energy-conversion cycles. Overall power-system models are required to simulate the energy conversion, transmission, and distribution functions from the fuel to the consumer.

Congressional View of Siting. The Honorable Clarence J. Brown of the U. S. House of Representatives: Why is Congress considering the need for federal legislation to control the siting of power plants? That question can be answered in two words: demand and environment.

On the demand side, electric-power use in the U. S. has been doubling about every 10 years for several decades. This trend will continue, and perhaps even increase. Today electricity makes up roughly 25 percent of all energy consumed, and it is estimated that by the end of this century *one-half* of our total consumption of energy will be in the form of electricity.

In absolute terms of power-production needs, what does this mean? It means that over just the rest of the current decade—less than eight years—it is estimated roughly that we must construct the equivalent of 150 new power plants, each capable of producing 500,000 kw of electric power. Between 1980 and 1990 the outlook is the same—another 150 plants rated at 500,000 kw each will be needed.

That brings us to the other side of the question: environment. Environmental concerns have had a great impact on the construction of new electrical generating plants during the past several decades. The classic case is at Storm King Mountain on the Hudson River in New York. It has been more than 10 years since Consolidated Edison first applied to the FPC for a license to build the plant. Before the full gamut of litigation precipitated by monumental pressure is run, several more years of delay may accrue. Even if such proposals escape the courts, the problems of obtaining a site and construction permit often represent costly and time-consuming obstacles.

Commissioner James T. Ramey of the Atomic Energy Commission pointed out last summer that the dollar cost of power-plant construction delays can run as high as $50,000 to $100,000 per day per plant, covering such items as interest on construction loans, loss of revenue, cost of purchasing outside power (if available) to meet demands, and cost of attorneys' fees, consulting engineers, and others directly involved.

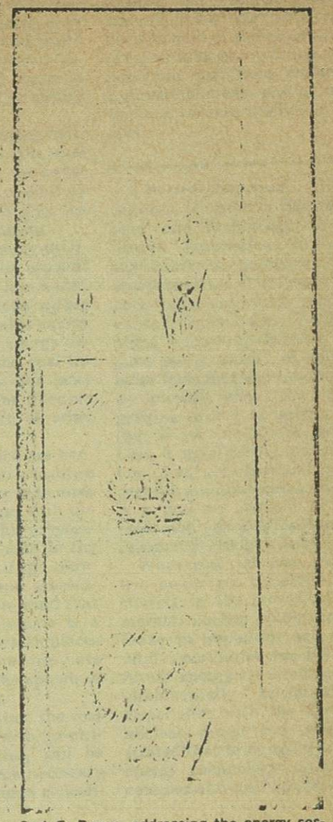
There are also indirect losses in tax revenues, inconvenience (and even dangers) to the public inherent in brownouts and blackouts, and hardships in a community resulting from inadequate power for public services (including pollution abatement), all of which are harder to measure.

But while serving the environmental concerns, we must also serve the public need for power—much of which, in fact, is necessary for the protection of the environment.

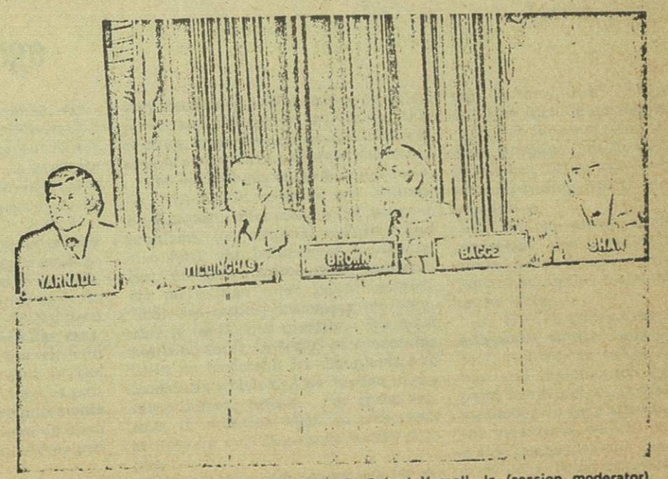
Lots of people, including well-meaning environmental activists, are using virtually every means available to halt increased electric production capacity, and they fail to see the connection between the power plant and the home wall socket, the kitchen trash masher, the subway system, the sewage-treatment plant, or even the power plant itself. Yes, the power plant, too. It requires approximately 9 to 10 percent of the generation capacity of the average plant to run cooling towers required to reduce thermal pollution, if cooling towers are required. In smoke-emitting plants, 3 to 4 percent of the output may be required to operate the precipitators needed to clean up the stacks.

