 481.68 dollars. By updating the oil costs in the 1972 Oil Jobbers study to the 1975 rate of 37 cents per gallon, operating costs for the oil heated "typical" home are 1115.18 dollars including electricity. Energy requirments for the all electric home comes to 60,044 KWH per year or an annual energy cost of 1274.72 dollars.[17]

Using these annual energy cost calculations, the solar alternative shows a yearly energy savings of 589 dollars over oil and 793 dollars over electricity. The critical question to be answered is whether the total lifetime costs of the solar alternative—capital and operational—will be competitive with electricity and oil.

Total Lifetime Cost Analysis

Lifetime cost comparisons can be figured on the basis of the following total cost equation:

$$TC = FC + pvac$$

The total cost (TC) of the system equals the fixed initial cost (FC) plus the present value of the annual average costs (pvac) of operation over the system lifetime. TC will vary depending on parameters for materials and construction costs in FC and with the cost of energy, discount rates, and system lifetime used to establish pvac. To discover how the solar alternative compares with oil or electricity, a sensitivity analysis was performed using different parameters for initial construction costs, conventional energy costs, and discount rates. System lifetime is estimated for conventional systems at 20 years. Since the solar system in question has proven to be at least as durable, there is no need to test lifetime.

The calculation for the present value of the annual costs (pvac) can be made using the following formula:

$$pvac = \sum_{i=1}^{n} \frac{\text{annual cost in year i}}{(1 + r)^{i}}$$

where n = the number of years of the project, and r = the rate of discount. A sample calculation for the pvac of the oil heat system over 20 years at ten percent is performed as follows:

$$TC = FC + pvac$$

$$TC = \$2300 + \sum_{i=1}^{n} \frac{\$1115}{(1.1)^{i}}$$

$$TC = \$11,789$$

The remaining calculation for changes in discount rate or cost of energy are performed using the same method.

Figure 4 compares the full cost range of the solar estimates to the oil and gas alternatives. It applies the total cost equation for lifetime costs given different discount assumptions and constant energy prices. Calculations show the following: (1) At discount rates of six, eight, and ten percent, each solar estimate offers a lifetime savings over conventional alternatives. (TC for solar is less than TC for oil or elec-

Figure 3

Annual Costs of the Solar System Operation

Component	Power Used (KWH)	Cost ($)
Water pump	90	2.44
Blower (Heat)	406	10.95
Compressor	3554	95.79
Blower (Cool)	671	18.09
Water Heat	3400	91.64
Miscellaneous	9000	242.56
Aux. Heat	750	20.21
Total	17871	481.68

Power costs are based on rates in Chapel Hill, N.C. effective March, 1975.

Figure 4

Sensitivity of Total Costs (TC) to Discount Rate

Discount Rate		Low Solar Estimate	High Solar Estimate	Doolittle Solar	Oil House	Electric House
	FC	$4400	$6000	$7300	$2300	$2300
6%	Annual Cost	482	482	482	1115	1275
	pvac	5495	5495	5495	12713	14535
	TC	9895	11495	12795	15013	16835
8%	pvac	4733	4733	4733	10949	12521
	TC	9133	10733	12033	13249	14821
10%	pvac	4102	4102	4102	9489	10850
	TC	8502	10102	11402	11789	13150
15%	pvac	3003	3003	3003	6946	7943
	TC	7403	9003	10303	9246	10243

tric). (2) In only one case, the highest (Doolittle) estimate figured at the highest (15 percent) discount rate, was the solar alternative more costly than its oil or all-electric counterparts. The discount rates chosen represent the range generally used in this type of calculation.

Sensitivity of the Findings to Rising Energy Costs

As expected, the solar alternatives become even more desirable to homeowners if energy costs rise. Figure 5, also derived by present value calculations, shows that a five percent rise in energy costs every five years will cause the lifetime costs (TC) of the oil and electric alternatives to rise four percent. Solar lifetime costs, however, rise by only 1.7 to 2.3 percent. This results in a present value savings of 651 dollars, and 2073 dollars, in favor of even the highest solar estimate versus the oil and all electric systems respectively.

A rise of 10 percent in conventional energy costs every five years results in present value lifetime savings of 921 dollars for the high cost solar estimates versus oil and 2415 dollars versus electricity. If energy costs rise 20 percent every five years, the solar savings grow to 1513 dollars and 3148 dollars respectively. Energy price rises in the range of 50 percent every five years are not unlikely given recent trends. In such an event, savings to solar systems would be at least 3660 dollars versus oil and 5844 dollars versus electricity. Again it must be emphasized that these savings are for the *highest* cost solar estimate. The lower estimates and mass-produced estimates offer even larger savings; as much as 8744 dollars for the lowest solar estimate versus all-electric when electric rates rise 50 percent every five years.

Cost Comparison from the Homebuyers' Perspective

Another way to compare the costs of solar housing with conventional types is to calculate lifetime costs for both systems and compare average total annual costs for each. In other words, on the average, how much will it cost the consumer each year, in mortgage payments and energy costs to heat his water and heat and cool his home, by each method? The original base cost for constructing the four identical homes in the same location should be the same, excluding the costs for heating and cooling equipment. If homebuyer O relies on oil heat, homebuyer E on

Figure 5

Sensitivity of Total Costs to Rising Energy Costs at 10% Discount Rate

Change in Energy Cost in 5 Years		Low Solar Estimate	High Solar Estimate	Doolittle Solar	Oil House	Electric House	Present Value of Doolittle Solar over Oil	Elect.
	FC	$4400	$6000	$7300	$2300	$2300		
5%	pvac	4299	4299	4299	9950	11372		
	TC	8699	10299	11599	12250	13672	651	2073
10%	pvac	4508	4508	4508	10429	11923		
	TC	8908	10508	11808	12729	14223	921	2415
20%	pvac	4956	4956	4956	11469	13104		
	TC	9356	10956	12256	13769	15404	1513	3148
50%	pvac	6589	6589	6589	15249	17433		
	TC	10989	12589	13889	17549	19733	3660	5844

electricity, and homebuyers S[1] and S[2], on solar heating, cooling, and water heating, how will their yearly outlays differ over the twenty years of system lifetime?

The mortgage sought by O and E will include 2300 dollars over base cost to cover conventional heating and cooling equipment. Using a discount rate of 10 percent to represent interest, insurance and other finance cost, O and E will each pay a total of 5330 dollars over a twenty year mortgage. S[1] will pay 9200 dollars on a solar investment of 4400 dollars over 20 years. S[2] will pay a total of 16,910 dollars on his original solar investment of 7300 dollars. The annual cost of these mortgages will usually be one twentieth of the total cost. By adding the annual mortgage payments to the annual cost of electricity or fuel under each option, Figure 6 illustrates that even with a high 10 percent interest rate (which is less favorable to the solar alternatives than lower rates), the average annual costs will be lower for S[1] by 390 dollars compared to O, and 549 compared to E each year. Even solar homebuyer S[2], who paid 7300 dollars for his initial solar equipment will be better off each year than O and E by 54 dollars and 213 dollars respectively. If lower interest rates or a rising cost of electricity and fuel oil are used, the solar homebuyers would fare better still.

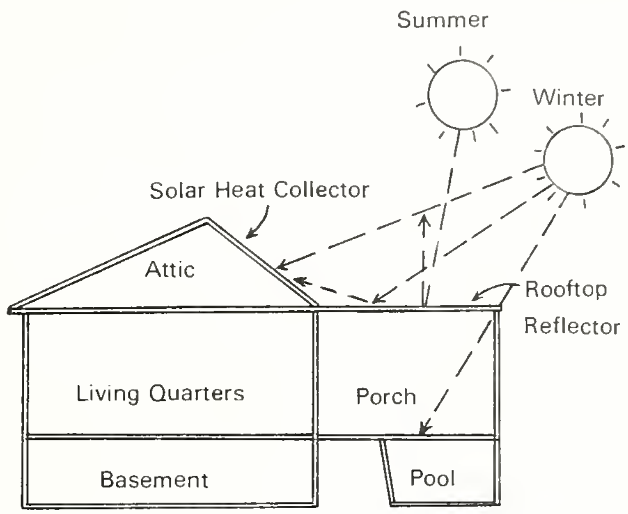
Limitations of Solar Housing

The probable economic advantage of single family solar housing is not a panacea. Much construction is not single unit dwellings. Further, many single family homes may not be able to be built facing North on unshaded lots. In addition, designers and consumers may doubt the aesthetic advantage of a building which has an odd slope to its roof and one side made of glass-covered sheet metal. Homebuyers may not be willing to take the risk that adjoining property owners might put up tall buildings, cutting off sunlight. Given these limitations and peculiarities of solar housing, are there ways to alter the technology or to adapt the surroundings to make the solar alternatives more attractive?

