Conditions of Grants and Contracts

The second issue for university-industry relationships concerns the appropriate principles in an agreement between an established company and the university when a company wishes to support basic research in a specific area. In discussing such agreements, questions of exclusivity often arise, either with regard to proprietary information provided by a company as part of an arrangement for cooperative research or with regard to exclusive license to whatever the university is entitled to patent.

The university is the only entity that can enter into arrangements for cooperative research, and the university's position with regard to exclusive licensing agreements is the following. In general, the university would prefer to grant nonexclusive licenses, in order to make knowledge as widely available as possible. The university, however, in certain circumstances, may grant an exclusive license, thus encouraging a firm to develop an invention. It will sometimes be clear that society will be better served by the grant of an exclusive license in order to bring the knowledge to the public and that the benefits to society from such exclusivity are greater than the costs of any diminished competition.

Each individual agreement must and will be negotiated on its merits. Through such negotiations, Yale will insist on principles which seek to assure that its patentable inventions will be fully and beneficially used, and that knowledge with a potential benefit to society at large will reach the public in a timely and useful fashion.

Research grants from business firms raise other questions as well, questions that are the same as those raised by research sponsored by the federal government or by private foundations. When contemplating a prospective grant or contract with any sponsor, the university will first consider whether the potential would exist for upsetting the intellectual equilibrium and human relationships in a department were one kind of research to be funded out of proportion to other kinds of research. As an indispensable condition to arrangements for cooperative research with industry, just as with government-sponsored research, the university will not accept restriction, inhibition, or infringement upon a member of the faculty's free inquiry or capacity orally to communicate the results of his or her research. In addition, the university will not accept any restriction of written publication, save the most minor delay to enable a sponsor to apply for a patent or license. Such a delay should not be so long as to lengthen appreciably the time normally required to bring results into print.

Yale has, through its faculty Committee on Cooperative Research, Patents, and Licensing and its Research Advisory Board, the capacity to assess adherence to these principles and conditions. The university will only agree to arrangements for sponsored research, from any sector of society, which are compatible with its norms and mission, and will not agree to any arrangement which will impair the environment of openness and free communication of ideas.

I have by no means addressed all the issues in this area. Difficult cases and anomalous situations, requiring the patience, wisdom, and goodwill of members of the faculty and administration alike, will present themselves. I have, however, suggested here some principles and general guidelines. We have responsible forums to explore these suggestions and to assess the cases that exist or that will arise.

The opportunities for cooperative research between universities and industries are very exciting and can rebound to the benefit of society. These opportunities should not drive us toward arrangements for basic research that abridge our principles. Nor should the university ignore the potential availability of funds from commercial sponsors. We should negotiate appropriate arrangements, openly arrived at, that can further our mission. The constant challenge for the university is to know in clear and principled terms how to cherish learning, and its pursuit, for its own sake; and how to assist in bringing the results of free inquiry to the rest of the society for the good of the public.

German Energy Technology Prospects

Manfred Popp

"Big science" in energy research and development, which depends on the strong involvement of governments through financing and planning, began with the first Geneva conference on the peaceful utilization of nuclear energy in 1955 and was devoted to the economic exploitation of a highly promising new technology. A second phase began with the energy crisis in 1973, which marked the beginning of an era of basically changed energy economics. At that time the success of the nuclear energy development program was clearly visible as the first full-scale commercial power plants were beginning operation. It seemed promising to pursue a similar R & D effort devoted to other new energy technologies in the areas of energy conservation, new and renewable energy sources, and coal, which had not been seriously considered before because of apparent economic problems. Many technologies suddenly seemed to offer new opportunities for providing a more efficient and economic energy supply or, at least, setting a ceiling on further price jumps in the oil sector. It was widely assumed that the remaining technical and economic problems could be solved by sufficiently strong R & D efforts. Consequently, a comprehensive energy R & D program was launched in the Federal Republic of Germany, as in all major industrialized countries of the Western world. International cooperation resulted in combined judgment on technological potentials, improved information exchange, and in a number of cases led to jointly financed projects.

