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Toward a renaissance of nuclear energy in Europe

Nuclear power remains the cheapest, safest, and cleanest source of energy ever devised—and it is urgently needed for expanding the capabilities of a European development triangle.

This report is an advance release from a forthcoming Special Report on a proposed European center of industrial development—a triangle linking Paris, Berlin, and Vienna, with spiral arms reaching other parts of Europe. The original will be published in German by EIR Nachrichtenagentur. In last week's EIR, *we published an overview of plans for railroad and other infrastructure development in the "Productive Triangle."*

After a decade and a half of anti-nuclear hysteria, the population of Europe, along with industrialists and politicians, are beginning to wake up to the fact that the continent has no future without nuclear energy. Even the Swedes, who voted in a referendum to stop producing nuclear power, have now shifted, and several parties are calling for a new referendum to reverse the earlier one. The misery of East Germany, which is covered with dust and soot from the burning of brown coal, has made a farce and a scandal out of the Greens' campaign against nuclear energy in West Germany. The Greens' leaders, who cultivated most friendly relations with the leaders of the German Democratic Republic's communist police-state system and are still defending the supposed "advantages of socialism," obviously knew very well what was going on in the G.D.R.

This scandal reveals once more that the violent anti-nuclear campaigns of the late 1970s and 1980s were no spontaneous social phenomena, but part of a carefully orchestrated attempt to destabilize and deindustrialize the Western nations. Fanatical malthusians such as the late Aurelio Peccei and Britain's Prince Philip, for their own reasons, played a leading role in fostering the radical environmentalist movement and sabotaging nuclear energy. Those circles are not accidentally closely linked with the major oil companies, such as Atlantic Richfield's Robert O. Anderson, or Prince Bernhard of Royal Dutch Shell, or the Rockefeller family, all of whom were and remain deeply involved in the environmentalist movements internationally.

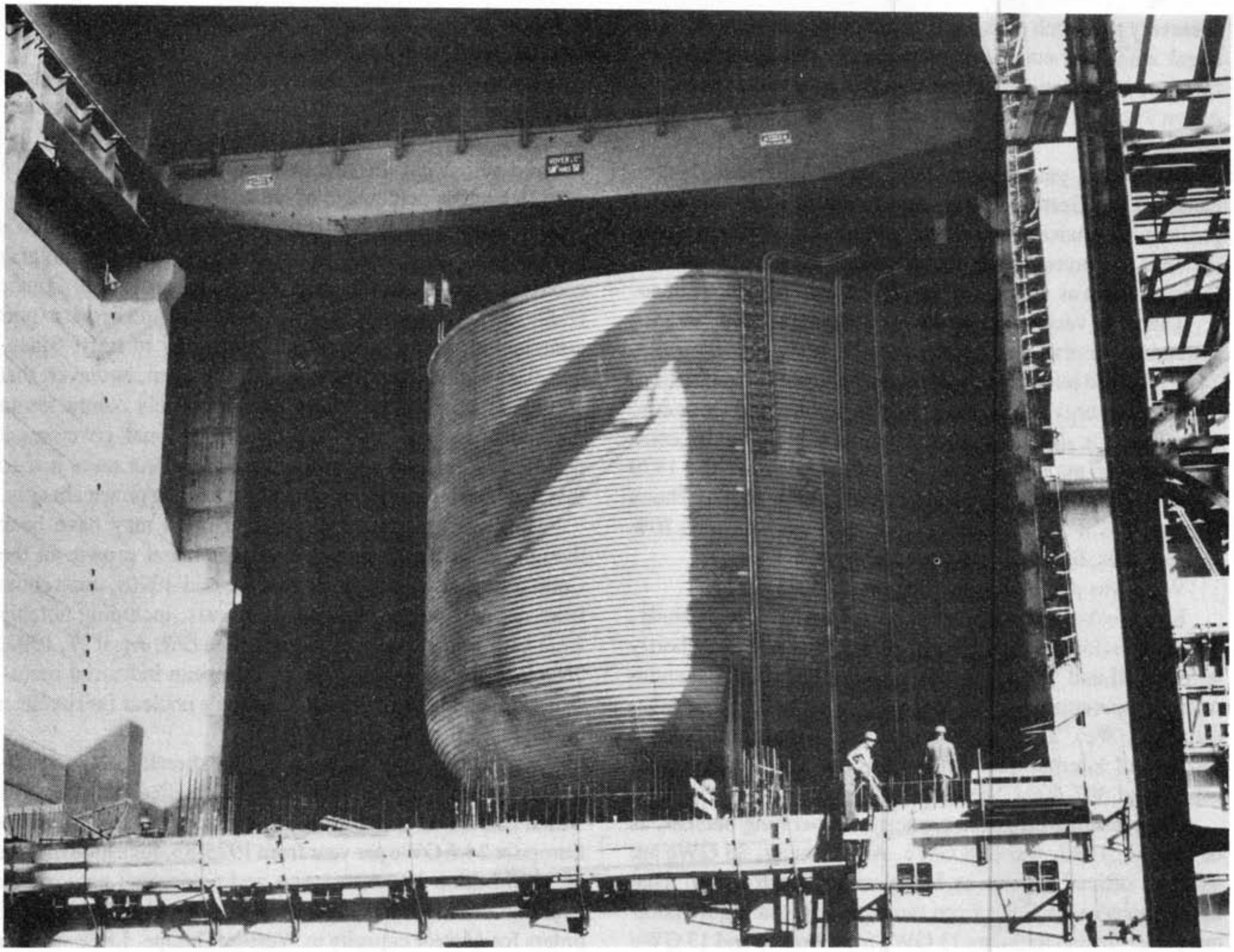
In the meantime, tremendous damage has been done to the world economy by the anti-nuclear campaign—damage which can be counted in tens of millions of unnecessary deaths by starvation and disease in the Third World. Vital time has been lost, which must be made up now.