Overcoming the constraint of the need for proper orientation of the solar collector while maintaining a regard for aesthetics is a principal challenge to solar designers. Since sunlight is a very low density energy source, its margin of effectiveness is small. Slight variations in direction of collector orientation or slope can undermine a solar system's effectiveness.[18]

Figure 7

Rooftop Reflector System for Increasing Collector Efficiency



Drawing by Dan Fleishman

A homeowner or builder must answer the question of whether on a given lot there can be a southern exposure for one side of the house without 1) interrupting the symmetry of the property by placing the house at a skewed angle to the frontage; 2) prominently displaying the collector toward the frontage; 3) obstructing an important southerly view; or 4) being shaded by desirable trees or other existing or potential structures? The orientation of houses with respect to road frontage is purely a matter of taste. If consumers reject alternatives to direct parallel road orientation and wish to hide the collector, only lots with North frontage will be suitable for solar housing.

Recent designs in solar collectors are aimed at overcoming this limitation as well as to improving other aesthetic aspects of the system. In a recent Thomason solar house, the roof of the enclosed pool is a sun porch of light colored material which acts to reflect sunlight onto the collector, thereby boosting collector efficiency and eliminating the need for making the entire south wall a collector surface.[19] Figure 7 shows how the roof reflector system works.

Figure 6

Homebuyers Total Annual Cost
(at 10% mortgage and constant energy prices)

	O	E	S[1]	S[2]
Initial Capital Cost	$2300	$2300	$4400	$7300
Interest Cost (20 Years)	3030	3030	5800	9610
Total Capital Cost	5330	5330	10200	16910
Average Annual Capital Cost*	267	267	510	846
Average Annual Operating Cost**	1115	1274	482	482
Average Annual Total Cost	1382	1541	992	1328

* the part of yearly mortgage payment which goes for heating and cooling
** yearly energy costs

The threat that new construction on adjoining land might block sunlight is a realistic one, especially in urban areas. There has been a longstanding legal debate over a "right to light and air" which American courts, unlike their British counterparts, have refused to recognize.[20] Recently there has been talk of granting such a right by zoning or by legislation.[21] There is a fear among some policy makers that the courts might view such action as an unconstitutional taking of property without compensation. There is also a contention that a "right to light" would discourage construction and thereby slow economic growth. The concurrence of the environmental and energy dilemmas, and the prospects for Zero Population Growth and lower economic growth, may in the future prove to be convincing reasons for a "right to light". Of course, even without this right, residential housing patterns make a considerable amount of solar home construction possible.

Most of the limitations of the solar system boil down to conflicts of savings versus aesthetics or inconvenience. It is likely that many of the aesthetic drawbacks will be ameliorated as the mainstream of the design community begins to work on solar housing. As more solar homes are built, new homebuyers will find their appearances less peculiar, and as energy costs rise, it is going to become more and more expensive not to make the decision to go solar.

Conclusion

Public benefits of solar housing in terms of energy conservation and environmental protection have been recognized for some time. Claims that solar housing is not competitive at its current state of development with oil and electricity have biased many homebuyers. This study indicates that at 1975 energy costs, using any reasonable interest rate, existing solar heating and cooling is not only competitive, but is significantly cheaper over its lifetime than conventional alternatives. As energy costs continue to rise, solar systems will compare even more favorably.

The barriers to solar housing implementation are basically institutional.[22] They include the reluctance of lenders to finance "peculiar" homes, the decentralization of the construction industry, the inability of the 30,000 U.S. building code jurisdictions to standardize building requirements, and the misappropriation of government research efforts for the development of new solar methods rather than the full exploitation of existing solar technology. Perhaps as the savings to solar housing becomes more apparent, the public sector will be encouraged to deal with the remaining obstacles to solar development.

Footnotes

1. Estimates of the costs of pollution in the U.S. vary, but generally range from ten to twenty-five billion dollars annually. See Thomas E. Waddell, *The Economic Damages of Air Pollution,* U.S. Environmental Protection Agency, Washington, D.C., May 1974 and Gerald Garvey, *Energy, Ecology, Economy,* New York, Norton, 1974.

2. Seidel, Plotkin, and Reck, *Energy Conservation Strategies,* U.S. Environmental Protection Agency, May 1973, pp 12-40.

3. Ibid.

4. This is called the Solaris system. Further explanation can be found in Harry E. Thomason, *Solar House Plans,* Edmund Scientific Corp., Barrington, N.J., and Harry E. Thomason, *Solar Houses and Solar House Models,* Edmund Scientific Corp., Barrington, N.J.

5. Thomason, *Solar House Plans.*

6. Thomason, *Solar Houses and Solar Models,* p 9.

7. Holcomb Brothers Heating Co., Elkin, N.C., interview February, 1975.

8. Alan McGinigle, private contractor, Chapel Hill, North Carolina, interview, March 1975.

9. Ibid.

10. James D. Kanak, private contractor, Prince George, Virginia, interview, January, 1975.

11. Ibid.

12. McGinigle, interview.

13. J.S. Doolittle, *Our Future Energy Resources: Part I Solar Energy,* NCSU Energy Information Program, Raleigh, North Carolina, June 1974, p 10.

14. Thomason, *Solar Houses and Solar House Models,* p 13.

15. North Carolina Oil Jobbers Assoc., Gerald P. Mathews, study results, December 6, 1972.

16. University of North Carolina Service Plants, Chapel Hill, North Carlina, March 1975.

17. Ibid.

18. For a discussion of the design criteria essential for utilization of solar thermal energy see generally Farrington Daniels, *Direct Use of the Sun's Energy,* Yale University Press, New Haven, 1964.

19. Thomason, *Solar Houses and Solar House Models,* p 14-15.

20. A landmark decision to this effect is *Parker and Edgarton v. Foote,* 19 Wend. 309, N.Y. Sup. Ct. 1838.

21. See H.R. 11677, 94th Congress, 2d. Sess., introduced by Rep. Joe Moakley (D-Mass.) which stipulated that no state or local zoning or other actions could permit construction "which would obstruct or otherwise interfere with sunlight" necessary for the operation of existing solar structures.

22. For a general discussion regarding the institutional barriers to solar housing see Ernest Ambler, "A Discussion of a Research Program", *Solar Energy Research: A Multidisciplinary Approach,* Staff of the House Committee on Science and Astronautics, 92nd Congress, December 1972, series 2 pp 64-84.

The Feasibility of a Multiple Residence Solar Energy System

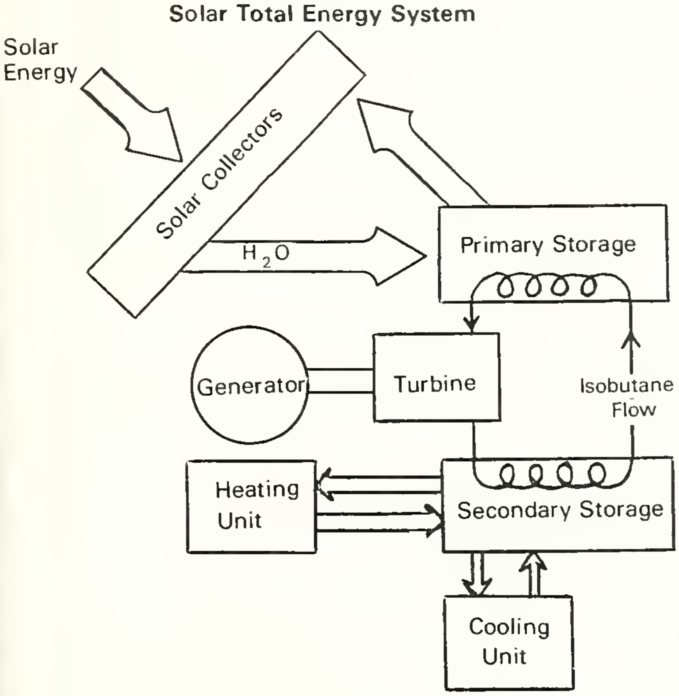
The search for new sources of energy to replace dwindling supplies of petroleum and natural gas has become a major national priority. Solar heat is widely discussed as a new source of energy in a variety of settings. Solar space heating appears to be on the horizon, but the economic potential of generating electricity from solar sources is very much an open question.