Today, almost 10 years after the beginning of this second phase of energy R & D, it seems clear that this approach was too optimistic. Although the price of oil is at a level that even the most pessimistic forecasts did not predict in 1973, a breakthrough of another new energy

The author, director for energy research and development since 1976, is at the Bundesministerium für Forschung und Technologie, Bonn 2, Federal Republic of Germany.

 0036-8075/82/1224-1280$01.00/0

source has not occurred, nor can it be expected. The success of the nuclear energy development programs has not been repeated in other areas. There have been improvements in the energy system and a large variety of innovations, but many new technologies still will not become economically competitive unless the energy price level again rises considerably. As a consequence of these disappointing results, there have been cutbacks in national R & D programs, most severely in the United States. Many demonstration projects have been terminated, among them even joint multinational projects, sometimes shortly after they were established following long and difficult negotiations.

Under these circumstances and with the additional pressure of shrinking government budgets, it is timely to review energy R & D targets and set the pace for further development. To avoid overreaction, such a review should be based on a proper assessment of the opportunities that remain. In the cases of big, centralized (some would say "hard") technologies such as coal liquefaction and solar power stations, R & D should concentrate on the improvement of key components instead of establishing large demonstration projects as early as possible. In the case of small, decentralized ("soft") technologies, a gradual improvement is still possible, particularly when further development is combined with specific energy policy strategies.

In the Federal Republic of Germany the research ministry, which is also in charge of research in areas such as space and aviation, raw materials, environment, data processing, electronics, and communication, as well as certain areas of basic science, spends almost 40 percent of its annual budget on the development of new energy technologies. Funds in this category amounted to about 2.5 billion deutsche marks (DM) (approximately $1 billion) in 1982. In March 1982 the government decided on its second Energy Research Program, which continues this strong effort and provides funds close to 11 billion DM for energy R & D in the years 1982 to 1985. The breakdown of these funds by category of energy research is shown in Table 1 together with previous levels of funding. The program attempts to establish a more realistic and more specific approach to energy technology development and in some cases sets more moderate targets. However, it pays attention to continuity in all areas of energy research, recognizing that scientific and technical capacities cannot easily survive stop-and-go decisions.

This article describes the status of energy R & D in the Federal Republic of Germany. The prospects for the various technologies are investigated against the background of more than 25 years of experience with R & D programs in nuclear energy and almost 10 years of experience in nonnuclear energy research. Further activities related to R & D and to enhanced market introduction of technologies are considered, covering the areas of energy conservation, new energy sources, coal technology, and nuclear energy.

Summary. After more than 25 years of development of nuclear power and almost 10 years of research and development in numerous areas of nonnuclear energy, there is now a good basis for judging the future prospects of energy technologies in the Federal Republic of Germany. The development of nuclear power has provided an important and economically advantageous new source of energy. Further efforts are needed to establish the nuclear fuel cycle in all stages and to exploit the potential of advanced reactors. In all other areas of energy technology, including energy conservation, new energy sources, and coal, economics has turned out to be the key problem, even at today's energy prices. Opportunities to overcome these economic problems through additional R & D are limited. There is some potential for special applications, and there are many technologies that could contribute to the energy supply of developing countries. In general, however, progress in energy conservation and the use of renewable energy sources will depend on the degree to which energy policy measures can improve their economic basis. For some technologies, such as solar thermal power stations and coal liquefaction, large-scale economic deployment cannot be foreseen today. Instead of establishing costly demonstration projects, emphasis will be put on improving key components of these technologies with the aim of having the most advanced technology available when the economic parameters are more favorable.

Energy Conservation

The enormous potential for more rational use of energy is often illustrated by the fact that almost two-thirds of the primary energy supply is lost during conversion to and application of the various energy carriers. The low efficiency of use of scarce energy resources has stimulated thinking about energy conservation, and it has even been suggested that savings are our best source of energy. Yet this idea is misleading, as there are thermodynamic limits to efficiency ratios. For this reason there are only few cases in which a dramatic increase in efficiency can be achieved; in most energy uses and conversion processes, only gradual improvements are possible. The same is true for the proper choice of energy carriers. In this respect, however, the struggle for improved efficiency in energy utilization is to some extent an uphill fight, since substitution for oil in many cases means replacement by a less efficient energy source. The growth of electric power utilization has often been criticized because of the low efficiency of electricity generation; nevertheless, the use of electricity in many applications, particularly in industry, results in very good total efficiency. For instance, in the German railway the replacement of steam locomotives by electric engines since 1950 has cut the specific energy demand by more than three-quarters.