The simple truth is that nuclear power—in the form used in West Germany, in particular—is the cheapest, safest, cleanest, and most universally applicable large-scale source of

of

briefly indicate here, but it is otherwise the only rational option available. It is time for rationality to return to our policymaking.

The "Productive Triangle" means a renaissance of nuclear energy—for Europe and for the world as a whole. Not only will the European nuclear programs be revived using updated new technology, but Europe will become the leading exporter of nuclear energy to the developing sector. The



Assembly of the Phenix breeder reactor, Marcoule Nuclear Center, France.

Europe of Marie Curie, Otto Hahn, and Enrico Fermi must carry through on the promise expressed in the U.S. Atoms for Peace program of the 1950s: to provide the technological basis for prosperity for the entire world population.

We shall first have a look at the present status of nuclear energy, and what sort of capabilities still exist for relaunching nuclear construction in Europe. Then, we turn to basic parameters for energy development in the Triangle and its spiral arms.

European nuclear capacities

A review of the world's major nuclear electricity power projects over the past 20-year period is revealing. If we take as the base year for comparison 1975, and examine the nuclear power plans of that time with what exists and is still planned today, the picture is one of a qualified disaster for future expectations from this most valuable engineering branch. In recent years, new plant orders have averaged something in the range of five to six plants worldwide. For the past 15 years the OECD nations have been merely completing the backlog of plant orders decided in the 1970s, before the industry was virtually destroyed.

Nuclear plans afoot by 1975, especially in Germany, France, Italy, Spain, if completed over the next decade, would have provided continental Europe with an industrial and power base from which the declining neo-malthusian economies of the English-speaking financial world would have been far surpassed. Since the end of the 1880s, the Anglo-American elites have sought to maintain control of the world energy feedstock, hydrocarbon fuels, and especially crude oil. For this reason, the institutions of the Establishment in New York and London, which planned and executed the 1973 October "Yom Kippur" war as a cover to trigger the 400% increase in world oil prices, by 1975 decided it necessary to launch a targeted "environmental" attack, combined with later economic, regulatory, and financial measures to, as Harlan Cleveland said when he was running the Aspen Institute's green seminar, "take the 'bloom' off the nuclear rose."

Now, 15 years after the Anglo-American faction launched the German Green movement to abort ambitious plans for German nuclear development, it is critical to examine what resources remain for rebuilding the infrastructure of Europe—East as well as West—in the coming decade or so.

There are various reasons why we take the year 1975 for beginning our review. That year is sufficiently past the 1973-74 oil shock to reflect the increased urgency of various national nuclear energy plans, especially in France and Germany. Therefore it is still a reasonable period to judge future commitments for nuclear power. Second, it is before the 1979 disaster year, when Three Mile Island (TMI), Iran oil shock #2, and U.S. Federal Reserve chairman Paul Volcker's 20% interest rates, hit the nuclear programs hard.

What was planned by leading nations in 1975?

Kurt Beckurts, then head of KFA Jülich, issued a study, "World Nuclear Energy Paths," which was released shortly before TMI and Volcker's measures. At that time, the entire world's operating nuclear capacity was at 71 gigawatts-electric (GWe). The Beckurts study, prepared for the Royal Institute of International Affairs, estimated a world nuclear capacity of 387-400 GWe by 1990.

Our present worldwide capacity of operating nuclear, as of July 31, 1990, was 338 GWe. Additionally, 88 GWe are listed in official reports as being under construction. That figure includes 25 GWe from the U.S.S.R.—a highly dubious target. It also includes 13 GWe from France and 13 GWe from Japan, meaning that more than half of all reactors listed as still under construction are included in those three countries. Looking at planned nuclear units, we arrive at a figure of 113 GWe worldwide. But again, the bulk of this is in the U.S.S.R. with 35 GWe. The other large nuclear plans still considered active are Japan with 15 GWe, Poland with 8 GWe (as of July 1989), France with 7 GWe, Czechoslovakia with 6 GWe (as of July 1989). So, the economies of Eastern Europe and the Soviet Union comprise some 45% of all listed planned nuclear units—making this a highly unreliable figure at present, given the state of disarray in the U.S.S.R. nuclear economy.