Large scale, central generation of electricity from solar sources is and will remain unacceptable for some time because extremely large fields of collectors are essential to harness the quantities of solar heat required. On-site solar generation of electricity, however, might prove a more feasible alternative. An on-site system eliminates land acquisition costs because collectors can be built into the rooftops of buildings. In addition, solar heat collected on site can be more efficiently utilized because residual heat unusable for electrical generation is employed for space heating. Single family homes must be ruled out since the high temperatures and complicated equipment involved in on-site generation make it infeasible for operation. Thus, our attention for on-site solar generation of electricity must focus on multiple-unit dwellings, and commercial and industrial applications.

This article attempts to estimate the economic feasibility of an on-site solar energy system which uses presently available technology for this type of development. The Total Solar Energy System (TSES) discussed, would generate electricity and provide space heating and cooling for twenty housing units, totalling 40,000 square feet, on a single site in piedmont North Carolina. The design requirements of the TSES are explained, then an approximation of the economic feasibility is presented.

Figure 1

Solar Total Energy System



Drawing by Dan Fleishman

Design of the TSES

The TSES gathers sunlight in rooftop collectors which use the sunlight to heat pressurized water. The pressurized water, on demand, heats isobutane, a liquid hydrocarbon, which drives an electrical generator. The isobutane loses temperature in the generation process, but retains enough heat to be used for space heating, cooling and hot water heating. A second storage system containing water is then heated by the isobutane, and directly supplies the energy for space conditioning. Figure 1 illustrates the flow of materials through the TSES.

The design of this system was chosen after searching for a generator which could operate at the appropriate temperatures using currently available collector technology. The isobutane generator produced by Solar Sea Power, Inc., and currently in commerical use harnessing geothermal power in the Far West is able to operate using isobutane heated to 300°F.[1] Of the methods currently available to achieve this temperature, flat plate solar collectors with special selective coatings are of the least cost.[2]

Present consumption rates for all electric residential customer in Chapel Hill were used to determine the size of the generation and heating system required.[3] A winter consumption rate of 34,000

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kilowatt hours per month is estimated to be the maximum which would be required by the development. The 100 kilowatt generator necessary to meet this demand was priced at 18,000 dollars; the required ancillary equipment cost 45,000 dollars.[4]

The size of the collector system required was determined by means of Equation 1, where A = the collector

$$(1) \qquad A = \frac{D}{S\, e_c\, e_g}$$

area, D = the daily energy demand during peak seasons, S = the solar constant (180 watts - m ^{2}), e_c = the collector efficiency, and e_g = the generation efficiency.

The daily energy demand during peak seasons was taken as 20/30 of the demand during January, 1975 for the average all electric residence in Chapel Hill.[5]

The collector efficiency is .5.

The generation efficiency is .15.

Using this method, the required collector area was determined to be 20,000 square feet.

One day's storage capacity is all that is used because of the high capital cost of providing a system capable of storing the high temperature, high pressure liquids for longer than one day. During periods of successive cloudy days, the development will rely on electricity supplied by the local utility company. The conventional equipment required to perform the heating and cooling during these periods which would be present both with and without the TSES, and the electrical wiring to each unit of the development are not included in the cost of the TSES.

The TSES is expected to last twenty years. Thomason solar homes equipped with similar collectors have been in operation this length of time[6] and extending this period would not significantly alter the system's feasibility.

Economic Feasibility of the System

The TSES would be considered economically viable if the capital and operating costs of the system were less than the savings resulting from lower electricity purchases from the utility. In order to make this comparison, all costs and benefits must be expressed at a common time. This comparison is made in Equation 2:

$$(2) \qquad PV = \sum_{i=1}^{20} (E_i / (1+r)^i) - K - \sum_{i=1}^{20} (M_i / (1+r))$$

where PV = the present value of net benefits from the solar system, E_i = the savings resulting from lowered electricity consumption in year i, K = the incremental capital costs of the TSES over a conventional system, M_i = the maintenance, and replacement costs in year i, and r = the rate of discount.

Maintenance and replacement costs (M_i) for the system were approximated at $400 per year from data for a similar type of installation made available by Sandia Laboratories.[7]

Figure 2

Capital Costs for the Total Solar Energy System

100 KW Generator and Boiler Cost*	$18,000
Fluid Transmission**	7,000
Fluid Processing and Distribution**	20,000
Pump**	6,000
Other Equipment**	12,000
Collectors at $10/ft^2 +	200,000
Collectors at $6/ft^2 +	120,000
Savings in Conventional System Components	(40,000)
Incremental Capital Costs at $10/ft^2	223,000
Incremental Capital Cost at $6/ft^2	143,000

* from Hilbert Anderson, Solar Sea Power, Inc., 1975.

**R. B. Pope and W. P. Schimmel, *The Solar Community and the Cascaded Energy Concept Applied to a Single Home and a Small Subdivision,* Sandia Laboratories, Alburqerque, 1973.

\+ see text for explanation of collector costs

The incremental capital costs of the TSES over a conventional system (K) are summarized in Figure 2. The TSES allows the removal of certain conventional elements from the development. These items (totalling $40,000) are subtracted from the total capital cost of the TSES to arrive at the incremental capital cost. Calculations were performed using both the present collector cost of $10 per square foot and a projection of $6 per square foot which might result from the use of mass production techniques. The total capital cost of the TSES is $223,000 at $10/ft^2,and $143,000 at $6/ft^2.

The calculations are performed at three rates of discount (r): 12 percent, 9 percent, and 6 percent. 12 percent is close to what a private investor would require as a return on his money in order to invest in a TSES. 9 percent and 6 percent are rates which might be artificially created by government intervention in solar energy construction. The environmental and economic consequences of energy supply and demand problems make this a possibility. One of the principle conclusions of the Ford Foundation Energy Policy Project, for instance, was that on-site total energy systems be encouraged as a means of saving substantial amounts of energy.[8]

The savings resulting from lowered electricity consumption in the TSES in each year (E_i), were calculated using Equation 3:

$$(3) \qquad E_i = P(Q_{ae} - Q_{tses})$$

where Q_{ae} = the quantity of electricity which would be required to meet all of the heating, cooling, and miscellaneous needs of the development if the TSES were not installed; Q_{tses} = the quantity of electricity which will be required to supplement the TSES during periods of cloudy weather; and P = the price of electrical energy purchased from the utility.

Q_{ae} is set at 20 times the average yearly consumption of electricity for all electric residential customers in Chapel Hill in 1975.[9] Q_{ae} = 262,000 kwh.

Q_{tses} is set at the average daily consumption of electricity for all electric residential customers in

Chapel Hill (718 kwh) times the average number of fully overcast days per year in piedmont North Carolina (96.73)[10]. Q_{tses} = 69,449 kwh.

The analysis is performed for three electricity price projections. In a *stagnant case,* P is fixed at the 1976 cost per kilowatt hour to all electric, residential custmers in the Duke Power System who use as much energy as would be used by the units served by the TSES[11] (P^s = 3.33 cents per kilowatt hour). In a *low dymanic case,* P is taken as 3.33 cents per kwh in 1976 and then is increased at a rate of 5 percent per year (P^l_1 = 3.33 cents per kwh. $P^l_{n+1} = 1.05\ P^l_n$). In a *high dynamic case,* P is increased from the same base at a rate of 10 percent per year (P^h_1 = 3.33¢/kwh. $P^h_{n+1} = 1.1\ P^h_n$).

The results of the calculations for the *stagnant* case ($P = P^s$), are presented in Figure 3. 175,124 dollars, for example, is the present value of an investment in the TSES computed at a discount rate of 12 percent, using present collector costs (10 dollars/ft²) and holding electricity prices constant at 3.33 cents/kwh. Figure 3 shows that if electricity rates were to remain constant over the next twenty years, the TSES would be uneconomical even at the government induced discount rate of 6 percent.

Figure 4 shows the results of the calculations under the *low dynamic case* ($P = P^l$). For example, 156,621 dollars is the present value of an investment in the TSES built in 1976 at a discount rate of 12 percent using present collector costs (10 dollars/ft²), and allowing electricity prices to rise 5 percent per year from a start of 3.33 cents/kwh. The values in Figure 4 indicate that the TSES is not economical when compared with a 5 percent increase in electricity rates.