Thus there is no simple common answer to the question of how a more rational utilization of energy can be achieved. An analysis of possible technical improvements is required for each particular energy application. In order not to become lost in the numerous cases, technology policy must rely on a thorough analysis of the most promising areas for large-scale energy savings. In the Federal Republic of Germany, such analyses were conducted for practically all areas of energy utilization during the mid-1970's. A set of the most important technologies for development and improvement was identified. These technologies are considered important in proportion to their potential impact on the existing energy structure.

In Germany the most important sector is residential heating, which accounts for almost 40 percent of primary energy demand and, in addition, is highly dependent on oil. The possible conservation measures identified in this sector include better insulation of buildings (together with controlled air circulation in extreme cases), passive use of solar energy through architectural design, improvements in fossil-fueled heating systems, and use of district heating systems and heat pumps. Many new technologies have been developed for these and many other areas. In all cases a number of

Table 1. Expenditure on energy R&D by the German government (in million deutsche marks).

Category	Until 1980	1981	1982	1983	1984	1985	Growth 1982 to 1985 (%)
Energy conservation	585*	155	156	178	194	228	+46
Coal and other fossil fuel	1489*	452	588	777	966	1221	+108
Renewables	791*	148	157	162	164	16	+6
Nuclear fuel cycle and safety	5306†	675	755	731	742	728	−4
Advanced nuclear reactors	5599†	654	701	693	707	808	+15
Fusion	1040†	99	100	112	120	128	+28
Total		2183	2457	2653	2893	3279	

*Since 1973. †Since 1956.

demonstration projects have been established. They have been most important (and most costly) in the area of district heating.

District heating is particularly promising in the Federal Republic of Germany for two reasons: (i) many parts of the country have a very high population density and hence a large heat demand, and (ii) the potential of unused heat sources—power stations and industries—close to load centers is very high. In addition, district heating leads to a decrease of environmental pollution in cities and industrial areas. It is therefore one of the few energy technologies that can, at the same time, reduce energy imports and environmental problems. Consequently, district heating has become one of the high-priority items in energy policy.

At present, the share of district heating in meeting the space-heating demand is only 8 percent. As there were only small subsidies for district heating in the past, this figure, although small, shows that district heating can be economically competitive under special conditions. There are three ways to improve the economic basis for increased use of district heating: technical development, financial aid, and regional planning. As district heating is not really a new technique, the potential for technical development is limited. Some improvements can be made in the materials used and the construction methods applied. In order to exploit the most important advantages of district heating, a number of large demonstration projects were established that employed new techniques of cogeneration and utilization of waste heat from industry. The largest project, the Ruhr "heat rail," combines many existing small district heating systems into a large system, which is connected to several power stations and industrial complexes—for instance, of the steel industry. Because of its size and complexity, this system is relatively independent of the availability of special heat sources and reduces the need for backup systems. Even on an improved technical basis, additional economic incentives are required for the expansion of district heating. A special government program provides investment subsidies for the establishment or extension of district heating systems, both for the individual user and for the supply companies. The level of funding depends on local conditions.

An important aspect of district heating, and of energy conservation in general, is better planning for the use of secondary energy carriers on the regional level. In the case of district heating the importance of planning is clear. Competing energy sources—oil, electric power, and, to a certain extent, gas—can be employed if the individual user chooses. District heating will be available only through regional planning, and its economics depends heavily on the degree to which all possible users are connected to the grid. As the share of distribution cost is particularly high in district heating, other supply systems—in particular natural gas—have economic advantages in incomplete or growing systems. In order to avoid competition between two or more capital-intensive energy supply networks, the government's energy program calls for the establishment of regional energy supply plans. These plans should identify, as a function of density of heating demand, areas for district heating (depending on the availability of heat sources), gas heating, and off-peak electric heating. The federal government has encouraged cities and other regional organizations to establish such regional supply plans. At present, pilot projects for a variety of cases are under way.