I am not against the environmentalists nor our efforts to clean up and protect the environment. That is a national priority that should get more attention, not less. And that is exactly one of the major reasons why we must have an overall national power-plant-siting policy. Such an "umbrella" policy would put environmental considerations into an orderly schedule that would enable us to compress the time that is now wasted in procedural and jurisdictional maneuvering that arises when controversies over siting develop. The enactment of federal legislation would bring long-range planning, review, certification, and licensing procedures under a comprehensive and workable plan.

How do we get from here to there? The effort was initiated in 1968 when



Carl E. Bagge, addressing the energy session on "Short-Range Solutions." He presented a fuels view.



"Short-Range" Symposiasts. From the left: D. Robert Yarnall, Jr. (session moderator), John A. Tillinghast, Congressman Clarence J. Brown, Milton Shaw.

President Johnson established the Federal Interagency Power Plant Siting Group (composed of AEC, FPC, NAPCA, REA, TVA, the Office of Science and Technology at the White House, and the Department of the Interior). The group submitted two reports—in January of 1969 and August of 1970—which came up with a four-point set of conclusions and recommendations for resolving the siting problem. They were:

1 Long-range planning of utility expansions on a regional basis at least 10 years ahead of construction.

2 Participation in the planning by the government environmental protection agencies *and private organizations* and notice to the public of plant site locations at least five years in advance of construction.

3 Pre-construction reviews and approval of all new large power facilities by a public agency at the state or regional level, or by the federal government if the states fail to act.

4 An expanded program of research and development for power production and transmission.

A Fuels View. Carl E. Bagge, president, National Coal Association: Coal is the one fuel that can, if it is allowed to, provide both short- and long-term solutions to the country's energy crisis. The industry must, however, be freed from excessive restrictions if its potential for providing ample supplies of clean energy is to be realized.

As the country faces an impending energy crisis, the coal industry is facing a short-term crisis of its own. Energy experts are predicting a rising demand for coal both in its present form and as feedstock for gaseous and liquid fuels, but the industry is presently beset by an environmental nemesis which is seriously impairing its ability to perform useful service.

Having just regained a firmer footing after years of setbacks, the coal industry is now beginning to teeter under the pressures exerted upon it by the Clean Air Act of 1970 and the public outcry against strip mining.

We must forge a set of energy priorities which take into serious account the quality of our air, land, and water, but this effort must be made within the parameters of our available energy supplies and our relentless energy demands. The attacks on the coal industry threaten to weaken our most plentiful fuel source at a time when we are running woefully short of other domestic fuel reserves.

State air regulations which are banning the use of coal by electric utilities must be eased if the country is to meet its immediate fuel shortages with domestic resources. While this proposal may sound an unpopular note in the environment camps, it is, if the country is to remain independent, a necessary one. We must bear in mind that the easing of these regulations is a temporary measure—one which places our concomitant search for adequate energy and clean air in the sphere of reality rather than illusion.

Granted the necessary stay, the coal industry, in conjunction with government and other industries, will be freed to pursue the research necessary to bring coal into the realm of a clean-burning fuel. Solutions to the energy crisis will be effected with coal through development of equipment for removal of sulfur dioxide, by bringing synthetic gas from coal from research to the commercial stage, and by opening up the vast western reserves of low-sulfur coal.

A Nuclear Proponent. Milton Shaw, director, Division of Reactor Development and Technology, U. S. Atomic Energy Commission: In the search for solutions to the problems of energy and environment, full use must be made of both traditional energy sources and advanced technologies. Nuclear energy offers important benefits in helping meet energy needs: it helps conserve other fuels for purposes for which they are uniquely suited; it provides a competitive source of energy with costs that do not vary appreciably with location; it significantly reduces the problem of air pollution and has other important environmental advantages; it is a positive element in our foreign trade and provides freedom from over-reliance on foreign sources.