Figure 5 gives the values for the present value of the TSES under the *high dynamic case* where electricity rates are seen to rise 10 percent per year. In all but one case the system fails to recover its capital costs in energy cost savings. In one case, with an assumed collector cost of 6 dollars and a discount rate of 6 percent, the system shows a positive present value.

Figure 3

Present Value of Total Energy System with Stagnant Electricity Prices (parentheses indicate negative values)

Collector Cost	$6/ft²	$10/ft²
Rate of Discount		
6%	($69,478)	(149,478)
9%	(82,302)	(162,302)
12%	(95,124)	(175,124)

Figure 4

Present Value of the Total Energy System at 5% Annual Increase in Electricity Prices (Low Dynamic Case)
(parentheses indicate negative values)

Collector Cost	16/ft²	$10/ft²
Rate of Discount		
6%	($32,342)	(112,342)
9%	(58,632)	(138,632)
12%	(76,621)	(156,621)

Figure 5

Present Value of the Total Energy System at a 10% Annual Increase in Electricity Prices (High Dynamic Case)
(parentheses indicate negative values)

Collector Costs	$6/ft²	$10/ft²
Rate of Discount		
6%	$35,586	(46,414)
9%	(6,116)	(86,116)
12%	(45,817)	(125,817)

Conclusions

The calculations presented show that with present technology and with reasonably expected growth in the cost of electricity, a TSES on the scale presented here is not economical. This is true even when the cost of the collector units are reduced by almost half from the present cost, and even at rates of discount substantially below those commonly used by private investors. Only in one case examined, where all inputs are assumed most favorable toward the TSES, does the system show a slight positive net present value.

It should be emphasised that these estimates compare the TSES to an all electric home, which is more expensive to operate than a fuel oil heated home. Had the comparison been made with a fuel oil heated home, the TSES would have fared even more poorly.

Predicted skyrocketing costs of energy produced by conventional means may change the competitive position of solar electrical energy production, as may advances in solar energy technology. For today, however, solar electrical prōduction on an intermediate scale is uneconomical in North Carolina.

Footnotes

1. Hilbert Anderson, Solar Sea Power, Inc., 1975.
2. Aden B. Meinel et al., *Solar Application Study: Status, Economics, and Priorities,* Recommendations for White House Energy Task Force, unpublished 1973. These collectors are available through numerous contractors in the state.
3. Gray Culbreth, University of North Carolina Service Plants, Chapel Hill, 1976.
4. The generator is available through Solar Sea Power, Inc. Estimates for the ancillary equipment come from R. B. Pope and W. P. Schimmel, *The Solar Community and the Cascaded Energy Concept Applied to a Single Home and a Small Subdivision,* Sandia Laboratories, Albuqerque, 1973.
5. Culbreth, supra note 3.
6. Pope and Schimmel, p. 8.
7. Pope and Schimmel, supra note 4.
8. Freeman, S. David et. al., *A Time to Choose, America's Energy Future, The Ford Foundation Energy Policy Project,* Ballinger, Cambridge, Mass., 1974, p. 326.
9. Culbreth, supra note 3.
10. Charles Carney, *Climates of the States, North Carolina,* Agricultural Experiment Station, North Carolina State University, Raleigh, p. 12.
11. Duke Power Company, *Schedule RA (NC): Residential Service, All Electric,* North Carolina Utilities Commission Docket No. E-7, Sub 197, Feb. 1976.

Where do Local Governments Fit into an Energy Conservation Strategy?

It has been nearly three years since the Arab Oil Embargo awakened the nation to a crisis in energy. Still, a consistent national energy policy has not emerged. No doubt, this has been due in part to a relaxation of the short-term crisis atmosphere; but primarily it can be attributed to the enormous complexity of the energy issue. There is so much we yet do not know, that the evolution of policy may take many more years.

It would be a mistake, however, to conclude that no progress has been made. At the height of the fuel crisis in 1974, almost everyone saw the problem as one of short-run fuel availability, and whether there was a conspiracy on the part of the petroleum industry. Accordingly, the most conspicuous policy issues were those of emergency allocation and independence from foreign suppliers. Those who saw a longer-range problem were divided into two camps: one favored the "supply" solution of finding new domestic sources (coal, nuclear and off-shore oil), while the other favored a "conservation" solution (reducing the existing rate of use and develop "flow resources" such as the sun).

As the public understanding of the energy problem has matured, two things have happened. First, a growing number of people realize that a long-range problem exists. Second, although there is still public misapprehension regarding the immediate development of miracle sources of energy, such as fusion or solar sources, it is increasingly being recognized that neither supply nor conservation solutions alone will be able to deal with the energy problem.[1] On the one hand, the lead times for development of new supplies are so long that a serious conservation effort is inevitable, whether voluntary or not; on the other, the economic impacts of too much conservation may be intolerable.[2]

Thus, conservation has come to be recognized as an integral part, but not the only part, of energy policy. Left to be resolved is the chicken-egg pair of questions: How much energy conservation do we need? How are we to achieve it? Since in most aspects, the energy problem is national in scope, the federal government has the primary responsibility for formulating policy. Even so, it is beginning to be recognized that there also may be significant opportunities for state and even local involvement. This study examines local government's role in energy conservation.

There are three broad areas where local government intervention can affect energy conservation. These include: (1) emergency allocation of fuels; (2) information and exhortation; and (3) policies which may influence individual energy consumption.

Emergency Allocation

During the fuel crisis, emergency allocation was the most important governmental activity. Necessarily, the federal government took the lead, allocating gasoline to each state according (roughly) to a fixed percentage of historical consumption. Each state also set up an energy agency to attempt to deal with distribution problems and to draw up allocation plans for future emergencies. As the crisis subsided, the state energy agencies began to delve into longer range problems. But, many retain a significant emergency orientation. In North Carolina the State Energy Division is still in the Division of Military and Veterans Affairs.

Some local governments also became involved in

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emergency allocation. In Durham, North Carolina, one of the hardest-hit areas in the nation during the energy crisis, the city government persuaded most of the service station operators to serve an individual motorist only on a certain day each week, depending on the last digit on his license plate.[3] Although widely disregarded, this action did seem to reduce the lines at the pumps during the critical period. In the aftermath of the crisis, a number of communities passed ordinances to help them cope in the event of a recurrence. Also, a few manuals have been designed to help communities handle emergencies better.[4]

Information and Exhortation

Operating on the premise that a great deal of energy waste is caused by ignorance, many states have established communication channels by which energy conservation tips can be conveyed to citizens, small businesses and local governments. Some, for example, have required that conservation information be included with utility bills. In North Carolina, the State Energy Division has appointed a conservation officer in each county. Usually a county official, this person is responsible for disseminating conservation information throughout the country. Within the Federal Energy Administration, there is talk of federal participation in a program similar to this, on the model of the soil conservation officer of the agricultural extension service.

Policies Which Affect Individual Energy Consumption

Ultimately, of course, a meaningful and sucessful energy conservation effort will necessarily affect the way of life of virtually everyone. Accordingly, a significant role for local government must go beyond the relatively minor elements mentioned up to now. That is, the potential for direct local intervention in individual energy consumption patterns must be investigated. It turns out that the range of policy alternatives is considerable. The possibilities run the gamut from mild incentives to direct regulation.

But which activities will local conservation efforts most likely be directed toward? It seems that there are three major possibilities: buildings, urban transportation,and urban land use. Intervention in these three areas has traditionally been in the province of local government (building codes, road construction and traffic control, zoning); moreover, they all hold out the prospect of large energy savings. Before proceeding, a brief examination of those savings is in order.

First, note the significance of the order in the preceding paragraph—buildings, then transportation, then land use. The corresponding energy conservation policies will more or less be arranged in decreasing order of technological (hardware) orientation, and correspondingly in increasing order of their impacts on the habits of individuals, which in turn implies a decreasing probability of successful implementation. There is indeed, an enormous gap between the first two and the third. Between energy use in buildings and transportation on the one hand and energy-land use relationships on the other is a

Table 1
Energy Use in the United States, 1974[a]

	Net Consumption		*Gross Consumption*	
Sector	QBTU	Percent	QBTU	Percent
Residential	10.0	13.7	14.2	19.3
Commercial	7.5	10.3	10.0	13.6
Industrial	23.9	32.7	30.6	41.7
Transportation	18.3	25.0	18.4	25.1
Utilities (waste heat)	13.3	18.2	—	—
Other	0.2	0.3	0.2	0.3

[a]Source: Laurence I. Moss, "Energy Conservation in the U.S.: Why? How Much? By What Means?", *Energy Conservation Training Institute*, Washington, D.C., The Conservation Foundation, 1976.