In other parts of the residential sector, progress in demonstrating energy-conserving technologies has not been so rapid. Many technologies, such as heat pumps, are not yet fully cost-competitive. The chances of closing the remaining economic gap by further technical improvements are limited. In addition, market introduction is hampered by the fact that greater skill and education are needed in handling these technologies. For these reasons, energy conservation measured in private housing—stimulated by government subsidies amounting to 4.35 billion DM during the past 5 years—resulted in most cases in the application of conventional insulation. More advanced systems such as heat pumps, after a good start in this program, are now meeting a reduced demand that has prompted a number of manufacturers to stop production.

Recent developments of technologies for residential heating show that the most likely outcome of energy conservation efforts will be a reduced but continued dependence on oil and gas. New systems such as heat pumps and direct solar heating are highly capital intensive. In using these systems it is necessary to reduce the heat demand considerably by insulation, and for the remaining demand a high investment for the heating system may not seem justified. There is therefore a growing demand for small, highly efficient oil- or gas-fired heating systems.

In the industrial sector, more rational use of energy depends on the choice or design of processes. A number of demonstration projects have shown a remarkable potential for energy savings with new processes. In most cases, the potential technical improvements can be realized only by investigating specific production lines. There is, therefore, no simple way to promote the use of energy-saving processes. As long as the technical risks of changes remain low, the introduction of improvements will depend on cost-consciousness in industry.

In transportation, high fuel prices are an incentive for the development of more economical cars. The potential for large savings or large-scale substitution for oil in this sector is limited. However, as the energy demand for transportation is much smaller in Germany than in many other countries, this is not our most important sector for energy conservation.

Renewable Energy Sources

After a comprehensive investigation of the opportunities for using renewable energy sources under the climatic conditions of central Europe, not much is left of the enthusiasm of the mid-1970's. Decentralized use of solar heat has a limited potential for hot-water production in summer. Under favorable climatic conditions—for instance, in many developing countries—there may be some potential for industrial process heat application and solar cooling. Other applications such as solar heating are inhibited by the unresolved problem of long-term heat storage. The most promising use of solar energy in Germany is through passive systems combined with other energy conservation measures in appropriately designed buildings.

Many different technologies have been investigated for the production of electric power from renewable energy sources. However, none of these at present shows promise of being an economic success. Solar thermal power plants have been tested in a number of demonstration projects, in many cases financed through international cooperation. Examples are a 1-megawatt (electric) solar power plant in Sicily and the Small Solar Power Systems project of the International Energy Agency in Almería, Spain. In another German-Spanish project, major components of a 20-MWe gas-cooled solar power plant are being investigated. The plants are based on the two concepts that are used for experimental solar power plants worldwide: the solar tower (a system with a set of mirrors focusing the light onto a single heat exchanger) and the solar farm (a system with many independent solar collectors). Recently, a 100-kilowatt (electric) solar power plant based on a new concept began operation in Spain; it uses the upcurrent created in a chimney which is connected to a large roof made of transparent plastic foil. This pilot plant is the cheapest solar power facility so far, and it shows that there is still room for new ideas in the renewable energy field.

The results of these demonstration projects will provide a better basis for assessing the economic potential of solar power plants. It must be borne in mind that availability of power from solar plants is a function of season, time of day, and weather conditions; hence, such plants cannot replace other power generation systems, and their total cost must be compared with the fuel cost of existing plants.

The same considerations are basically true for wind generators. A large wind generator with a capacity of approximately 3 MWe is under construction on the northern coast of the Federal Republic of Germany and will be used to study the basic economic parameters of large windpower plants. Its prospects are limited, however, and correspondingly little interest has been expressed by utilities. Another project, a comparative test of ten commercially available wind generators in the 10-kWe range, has revealed many existing technical problems. Further R & D is needed to improve the reliability and structural stability of such converters.

In general, 10 years of comprehensive study and government-financed demonstration projects have resulted in a reduced estimate of the potential contribution to power production by renewable energy sources in central Europe. In some cases, however, the R & D work has revealed encouraging prospects. In particular, progress has been made in the development of photovoltaic cells, and a further reduction in the production cost of silicon cells seems possible. This could open up a market for photovoltaic power supply systems of small- and medium-size capacity, at least for remote areas, where the economics of competing systems are affected by fuel transportation costs.