While coal, oil, gas, and hydroelectric power are projected to continue sharing in the growth of the energy market, nuclear energy can and must make an important and eventually a vital contribution toward meeting our future energy requirements in an environmentally acceptable manner. Experience with the development of nuclear power has clearly demonstrated that bringing in any new major energy technology is an extremely complex and costly undertaking.

The Long Range

A Utility View. W. B. Behnke, vice-president, Commonwealth Edison Co.: Ten years ago about 18 percent of our primary energy was used to generate electricity. Today about 25 percent is used, and by 2000 we expect it to be about 50 percent.

First, what is the outlook for energy demand? Per capita energy consumption in the U. S. is expected to increase about 2 percent annually for at least the next several decades. Population will probably grow at a similar rate. As long as these rates of growth hold true, overall energy demand in the U. S. will go up between 3 and 4 percent annually, and world requirements may exceed that rate, depending upon what happens in the underdeveloped nations.

Fossil fuels currently supply about 96 percent of our domestic primary energy needs and will continue to be an important source for the rest of this century, even though nuclear fuel will supply an increasing share of the total.

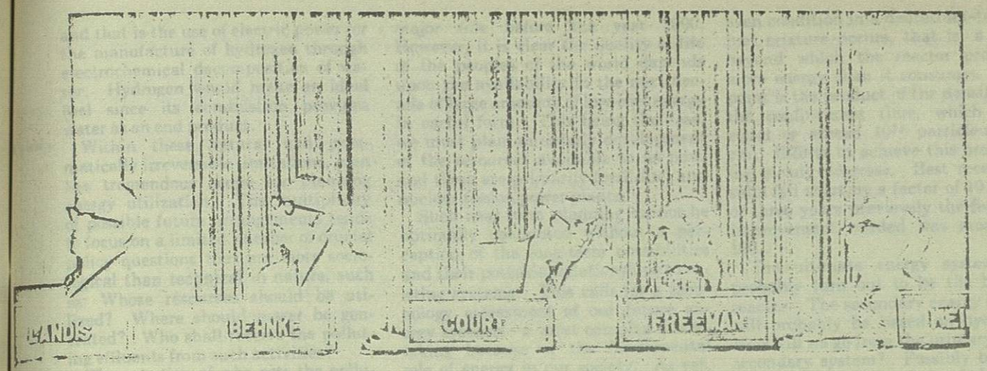
The oil and gas outlook is pessimistic. Domestic reserves are limited. Fuel imports offer some relief but pose problems for national security and also hurt our balance of payments. But precious hydrocarbon resources are more than mere latent calories. They are rapidly becoming too valuable to be burned directly. We must begin to think in terms of conserving them as feedstock for chemicals and foodstuffs which will be needed in the more distant future. For these reasons, it is critical that we seek other sources for our long-range energy supplies.

Second, what are the options for assuring adequate supplies of clean energy in the future? There are many, and they include the following:

1 For the immediate future, available uranium resources can be expanded by lifting the foreign embargo and expanding the U. S. enrichment capability.

2 We can move ahead with demonstrating the breeder, and we are doing this on a top-priority basis, aiming at having this technology available in the 1980s.

3 We can develop environmentally acceptable ways to mine oil, shale, and coal, and we can perfect coal gasification and liquefication systems to expand fossil-fuel availability, but these methods will take time to develop. In the meantime, we will do well to critically reappraise the potential of the technology being developed for removing sulfur oxides from flue gases. Per-



The "Long-Range" Panel. From the left: John W. Landis (session moderator), W. B. Behnke, Jr., John Court, S. David Freeman, Alvin M. Weinberg. Another panelist (not here shown) was Chauncey Starr.

haps we should adopt the British system of using high stacks as the most feasible way of dealing with stack gases until reliable and economically feasible stack-gas cleanup systems, or some other alternative, can be perfected.

4 We can get on with developing entirely new energy systems such as fusion, hydrogen, solar, and geothermal power as a means of assuring adequate supplies of clean energy into the far-distant future.

5 Efforts must be made to further improve the efficiency of energy utilization.

Tremendous amounts of capital will be needed to pay for the needed research and development and to finance expansion of future energy systems. It is estimated that the industry's total capital requirements will be on the order of $400 billion to $500 billion, valued at 1970's prices, between 1970 and 1990.