Table 2
Energy Use by Function, 1974[a]

	Gross Consumption		*Annual Growth Rate*
Function	QBTU	Percent	Percent
Transportation	18.1	24.8	4.2
Space Heating	13.1	17.9	4.0
Process Steam	12.2	16.7	3.6
Direct Heat	8.3	11.4	2.8
Electric Drive	5.8	7.9	5.3
Feedstocks and Raw Materials	4.0	5.5	5.1
Water Heating	2.9	3.9	4.3
Air Conditioning	1.8	2.5	10.1
Refrigeration	1.6	2.2	5.3
Lighting	1.1	1.5	—
Cooking	0.9	1.2	2.2
Electrolysis	0.9	1.2	4.7

[a]Source: Laurence I. Moss, "Energy Conservation in the U.S.: Why? How Much? By What Means?", *Energy Conservation Training Institute*, Washington, D.C., The Conservation Foundation, 1976.

difference in degree so great as to constitute a difference in kind.

Buildings

Energy use in buildings is approximately coterminous with residential and commercial use. As shown in Tables 1 and 2, approximately 24 Quadrillion British Thermal Units (QBTU) were consumed in these sectors in 1974, of which about 15 QBTU were used for space heating and cooling. Appreciable amounts were also used for water heating, refrigeration, lighting, and cooking. Evidently, substantial percentage savings are achievable in every one of these uses, but because of their promise of large absolute savings, space heating and cooling are attracting the greatest interest.

Initial work in this area suggests that surprisingly large energy savings can be achieved through simple changes in operating procedures and relatively minor retrofit. Lowering of thermostats from 72 to 68 degrees in northern climates can save at least 15 percent on annual heating bills.[5] Likewise, case studies by the Federal Energy Administration (FEA) indicate that office buildings can reduce energy consumption by up to 15 percent when operating procedures are changed.[6] Simple capital improvements of existing buildings offer even more promise. An energy conservation study by the Enviromental Protection Agency (EPA)[7] suggests that additional insulation—in attics, storm windows, and weatherstripping—can save close to 20 percent of home energy consumption in the approximately 18 million older homes without such insulation.

"What is surprising about the ADL results is that construction costs were also found to be reduced under the new standard."

As one would expect, nonetheless, the greatest efficiency in building use will result from the incorporation of energy-conscious design from the ground up.[8] The American Society of Heating, Refrigeration and Air Conditioning Engineers has recently drafted a standard (ASHRAE 90-75) for new construction which strongly emphasizes the goal of energy conservation. According to a study done by Arthur D. Little, Inc. (ADL) for the Federal Energy Administration,[9] use of this standard would result, for various types of buildings, in the following average savings over current practice:

Single-family dwelling	11.3 percent
Low-rise apartment	42.7 percent
Office Building	59.7 percent
Retail store	40.1 percent
School building	48.1 percent

What is surprising about the ADL results is that construction costs were also found to be reduced under the new standard. It turns out that while ASHRAE 90-75 increases the cost of walls, floors and roofs, the savings in lighting and heating and air conditioning equipment would be more offsetting. Construction savings are largely balanced by increased architectual fees, but nonetheless, it appears that ASHRAE 90-75 would result in buildings that would cost no more to build and would still be considerably less expensive to operate.[10]

If these results are valid, then there presumably is no need to have a policy to encourage or force adoption of ASHRAE 90-75. Despite this, a number of alternative policies have been suggested, such as tax incentives, new rules for lending institutions, and incorporation of ASHRAE 90-75 into building codes. The last has local implications. While localities typically do not draw up their own building codes, they do enforce them. Thus, building code enforcement may offer an energy-conserving opportunity—or burden—to local governments.

Will more compact development aid in the energy conservation effort?

Photo by Bruce Stiftel

Transportation

Energy savings of a similar order are potentially achievable in urban transportation, which accounted for approximately 9 QBTU in the United States in 1974. This total is the sum of energy consumption across all urban modes (almost all private auto). Within each mode energy consumption is a product of three factors: (1) Total person miles traveled (demand); (2) Vehicle occupancy ratio (use efficiency); and (3) Energy consumed per vehicle mile (technical efficiency). The demand factor is intimately connected with land use, and therefore will be considered in more detail later. The technological efficiency factor is clearly beyond the scope of local government. This leaves two possibilities: switching travel to modes which are inherently more efficient technically, and improving the occupancy in each mode. There are steps local governments can take at each level to reduce energy consumption.

Carpooling

Improving vehicle occupancy has received an enormous amount of attention lately, for several reasons, not least of which is that there are few places where energy waste is more glaringly evident. Nationally, about 5 QBTU per year are consumed transporting people to work in cars containing an average of 1.2 persons each. The United States Department of Transportation estimates that if the use of carpools expanded beyond the current 47 percent of all workers to 75 percent, then 375,000 barrels of oil per day would be saved. No costly capital investment is required in carpooling, and the energy savings are realized immediately.

However, belonging to a carpool often entails some individual sacrifice. Car poolers must adapt travel schedules with co-riders. For those with even moderately irregualr working hours, membership in a carpool might be impossible. Carpooling also presents information problems. A person interested in forming a carpool must be able to find similarly minded people who both live and work in reasonably close proximity. For this reason, the most successful carpooling programs have been organized at major installations of large corporations, where at least one destination is fixed. Some corporations, notably the 3M corporation, have gone beyond carpooling to vanpool programs, in which the company supplies a van for 8-10 people to use for the journey to work.[12]

There is an obvious role for local governments to play in localities where employment is too small-scale and dispersed to permit intracompany carpooling programs. In Washington, D.C., a computerized carpool matching program service is provided by the Metropolitan Washington Regional Council of Governments. (MWCOG) Anyone who wishes to join a carpool fills out a questionnaire and returns it to the MWCOG. Beyond this information role, some cities are experimenting with incentives to join carpools.

Transit

The most obvious and widely discussed conservation strategy involves changes in mode choice: get people *out* of their cars and into less energy consumptive vehicles. Inevitably this means mass transit, although other modes offer more energy-saving potential. Motor scooters, for instance, get up to 150 miles per gallon (mpg), and bicycles of course consume no fuel at all. Unfortunately, they have their own drawbacks. Neither is what could be called an all-weather vehicle, and they are almost surely not as safe as cars. The latter problem is one which can be largely if not entirely eliminated by construction of a bikeway network to obviate the need to travel on busy urban thoroughfares.[13] However, in spite of the obvious attractiveness of bikeways for energy conservation, the funds allocated for their construction have been very limited, and there has been no discernible groundswell among the public to speed up the program.

In any case, transit does offer some promise of energy as well as money savings.[14] A bus with 20 passengers achieves about 80 passenger miles per gallon, compared to about 30 passenger miles per gallon for a car with two occupants. Traffic-choked cities for years have been trying to induce their inhabitants to forsake their cars for new or refurbished transit systems. In doing so they have been primarily concerned with the automobile's profligate use of space instead of energy: space on the freeway and in the parking lot. With the energy crisis, then, modal choice policies gain new interest and importance.

Price in Transportation

Modal choice policies fall into two categories: those which discourage auto use and those which encourage transit use. To discuss the relative merits of the two we must touch briefly on the concept of price in transportation. With most goods, the price one pays is a reasonably good surrogate of the opportunity cost of having the good.* The price of auto transportation, on the other hand, has as one component this same out-of-pocket cost: fuel, maintenance, tools, parking (which is marginal with respect to number of trips,if not to miles traveled), but this is only the tip of the iceberg. There is a large fixed component, mainly amortized purchase price and insurance, which must

> "The most obvious and widely discussed conservation strategy involves changes in mode choice: get people out of their cars and into less energy consumptive vehicles."

be paid regardless of whether the vehicle is operated, and which therefore does not enter into the short-run travel decision. The short-run or perceived price of travel is rather small compared to the fixed cost. Ordinarily, people make their trip decisions based on only a small fraction of the cost of auto use, and this makes it very difficult for transit to compete solely on the basis of price. Besides, the mode decision rests on much more than price, for people consider elapsed time, comfort, security, and privacy. Under most circumstances it is hard for transit to compete successfully on these terms. For these reasons, policies which attempt to entice people out of their cars by improving the quality and price of transit will rarely succeed.