Apart from electricity generation, good technical progress has been made in the production of gas from biomass. Although energy farming has practically no potential in central Europe, this technology offers many opportunities for utilization of organic waste materials for energy production.

Many technologies for the utilization of renewable energy sources have difficulty competing in highly developed industrial states. Their chances may be better in areas with little or no infrastructure, in particular in the tropical zones. It is therefore a target of the German energy R & D program to promote the application of these technologies in developing countries. Cooperative projects with countries such as Argentina, Brazil, Egypt, India, Indonesia, Kuwait, Mexico, and Saudi Arabia are intended to exploit these opportunities under realistic conditions.

Coal Technology

When many countries readdressed their energy policy to improve their utilization of coal after 1973, the Federal Republic of Germany was well prepared. Domestic coal production, although far from being economically competitive with oil even at its present price, had been protected by high government subsidies for the purpose of supply security. Subsidies are paid to maintain coal production, to improve production efficiency, to employ sufficient amounts of coal in electricity production, and to reduce environmental pollution. In total, coal subsidies amounted to more than 6 billion DM in 1980. The main target of R & D is to make the best possible use of this expensive domestic source of energy, in particular by replacing imported oil. In addition, R & D should serve to improve the economics of coal production.

Coal technologies have a traditional basis in Germany. This is true for coal mining, as the difficult geologic conditions in Germany have necessitated the development of effective mining technologies, and it is also true for coal gasification and liquefaction. During World War II Germany's oil demand of some 4 million tons per year was met by coal liquefaction, and that experience is still available. A comprehensive R & D program has led to improvement of the economic and environmental aspects of these technologies.

In the area of coal gasification, five pilot plants with capacities of some tons of coal per hour are in operation. Three of them produce synthesis gas from hard coal, one uses lignite, and one converts coal gas into synthetic natural gas. On the basis of the experience gained with these plants, two or three demonstration plants with capacities up to 1 million tons of coal per year will be constructed—a smaller number than foreseen in previous plans. One of these plants will be based on lignite, Germany's cheapest energy source, and this is the only plant that does not depend on government subsidies.

Since finding substitutes for imported oil is the main target of our energy policy, liquefaction is considered the most important coal technology. Two pilot plants are in operation, one at 200 tons of coal per day in the Ruhr district and the other at 6 tons per day in the Saar area. In 1981 three parallel engineering studies were conducted on the construction of full-scale demonstration plants with capacities in the range of 2 million to 6 million tons of coal per year. These studies came to the conclusion that the price of gasoline from German coal would be more than 2 DM per liter, compared to the current gasoline price of about 1.30 DM per liter. Even removal of the heavy tax on gasoline would not lead to economic competitiveness. As this result is due mainly to the high specific cost of German coal, efforts will now be focused on applying advanced coal liquefaction technology in international cooperation. On-site liquefaction at highly economic coal mines for export has the potential of yielding greater economic benefits for the producing country and of reducing transportation costs.

Many coal liquefaction techniques can also be used in refining heavy crude oil, an application that will certainly increase in importance and offer economic viability much earlier than coal liquefaction. Even if domestic coal liquefaction is not soon established on a large scale in Germany, development will continue to further improve key technologies. The program will ensure that German industry will continue to be able to build liquefaction plants based on the most advanced technologies, either in internationl cooperation or domestically in case of a change in the economic basis.

Underground coal mining technologies will also be further improved. The progress so far is reflected in the high productivity achieved—more than 4 tons per man per shift (compared to 1.6 in 1957)—a top figure in Europe. Further development will take care of the need to exploit coal seams at even lower levels and to improve safety in coal mining.

Nuclear Energy

Since the beginning of funding of energy R & D, only one new energy source has had a significant impact on world energy supply statistics. In 1980 nuclear power plants generated 14 percent of the electricity in the Federal Republic of Germany and more than 10 percent in Japan, the European community on the average, and the United States. Compared to the total primary energy supply, the share of nuclear energy in Germany today is 4 percent and it will be approximately 12 percent in 1990.