We think the utilities will turn increasingly to nuclear power in the decades ahead, and with the breeder, nuclear power will account for a growing share of our domestic energy production. Over the longer term, however, new technology will probably favor the fusion reactor employing direct conversion to electricity at some point. Fusion looks like the brightest long-range prospect for substantially increasing the energy supply. A combination of the breeder and fusion would supply us with an almost limitless amount of energy.

Our model for the remainder of this century envisions large dispersed energy-conversion centers. Regional grids of EHV and UHV transmission will interconnect these centers with urban markets.

A Scientist's View. Chauncey Starr, dean of the School of Engineering and Applied Science, University of California at Los Angeles: Since 1900 the average per capita energy consumption in the world and in the U. S. has doubled every 50 years, with some short-term perturbations. There appears to be small likelihood that this long-term trend will change markedly in the next several decades, because of the balancing of pressures.

In the development of future concepts for our energy systems there are a number of constraints established by nature. The most obvious of these is the depletion of resources for energy production. The depletable supply of fossil fuel certainly appears adequate for some period beyond the year 2000, both for the world and for the U. S. As has often been stated, nuclear fission provides another major resource—with the present light-water reactors about equal to the fossil fuels and with the breeder reactors almost 100 times as much. The continuous supply of solar energy is, of course, an enormous resource we still do not know how to tap effectively. There is also the internal heat of the earth, in the form of steam, hot water, and hot rock.

For the next half century, mankind is unlikely to run out of available energy. Instead, the important issue is whether the increasing cost of energy (including environmental costs) will handicap societal improvement.

Another natural constraint arises from waste-heat dissipation. This problem will always be with us and cannot be removed by technological ingenuity—all energy use eventually ends up as heat. All that technical development can do is to alter its area concentrations. However, the solar heat load on the atmosphere is so great that the incremental contribution likely to be made by man is not an important fraction thereof. What is of importance is the geographic and urban concentrations of energy dissipation which may alter natural and urban environments. Heat dissipation may be one of the long-range limitations on urban population density. At the present average U. S. energy dissipation of 10 kw thermal per capita, a population density of 30,000 people per square mile (half New York City's density) will produce waste heat equal to the average solar heat loading of the atmosphere.

Of the uncertain natural limitations, the effect of carbon dioxide—which is an inevitable end product of fossil-fuel utilization—is as yet a long-term environmental mystery. We do have at least several decades for determining the closed CO_2 cycle in our biosphere and the equilibrium relationships. The alleviating development is the use of nuclear power. Nevertheless, it appears that we will always need a combustible fuel, and certainly for several centuries this is likely to be a hydrocarbon in some form. If, however, the CO_2 problem were determined to be serious on a worldwide basis, there is an ultimate but very costly technological solution,

and that is the use of electric power for the manufacture of hydrogen through electrochemical decomposition of water. Hydrogen would make an ideal fuel since its combustion provides water as an end product.

Within these natural and pragmatically irreversible limitations, man has tremendous scope for planning energy utilization. The multiplicity of possible future arrangements tends to focus on a limited number of crucial policy questions that are more sociological than technical in nature, such as: Whose resources should be utilized? Where should power be generated? Who shall receive the polluting effluents from such activities?

The question of who gets the pollution, as contrasted to who gets the energy, is not only one of geographic distribution but also of time. For example, if as a result of the rapid increase in strip mining for coal, acid drainage and soil erosion destroys the ecology of large regions, it may take decades to repair the damage in spite of extensive restorative efforts by the coal-mining industry. This generation of energy users will be long gone when the next generation faces the problem and the cost of repairing damage of such ecological deterioration.

If, as a result of the effluents produced from energy conversion, we produce environmental damage which may have genetic consequences, we also face the problem of distributing the pollution effect through time. For example, if the waste emissions from both fossil-fuel and nuclear power plants are permitted to pollute the environment, the consequences may not be serious in this generation, but they might be in the next because of delayed genetic effects. Fortunately, this problem has been thoroughly studied, and reasonable technological controls can remove this issue.