Even if transit is made so attractive, the energy savings might be at least partially nullified by what economists call an "income effect " The lower price of one good will free up resources for the consumption of other goods, including those that compete with it. The suburban commuter who switches to transit because of its lower price may spend the money (and time) saved on still more energy-consumptive activities. For these reasons it appears that modal shift can be more easily achieved by policies to discourage automobile use, either by increasing the price of trips or by decreasing their quality.

Taxation to increase the cost of fuels and maintenance, even if localities had the power, would probably be of limited effectiveness, because it would probably drive people into buying gasoline in neighboring jurisdictions before it would affect their automobile use. Tolls, on the other hand, require a

**The opportunity cost of a good is the sacrifice a person must endure in order to possess the good; namely the opportunity to enjoy other goods and services.*

large maintenance expense. Accordingly, it may be that the most effective way of increasing the marginal cost of automobile travel is through parking restrictions which are therefore potentially valuable energy conservation strategies for cities. Again, there are a number of ways to discourage parking, especially in municipally owned lots. In addition, surcharge or taxes can be directed against privately-owned lots.

At present, urban policy actually encourages the provision of parking facilities in at least one way. Zoning and subdivision regulations often stipulate that so many parking spaces must be provided for a building of a certain size. The aim of such clauses, of course, is to prevent congestion, but the result may be to encourage overprovision of parking spaces,as well as to promote low-density development.[15]

Unlike controls on buildings and vehicle occupancy, for which secondary effects will probably be relatively unimportant, there are a great many uncertainties in the establishment of parking regulations or taxes. Parking management will likely have strong spatial implications, and it seems that any proposal with spatial implications cannot fail to have secondary effects. Will parking management make the central business district less attractive than suburban locations? It would seem that retail establishments would be especially affected, and it is not inconceivable that over time, overall development downtown might suffer. Obviously, these are not policies to be embarked upon casually. Indeed, parking management might better belong in a category of land use policies rather than purely transportation policies. It seems, therefore, that this is a good time to move on to an examination of the relationship between land use and energy consumption.

Energy Consumption and Urban Spatial Structure

Up to now, two prominent links between urban spatial structure and energy consumption have received the most attention. First, as population density increases, it is hypothesized less energy will be required for transportation because the demand for travel will drop and more efficient transportation modes can be supported. Secondly, higher population density implies a shift away from detached single-family dwellings to multiple units, which can be heated and cooled more efficiently.

The Empirical Evidence

These suppositions imply that as population densities increase, both transportation and residential energy consumption should decline. The earliest attempt to support such assumptions through empirical examination was conducted jointly by the Regional Plan Association of New York and Resources for the Future.[16] The study area, the New York City region, has one of the highest population densities in the country, while New York City itself supports the largest transit system in the world. The feeling was, if density does make a difference in energy consumption, it would certainly show in New York.

The study indicated in 1960, per capita energy consumption in the region was 71.3 percent of the national average, and had dropped to 67.4 percent by 1970. Not only was energy consumption in the region lower than in the nation as a whole, but it was also growing more slowly.

Part of this disparity, however, could be accounted for by the relative lack of manufacturing in the New York region. When allowances were made for the "importation" of energy into the region in the form of manufactured goods, the differences observed would be moderated considerably. However, the differences would not disappear, especially in the case of New York City alone. Residential plus transportation energy consumption (Table 3) in New York City is dramatically smaller (nearly 40 percent) than in the United States as a whole. Per capita differences between the region and the United States are not as large, but still highly significant. These findings are substantited by a similar analysis of energy consumption in metropolitan Washington,[17] another high-density area, where per capita residential and transportation energy consumption is only 82 percent of the national average. Actually, the true percentage in Washington is probably even smaller, because

Table 3

Per Capita Energy Consumption by Sector, 1970: New York, Washington, and the United States

Sector	Energy Consumption (million BTU) New York City	New York Region	Metropolitan Washington	United States
Residential	53.1	54.2	45.3	46.9
Commercial/ Public	39.2	44.0	53.7	30.1
Industrial	8.0	16.0		96.1
Transportation	24.3	57.7	61.6	81.9
Total	124.6	171.9	160.6	255.0

[a]Sources: Joel Darmstadter, *Conserving Energy,* Baltimore: Johns Hopkins Press, 1975, Chapter 1; Metropolitan Washington Council of Governments, Energy Consumption in the Metropolitan Area, Washington, D.C.: The Council.

Table 4
Space Heating and Cooling Demands
(10^6 BTU/Square foot/year)

Housing Type	*Arthur D. Little Associates* [a] North-east	North Central	South	West	*Hittman Associates, Inc.* [b] Baltimore-Washington
Mobile Home	.1307	.1536	.0961	.1107	—
Single-family-detached	.1148	.1307	.0714	.0906	.0585
Single-family-attached	.0999	.1261	.0662	.0835	.0689
Low-rise Apartment	.0838	.0991	.0467	.0546	.0512
High-rise Apartment	.0776	.0889	.0414	.0466	.0506
		(Percent of Single-family-detached)			
Mobile Home	114	117	135	122	—
Single-family-detached	100	100	100	100	100
Single-family-attached	87	96	93	92	118
Low-rise Apartment	73	76	65	60	88
High-rise Apartment	67	68	58	51	86

the savings in New York and Washington may not be generalizable to other cities. For might not the near-dearth of manufacturing in both the New York and Washington regions affect the demand for transportation? After all, more than 30 per cent of the nation's transportation energy use moves goods.

The second hypothesis is not supported by either the New York or the Washington study. Since space heating typically consumes approximately 70 percent of residential energy, one would certainly expect lower space heating use to show up as lower residential energy use. As shown in Table 3, however, per capita residential energy consumption in New York City is 16 percent *higher* than in the nation as a whole. One possible explanation for this surprising result is that per capita income in the New York region is 24 percent higher than in the nation. With income elasticities of energy consumption being variously reported as between 0.3 and 0.7, it is evident that a portion of this difference can perhaps be ascribed to higher income levels.

However, under closer examination, the income explanation will not hold up. While per capita residen-

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Energy and Type of Building

The relationship between energy consumption and housing type can be explored by empirical or hypothetical studies. An empirical investigation would require a controlled comparison of household energy consumption among various housing types, but apparently none have yet been completed. Fortunately, the hypothetical studies in this area seem to be on firmer ground than transportation studies, because they depend more on well-understood engineering principles and less on the responses of individuals.[19] It appears the most accepted data on energy consumption and housing were derived by Hittman Associates, Inc.[20] and Arthur D. Little Associates, Inc. (ADL).[21] Their results are compared in Table 4. As shown, the two studies agree that energy savings can be achieved by a shift away from large maintenance expense. Accordingly, it may be that the most effective way of increasing the marginal cost of automobile travel is through parking restrictions which are therefore potentially valuable energy conservation strategies for cities. Again, there are a number of ways to discourage parking, especially in municipally owned lots. In addition, surcharge or taxes can be directed against privately-owned lots.

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1973 Washington data are being compared to 1970 U.S. data.

In both New York and Washington, D.C. the difference can be accounted for entirely by the large savings in the transportation sector, a result which lends support to our first hypothesis. Although these findings tell us high density development can lead to substantial transportation savings, they do not tell us exactly why. In other words, we do not know to what extent, if any, these savings are attributable to a reduced demand for travel, and to what extent to the more extensive use of transit. Also, the magnitude of the savings in New York and Washington may not be generalizable to other cities. For might not the near-dearth of manufacturing in both the New York and Washington regions affect the demand for transportation? After all, more than 30 per cent of the nation's transportation energy use moves goods.

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However, under closer examination, the income explanation will not hold up. While per capita residential energy consumption is 20 percent to 50 percent greater than the national average in various places in the New York region, per capita electricity consumption is 30 percent to 50 percent *less*, probably a reflection of the fact that electric power costs in the region are the highest in the nation. Since the overwhelming bulk of nonelectric residential energy consumption goes for space heating, this only intensifies the discrepancy.

A second possible explanation for the higher residential consumption is that the climate of the New York region, while not severe, is rather colder than the national average. (Space heating requirements in New York City exceed those of Washington by about 10 percent).[18] Nonetheless, although climate may be a factor, the fact remains that neither the New York nor the Washington study support the second hypothesis.