In 1981, nuclear energy generation experienced the highest growth rate of all energy sources, going up by 23 percent. However, this high figure is an effect of the momentum nuclear energy gained during the first half of the 1970's. In Germany, as in many other countries, nuclear energy expansion slowed down considerably in spite of the energy crisis. The reasons for this paradoxical development are manifold. Because of public opposition and economic and political developments during the past 5 years, very few new power plants were ordered and licensed. In particular, in Germany there was no immediate need for oil substitution, as the dependence on oil for electricity production was very low—at present it is 7 percent. Further, the economic depression of the past years as well as energy conservation policies led to a slowdown in electricity growth. Energy policy has given priority to the utilization of domestic energy sources, in particular coal. In order to fulfill existing contracts between the utilities and the coal industry providing for a scale-up of coal utilization in electricity production, most of the extension of generating capacity has been in the form of coal-fired power plants. Today, the end of the period described above is indicated by a number of new orders for nuclear power plants. Although the economics of nuclear energy has been affected, as in many other countries, by rising construction costs, extended licensing procedures, and additional fuel cycle requirements, our evaluations still show that nuclear energy has a clear economic advantage over other energy sources (apart from lignite, which is nonextendable in production). In 1981, the federal government decided on a number of measures designed to streamline the licensing process through plant standardization and improved cooperation of licensing authorities.

The prospects for future utilization of nuclear power are closely connected to progress in the closing of the fuel cycle. The government's plan calls for interim storage of spent fuel at the reactor site, intermediate storage of spent fuel at central facilities away from the reactor site, construction of a reprocessing plant, examination of the safety aspects of disposal of unreprocessed spent fuel, and investigation of the salt dome at Gorleben as a respository for highly active wastes. At present, this plan is well under way. Construction of the first away-from-reactor storage center, which will have a capacity of 1500 tons per year, has begun at Gorleben. A second center is in an advanced planning stage. Both centers will employ dry storage in cast-iron transport containers. Licensing procedures for reprocessing plants have started at two sites, one in Hesse and one in Bavaria. The first phase of investigation of the Gorleben salt dome, consisting of four deep drill holes at the fringes of the dome and numerous surface drill holes, has been concluded. Exploratory shaft drilling is now under way.

With the aim of procuring an additional repository for low-level wastes and wastes from decommissioning, a recently closed iron ore mine has been investigated; the geologic conditions of this mine seem to be almost ideal for low-level waste disposal. The Asse salt mine, operated since the mid-1960's, will continue to serve as an R & D facility for the storage of medium- and high-level wastes.

A demonstration plant for vitrification of high-level waste is under construction at the Eurochemic reprocessing plant site in Mol, Belgium, funded jointly by the German government and German industry. A study on the safety aspects of the final disposal of unreprocessed spent fuel has made progress. It is meant to provide a basis for a decision in 1985 whether to develop this technique for large-scale use.

As progress in reprocessing and waste management is, by legislation and jurisdiction, a prerequisite to further construction and operation of nuclear power plants, this subject will need continuous attention in the future. For the same reason there is a need for a reliable national solution in order to avoid a long-term dependence on foreign facilities.

Regarding fuel supply, the development of the centrifuge process for uranium enrichment in cooperation with the United Kingdom and the Netherlands had remarkable technical success. The process has the great advantage that its specific energy demand is only 5 percent of that of the conventional diffusion process. The extension of the first stage of production capacity at the sites of Almelo (Netherlands), Capenhurst (United Kingdom), and Gronau (Germany) is under way; it is financed with support of the governments of the three countries in order to make up for the advantages of the competing suppliers, whose activities could be based on large-scale development for military applications.

The safety and reliability of commercial light-water reactors are well advanced. In 1981, the German nuclear power stations had an average availability of 6000 hours, with three plants reaching 7600 hours. Strict licensing requirements and a comprehensive safety R & D program have led to high safety standards. Recent studies of possible consequences of hypothetical large accidents may lead to a reassessment of the existing accident scenarios. If the results of these studies are further supported by experiments, it may turn out that the potential consequences of large accidents have been overrated. Therefore, although reactor safety research may still lead to further important results, in the long term this area will not have to be funded at the present level.