Perhaps the most fundamental question of national planning is the allocation of our present resources for the benefit of future generations. In the technological domain of new energy devices, we are really working for the next generations, rather than for our own. Even nuclear power, which was certainly supported by government as enthusiastically as any technology in history, has taken 25 years to establish a commercial base, and it still hasn't made a real impact on our energy supply. So the development of new speculative energy resources are investments for the future, not a means of remedying the problems of today. The attraction of "jam tomorrow" may persuade us to neglect the need of "bread and butter today." Because of the very long time required for any new energy device to become part of the technological structure of our society, even if successful these speculative sources could not play a major role before the year 2000. However, it is clear the quality of life of the peoples of the world depends upon the availability in the next decade of large amounts of low-cost energy in useful form. This being the case, we must plan an orderly development of the resources available to us now, and these are primarily fossil-fuel and nuclear-fission power plants.

Such near-term planning cannot be optimally conducted without a perception of the long-term possibilities and their potential relationships to existing systems. This calls for a technology assessment of our future energy systems—a most complex undertaking because of the fundamental role of energy in our society. As yet, only the most rudimentary steps have been taken toward such an assessment.

A Technological View. Alvin M. Weinberg, director, Oak Ridge National Laboratory: Until new knowledge is available, work on the development of solar energy is a waste of time.

The design proposed by a group headed by Aden Meinel of the University of Arizona is imaginative but is probably too costly ($1000–$3000/kw). This reduces to roughly 2.7 ¢/kw. Meinel's scheme would use Fresnel lenses to focus sunlight onto a stainless-steel or glass-ceramic pipe, concentrating the solar flux about 10 times its normal value. The pipe, covered with a selective coating that emits only a small proportion of the energy it absorbs, is enclosed in an evacuated glass chamber to reduce conductive and convective heat losses. Nitrogen gas pumped through the pipe transfers the heat from the collectors to a central storage unit. The heat would then be used to produce steam for a turbine as needed.

For the short range, we can use geothermal resources. There are three: hot steam, hot water, and hot rock (by far the largest). Hot rock is particularly attractive because it can be utilized anywhere.

Tapping this heat can be done in the following manner: Two wells are drilled, one to 15,000 ft and the other to 12,000 ft. Hydraulic fracturing would then be used to create a large heat-transfer bed between them. Water would be pumped down the first hole. It would be circulated through the underground fracture system where it would be heated and then forced up through the second and shallower hole to the surface. We will have fusion power at some time *X*—perhaps by the year 2000, perhaps later—but we can't base an energy policy on this prospect.

Laboratory success of fusion depends on meeting Lawson's criterion. This is the point at which a breakeven condition in a deuterium–tritium fuel mixture occurs, that is, a point beyond which the reactor produces more energy than it consumes. This point is the product of the density and the confinement time, which must equal or exceed 10^{14} particle-sec/cu cm. Efforts to achieve this are making steady progress. Best recent results fall short by a factor of 10. Two or three years previously the factor of improvement needed was more like 100.

The ultimate energy system will probably turn out to be the breeder reactor. The secondary energy system will probably be based on hydrogen. How will we go from the primary to the secondary system? Possibly by electrolysis or a series of coupled closed chemical reactions with heat the only input (temperatures no higher than 800 C). Hydrogen may also be produced through a biological system, using sun or bacteria as catalysts, working on water.

As far as the dangers of a breeder system, engineers must demonstrate a commitment to excellence so that power can be used with a high degree of security.

The Government View. John Court, deputy assistant administrator for planning and evaluation, Environmental Protection Agency: As major changes in prices occur, the nature of the energy crisis will undergo big change. There will be a greater supply because of higher prices, and new forms of energy will be developed because higher prices will facilitate their economic development.

A Public View. S. David Freeman, project director, The Energy Policy Project, Washington, D. C.: There will be a fundamental change in energy supply in the next decade. A consequence will be a sharp increase in price after decades of consistently stable and low-priced energy. Long-term solutions to the energy crisis must be planned now. Finding energy for the 1980s and 1990s must be on our current agenda.

The world won't tolerate the U. S. wasting a major part of its abundant energy while there are grave shortages in the rest of the world. The U. S. must, therefore, improve efficiency of energy use (at present, our transportation system runs with an efficiency of only 6 percent, considering all links in the energy chain). The government program must be on the level of the Apollo program—R&D in the billions are needed, in solar, geothermal, fusion, etc.

As Pogo says: "We have met the enemy and they are us."