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The principal mechanism promoting greater energy efficiency among multiple family dwellings is the ratio between building volume and the surface area exposed to the outside air. Thus, a row house should consume less energy for space heating than a detached dwelling, a low-rise apartment less still, and a high-rise even less.

In practice, however, energy savings may not be achieved in existing multiple-family dwellings. For example, ADL found multiple-family dwellings were not as well constructed as single family homes. Even where apartments are soundly constructed, energy conservation may be thwarted by a failure to meter utilities separately. In many apartments and condominiums the electricity, water, and even heat are included in the rent or monthly service charge. In that situation, utilities become essentially free goods, and are subject to the abuse that is the fate of free goods everywhere. The resulting waste could not be corrected by charging each dwelling the same average (but time-variant) utility fee, for although utilities would no longer be free, they would be common property resources and still subject to abuse. Separate metering is the only way of confronting each apartment dweller with the cost of his energy consumption, giving him an incentive to conserve.

Spatial Structure and Behavior

The analyses described in the foregoing,attempted to estimate the effects of spatial structure on energy consumption while assuming the underlying individual preferences remain fixed. However, it is commonplace that changes in spatial structure have profound impacts on lifestyle and preference patterns, and these changes may also have significant energy implications. For example, when people live in apartments, compared to single-family homes, do they have a greater desire to travel, to get out into open space? What are the implications for travel demand?

Some Caveats

Up to now, everything which has been said suggests that high density will be a powerful impetus to energy conservation. However, some contrary considerations should be mentioned. In the first place, many of the more extravagant claims of 40 percent and 50 percent savings almost certainly can never and will never be achieved. After all, it is extremely unlikely the existing spatial pattern will be dismantled in favor of a more energy-saving one, so savings will be limited by the existing pattern. This pattern will only change slowly, which means that energy savings from land use changes are well into the future.

In an article on this subject, Dale Keyes[22] tried to calculate the energy savings which could reasonably be expected from land use controls by the year 1990. He concluded it would be extremely unlikely that consumption would be reduced more than 3 percent from a projection with no controls. This is considerably more modest than many of the claims discussed above, but nonetheless is significant.

Furthermore, high density development may even interfere with other conservation possibilities. Among environmentalists, the ultimate clean energy source is the sun, but solar energy may conflict with high-density development.[23] Although there are some prospects in the distant future of solar electric power generation, the only commercially available application of solar energy for a long time to come is for space and water heating. Solar collectors for heating, of course, must be located on site, and therefore they need space not found in high-density areas.

So far, the entire land use discussion has taken place within a metropolitan area: the regional or national land use pattern has been assumed to be fixed. Yet in one of the great demographic movements of history, urban areas continue to grow at the expense of the hinterland. In the 1970 census, 70 percent of the population lived in SMSA's, and this is projected to rise to 85 percent in 1990. At the same time, there seems to be a shift among urban areas, with the South and Southwest (the famous "Sunbelt") gaining at the expense of the Northeast. While this latter shift may imply lower per capita consumption of space heating, it also involves the movement from generally high-density urban areas to generally lower ones. The regional implications of such shifts have only begun to be investigated.[24]

Energy Conservation and Intergovernmental Relations

From this review it appears that there is at least a potential for meaningful local government intervention for energy conservation. There are several activities which have been shown to be of great importance for energy conservation, and which have traditionally been within the regulatory province of local government. These activities, discussed in previous sections of this exploration, are land use, building construction, and the local transportation network.

> "After all, it is extremely unlikely the existing spatial pattern will be dismantled in favor of a more energy-saving one, so savings will be limited severely by the existing pattern."

However, whether a strong local involvement in energy conservation policy is desirable remains to be seen. What, after all, are the incentives for local governments to intervene to conserve energy? To be sure, the motivations for dealing with emergency allocation problems are clear enough, but what of longer range problems? When energy conservation programs are implemented successfully, the result is that more energy is available nationally. Local energy conservation is therefore a public good, since its benefits cannot be captured by the unit providing it. The theory of public finance indicates that conservation will be underprovided if left to local initiative.

If this is true, how can the apparently intense local and state activity in energy conservation be explained? The amount of state energy legislation enacted since the fuel crisis literally fills volumes, and much of it deals with conservation. Local and metropolitan planning agencies have also been quite active in energy planning. Up to now, however, the conservation measures that actually have been implemented are quite inexpensive in that none has entailed a large sacrifice (a statement as true at the national level as at the state and local level). Any attempt to implement a program with teeth may be a different story, and the natural question for local people to ask is, "What good will it do *us*?"

An incentive for local governments to adopt energy-conserving land use measures may arise out of the reciprocal relationship between energy consumption and spatial structure. As energy becomes more expensive or unavailable, compact cities will suffer less than their sprawling neighbors. It takes time for spatial structure to change, and decisions being made now, when energy is inexpensive,will continue to influence consumption decades hence, when it probably will not be so inexpensive. The specter of a spread city run out of gas may prompt a local concern for conservation, although it is rather difficult to visualize this argument successfully presented as a sole justification for curbing sprawl. On the other hand, there are indications that the private sector may be thinking along these lines. A survey of prominent developers in the Richmond, Virginia area land development market suggests a major shift in the evaluation of site attractiveness has occurred since the energy crisis, with trip lengths and access to transit now being given much more weight.[25]

Apparently then, local and to a lesser extent state involvement in energy conservation will require incentives beyond the rather weak and problematical ones discussed here, and the federal government, for which energy conservation incentives obviously do exist, must transmit these incentives to local governments.

Conclusions

This examination has reviewed a rather wide range of current research relating to energy conservation, with particular attention to those aspects of energy use which can be affected by the actions of local governments. At this point, unfortunately, there is no good answer to this question: What is the role of local government in energy conservation policy? The review and analysis has revealed a number of serious research gaps which must be filled before appropriate local roles and policies can be delineated. In particular, three separate issues are involved. First, what is the potential for local intervention to conserve energy? Second, what can be said about the policies available to implement a local conservation program? And third, what motivations would local units of government have to adopt them, anyway?

As to the energy conservation potential of local government, we must know where and how energy is used and the variables affecting that use. Very nearly all the work described in this report was directly concerned with this question. The results can be summarized briefly in the following assertions.

1. Nearly 18 percent of national energy use goes for space heating. Dramatic opportunities for energy savings are available in this area. Changing operating procedures (for example lowering thermostats) can save at least 15 percent of annual energy consumption for space heating. Simple capital improvements to existing buildings can save up to 20 percent. In new construction, energy consumption can be cut by up to 60 percent depending on the type of building.
2. More than 10 percent of the total U.S. energy budget is used by the urban automobile, and rather inefficiently at that. The potential for reducing this figure through increased use of carpools and transit is considerable, although it is uncertain at this point how successful such programs will be.

Unfortunately, neither of these assertions is particularly well established, being based to an unacceptably high degree on simulation models instead of empirical studies. Even where this is not the case, the empirical support is often very sparse, for data on energy consumption either are not kept or are kept in such a way as to make analysis difficult.

Figure 1 provides a partial list of potential energy-saving policies suitable for local implementation and administration. How effective will each be in curbing energy use, and what will be the costs? What is the timing of the conservation benefits: Will they be realized immediately or will they only be significant in the long term? What impacts will conservation policies have on other public policy goals? What about legal and political feasibility: in particular, how will the implementation of conservation policies be affected by the pattern of jurisdictional atomization so prevalent in metropolitan areas? How do various strategies interact with one another? Some pairs may be mutually exclusive in that they attempt to conserve the same energy. Finally, how do these policies compare with conservation programs to be implemented at the federal or state level?

Answers to these questions are absolutely necessary if the previously discussed bias against policies which raise the price of energy is to be corrected. Indeed, the whole exercise can be viewed as a step in a larger analysis of the extent to which we should or can rely on noneconomic means to control energy use.

If, it turns out that there is probably no significant role for local government to play in energy conservation, the search will not have been in vain, for much of this same information must be developed for energy policy at any governmental level. But if there is a role, the third issue arises. What incentive does local government have for playing it? A great many of the proposals listed in Figure 1, especially those concerned with transportation or land use policy, have been advocated by planners for years in connection with other urban problems. It would appear, then, that energy conservation is consistent with the generally accepted principles and practice of urban planning.