Advanced Reactors

Two advanced reactor systems being developed in the Federal Republic of Germany are the sodium-cooled fast breeder reactor and the high-temperature gas-cooled reactor. The fast breeder program is similar to the program in other major industrial countries. There is very close cooperation between France, Italy, Belgium, the Netherlands, and the Federal Republic of Germany in the areas of research, industry, and utilities. In Germany, a 300-MWe prototype fast breeder (SNR 300) is under construction at Kalkar.

The next full-scale breeder is being planned by the largest German utility which is also involved in financing the construction of the Super-Phénix in France. As in many other countries, particularly the United States, the breeder program has been heavily contested in public and political arenas. A major point will be reached when the discussion in the Bundestag on the future utilization of breeder reactors in general and the operation of the SNR 300 in particular, after 2 years of study by a special inquiry commission, comes to a conclusion in October 1982.

The SNR 300 is subject to a normal licensing procedure. As it is the prototype of a new reactor line, this has led to many delays in construction and consequently to many revisions of cost estimates. Following a rise in construction costs up to about 5 billion DM, which coincided with severe cuts in the federal budget, the financing of the SNR became a key issue in nuclear energy policy during 1981. In February 1982 the ten major utilities agreed to contribute approximately 1 billion DM to financing the reactor. Including this contribution, the share borne by the utilities will rise from the present 8 percent to about 28 percent. Meanwhile, a new cost estimate led to a figure of 6.1 billion DM and an additional 400 million DM for future risks of further delays in construction. A government decision on the financing of these additional costs is expected in October 1982.

The development of the high-temperature reactor cannot be based on broad international cooperation, particularly since the U.S. high-temperature gas-cooled reactor (HTGR) program practically came to a halt. The original target of this development—procurement of nuclear process heat for coal gasification and other chemical processes—has turned out to be technically very difficult. Many problems with techniques and materials remain to be solved. At present, the potential of small high-temperature reactors to supply both electricity and steam for chemical plants and aspects of the siting of such reactors are being investigated. A 300-MWe prototype high-temperature reactor (THTR 300) is under construction but has been affected by the same problems as the SNR 300. Although construction of the reactor is well advanced, a new cost estimate made in March 1982 showed a rise from the previous estimate of 3 billion DM to approximately 4 billion DM. During a reassessment period extending to 31 October 1982, special emphasis will be placed on efforts to arrange for a contribution by possible future users in the gas, coal, and chemical industries. The outcome of these discussions is uncertain. Up to now, all efforts failed to define a commercial high-temperature reactor project in Germany as a follow-up to the THTR 300 in 1981.

In the area of fusion, R & D will continue as part of the close European collaboration centering around the Joint European Torus experiment (JET) at Culham. As part of the preparation for the next European torus experiment and for the future development of fusion, research into the technology of fusion reactors will become a major part of the energy program.

Conclusion

In general, the past 10 years of comprehensive R & D in all areas of energy technology have not led to easy solutions to the energy problem. The important potential of energy conservation cannot be exploited through improved technologies alone; market introduction and other energy policy measures are required to further the application of these techniques.

If the idea of the development of alternative energy sources was to set a ceiling on oil prices, this ceiling has turned out to be rather high. It is certainly well above the present price level in the cases of coal conversion and many ways to use renewable energy sources. For many technologies, in particular conversion methods that make use of low-density energy flows, the potential for further technical improvements is limited.

Despite the problems and difficulties with its public acceptance that have arisen, nuclear energy remains one of the most important technologies for the future energy system in Germany. Government support for R & D and implementation is still required, as the problems experienced during the 1970's have delayed the establishment of a powerful industry in all areas of the fuel cycle. Gradually, during the 1980's, the responsibility for financing will have to be taken over by industry, beginning with the fuel cycle but ultimately including advanced reactor systems.

Compared to attitudes in the early 1970's, the approach to new energy technologies today is less enthusiastic and more realistic. That may not be a disadvantage as long as continued government support is provided to ensure the survival of scientific and technological capacities. As demonstrated in the area of nuclear energy, the development of a new technology takes many decades and unforeseen obstacles may have to be surmounted. Our future energy needs are great enough to justify a continued high level of effort in the development of new technologies.