Maybe this suggests a strategy for getting local governments involved in energy conservation. Instead of federal sanctions to encourage local conservation programs for their own sake, such as the national building code, a program of subsidies or incentives to encourage localities to do what they would almost be willing to do by themselves might be more appropriate. Actually, programs of this sort already exist, such as capital grants to communities to establish transit systems. There is, to be sure, much research remaining to be done. Specifically, just how consistent is the goal of energy conservation with other community objectives, and how much energy will be involved? If the answer is not much, then we must question whether local government is the proper place to implement conservation programs. If a significant amount of energy is at stake, then this multiple objective approach is likely to be far more effective in the long run.

Figure 1

Local Energy Conservation Strategies

Automobile Discouragement Strategies

1. Increase fixed cost:
   a. Tax engine displacement, weight, and/or miles per gallon.
   b. Tax second cars.
   c. Require mandatory maintenance/inspection.
2. Increase variable cost:
   a. Increase gasoline tax.
   b. Enact road-use tax.
   c. Increase perception of variable costs through smaller gasoline tanks and/or limits on the amount of gasoline purchased at one time.
3. Increase out-of-pocket costs:
   a. Increase parking costs; require that costs be paid daily.
   b. Increase tolls.
4. Increase travel time:
   a. Reserve lanes for efficient vehicles.
   b. Delineate automobile-free zones.

Land Use Strategies

1. Require land use plans to incorporate conservation guidelines.
2. Require coordination of land use and transportation planning.
3. Create high density zones along transit corridors.
4. Adopt housing and taxation strategies to encourage repair and rennovation in the inner city.
5. Curb redlining and insure the availability of mortgage money for inner city homes.
6. Create incentives for the creation of mixed-use centers.
7. Make cities aesthetically attractive through the public acquisition of historic buildings and other means.
8. Redistribute property taxes so that central city services do not suffer.

Parking Management Strategies

1. Amend zoning ordinances that require construction of off-street parking facilities.
2. Reduce off-street commuter parking.
3. Ban early-morning on-street parking.
4. Require residential parking permits.
5. Tax commercial parking.
6. Revise off-street parking rate structures to make all-day parking more expensive than short-term parking, thereby discouraging commuting.
7. Eliminate free and subsidized government parking.
8. Redesign parking facilities.

Transit Strategies

1. Extend transit service.
2. Increase population density.
3. Improve coordination of transit services with other modes of travel.
4. Improve the security of walking, bicycling, paratransit, and promote their use.
5. Remove legal restrictions against paratransit.
6. Provide more frequent and reliable transit service.
7. Improve transit fare collection procedures.
8. Provide better transit route and scheduling information.
9. Decrease perception of waiting time by providing shelters and increasing security.
10. Decrease riding time by using express buses, priority buses, bus activated traffic signals and other means.
11. Decrease crowding by expanding capacity, initiating peak-load pricing, and encouraging flexible working hours.
12. Subsidize transit fares.
13. Change perception of fares by changing from out-of-pocket to monthly or annual passes.
14. Improve seating design.
15. Improve personal privacy by encouraging company vans and carpools and providing commuter trains.
16. Improve passenger security.

Footnotes

1. However, a strong case that the two paths are mutually exclusive is made by Amory B. Levins, in "Energy Policy: The Road Less Traveled By," *Foreign Affairs,* June 1976.

2. Two well-known publications which make a case for conservation are Energy Research and Development Administration, *The National Energy Plan,* ERDA-48, Washington, D.C.: U.S. Government Printing Office, 1975 and Energy Policy Project of the Ford Foundation, *A Time to Choose: America's Energy Future,* Cambridge, Mass,: Ballinger Publishing Company, 1974. There were many who accused the Ford Foundation report of being far too sanguine regarding our ability to reduce energy consumption to any substantial degree. See, for example, Donald C. Burnham's statement at page 362. ". . . Nonetheless, given the latest cost estimates for new electric power facilities and synthetic fuel plants (e.g. 1000dollars/kw installed and $25dollars/barrel for crude oil from coal), it is clear that conservation investments involving a substantial share of U.S. energy consumption are now justified on the basis of cost alone."

3. A. Light, R. Navazio, and R. Spaulding, "Allocation and Conservation: The Triangle Responds to the Energy Crisis," *Popular Government,* Vol. 41 (Summer 1975), pp. 44-49.

4. See Edward H. Allen, *Handbook of Energy Policy for Local Governments,* Lexington, Mass.: D.C. Heath and Company, Lexington Bo ks, 1975.

5. David A. Pilati, "The Energy Conservation Potential of Winter Thermostat Reduction and Night Setback," Oak Ridge, Tenn.: Oak Ridge National Laboratory, 1975. Actually, percentage savings in the South are even greater (32 percent in Atlanta), although absolute savings are greater in colder climates.

6. Federal Energy Administration, "Total Energy Management: A Practical Handbook on Energy Conservation and Management," Washington, D.C.: Office of Conservation and Environment, Federal Energy Administration.

7. Environmental Protection Agency, *Comprehensive Evaluation of Energy Conservation Measures,* Final Report, 230-1-75-003, Washington, D.C.: The Agency, March 1975, p. 11-25. This report was cited in D. Large," Hidden Waste," in *Energy Conservation Institute,* Washington, D.C.: The Conservation Foundation, 1976, which offers a good account of the possibilities of energy conservation generally.

8. National Bureau of Standards, "Technical Options for Energy Conservation in Buildings," Gaithersburg, Md,: The Bureau, June 1973.

9. Federal Energy Administration, "Energy Conservation in New Building Design: An Impact Assessment of ASHRAE 90-75," Conservation Paper No. 43A, Washington, D.C.:

10. National Bureau of Standards, 1973.

11. *Pool-it News,* Vol. 1 (September 1975). (This is a bimonthly publication of the U.S. Department of Transportation and the Highway Users Federation.)

12. *Pool-it News,* Vol. 1 (May 1975).

13. Although a recent study by the League of American Wheelmen indicates that bikeways exceed even the busiest streets in serious accident frequency per mile of bike travel, presumably because of poor design, low maintenance and multiple use.

14. Albeit not as easily as carpool. See "Comparison of Urban Travel Economic Costs," TSM #6, Washington, D.C.: Highway Users Federation, February 1973.

15. Durwood J. Zailke, "Energy Conservation through Automobile Parking Management," ECP Report, Washington, D.C.: Environmental Law Institute, 1976.

16. See Joel Darmstadter, *Conserving Energy,* Baltimore: Johns Hopkins Press, 1975.

17. James S. Roberts, *Energy, Land Use and Growth Policy: Implications for Metropolitan Washington,* Washington, D.C.: Metropolitan Washington Council of Governments, 1975.

18. James Ruffner, ed., *The Weather Almanac,* Detroit: Gale Research Company, 1974, pp. 286, 443.

19. Good bibliographies of engineering analyses of various housing types are available. See, for example, Curtiss Priest, Kenneth Happy, and Jeffrey Walters, *An Overview and Critical Evaluation of the Relationship Between Land Use and Energy Conservation,* Washington, D.C.: Federal Energy Administration, 1976.

20. Hittman Associates, Inc., *Residential Energy Consumption - Single Family Housing,* Report No. HUD-HAI-2, Washington, D.C.: U.S. Department of Housing and Urban Development, March 1973: Hittman Associates, Inc., *Residential Energy Consumption - Multifamily Housing,* Report No. HUD-HAI-4, Washington, D.C.: U.S. Department of Housing and Urban Development, June 1974.

21. Cited in Priest, et al., 1976.

22. Dale Keyes, 1976. Additional skepticism can be found in Guy Parker, "Can Land Management Reduce Energy Consumption in Transportation." Santa Monica, Calif.: RAND Corporation, May 1974.

23. On the other hand, there are some strong sources of compatibility between the two. Solar heating requires large amounts of plumbing and ductwork, which would be much cheaper on a per unit basis in a multiple family as opposed to a detached dwelling. Solar heated apartments and office buildings would require the use of the sides of the building as well as the top, and this would probably intensify the legal issues associated with solar access.

24. However, see Owen Carroll, *et al., Land Use and Energy Utilization: Interim Report,:* Brookhaven-Stoneybrooke, 1975. They make a first attempt to get at the relationship between land use and industrial energy use.

25. Richmond Regional Planning District Commission, "The Energy Fuel Crisis and Land Development Trends," Richmond, Va.: The Commission, February 1974.

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