Now, let us look more closely at concrete country-by-country plans (**Table 1**).

The data shown for the United States represent a decline of 54% from planned levels of 1975. Most of the decline has been due to massive order cancellations by U.S. electric utilities facing bankruptcy from nuclear cost overruns. Since the mid-1970s, some 3 GWe have been permanently shut down, including Three Mile Island-2. But 109 committed nuclear projects have been canceled, for a total of 125 GWe. That, had it been completed, would have been enough electricity to provide the entire electric power requirements of Germany and France combined.

As the table shows, France is the only major industrial country which has held to its commitment (with the possible exception of Japan, which maintains such plans, but has delayed somewhat the rate of completion). France has the world's highest percentage of nuclear-supplied electricity—70% of all electric power being generated from the nation's nuclear grid, as of 1989. In recent years, with the sluggish economic growth of the early 1980s, Electricité de France (EdF) faced a temporary electric power glut and began export contracts to sell surplus nuclear electricity to Italy, Spain, and elsewhere. According to EdF spokesmen, however, that surplus margin has now been almost entirely contracted to the end of the century. France, as a national government policy, has decided not to build more nuclear units just so that neighboring countries can import nuclear power cheaply.

Thus, the margin of electricity which may have been thought available to fuel industrial demand growth in the Central European economies past the mid-1990s, must come from net new power plant commitments, including notably from the German nuclear industry. (See *EIR*, April 27, 1990, "Nuclear energy base crucial to European industrial reconstruction," and July 6, 1990, "Europe's nuclear fuel cycle: a bottleneck to economic growth.")

Considering only Western Europe directly, the consulting group Frost and Sullivan issued a detailed study in 1975 which calculated expected new orders for nuclear plants in Europe at 24.5 GWe per year from 1975-85, for a total market of $116 billion in construction and equipment new orders over that decade. That alone would have added 245 GWe of orders for nuclear capacity to Western Europe. Little wonder that the Seven Sisters and the Anglo-American oil and banking interests deployed assets in Friends of the Earth, the Greens, the World Wildlife Fund, and the rest to kill the European nuclear industry in its most vulnerable points—Germany, Italy, and Spain.

Nuclear 'bill of materials'

If we examine what a "bill of materials" would require for construction of 75-250 GWe of nuclear capacity by the next 15 years or so, some interesting problems are thrown up. First of all, we have a new rate of orders for Europe's nuclear steam suppliers—France, Germany, and the Swedish-Swiss Asea-Brown Boveri—of some 10-20 new reactor orders per year in the initial five years, with the rate tapering off toward the end of the 15-year time period. Immediately, the bottleneck of qualified engineering skilled labor is going to be felt. Germany at present has a drastic shortage of qualified engineers of any type, let alone qualified nuclear plant engineers, materials engineers, and such.

The difficulty in estimating present rates of construction of a new nuclear plant, is that most of the relevant detailed studies are from the 1970s. A detailed study was done by the

TABLE 1
Nuclear power—plans vs. reality

	1975 plans	1990 reality
U.S.A.	235 GWe by 1990 or sooner (Atomic Industrial Forum)	107 GWe—(USCEA) actual capacity; 4 more are under construction; no new reactor order since 1979
France	55 GWe (CEA's planned program, by 1985)	55 GWe completed with 13 GWe in construction
Federal Republic of Germany	50 GWe (government plan, by 1985)	24 GWe—actual installed; no more planned
Italy	26 GWe (Donat-Cattin Plan, by 1990)	0—not one watt of nuclear; no more planned
Spain	14 GWe committed or installed	8 GWe installed; no more planned
Japan	49 GWe (to be built by 1985)	29 GWe installed; more than 27 GWe additional are presently under way or planned, bringing the total to 56 GWe

Berlin DIW economics institute in 1976, and a second study, much more superficial, by Westinghouse in 1980.

DIW carried out an "input-output" analysis of the complete labor requirements of a typical PWR power plant in the Federal Republic of Germany (F.R.G.). Calculating the effects on steel, machinery, chemical industry, specialized ceramics, mining, and the necessary banking and services support for building a nuclear plant, both direct and indirect, DIW calculated that construction of one plant per year requires employment of 39,000 man-years. Of this, some 70% are involved in the plant construction; 8,000 man-years are directly from the steel and machinery sectors.

In a paper prepared to lobby against the foolish Percy-Glenn Bill, which effectively banned U.S. nuclear exports back in 1980, during the Carter years, Westinghouse claimed that one nuclear plant for export meant some 60,000 man-years of employment: 15,000 man-years of direct employment, 15,000 man-years of indirect employment, over a 6-7 year design and construction life. The study added 30,000 man-years over the entire 20-year life of the plant, to come up with a final figure of 60,000 man-years of employment per nuclear plant.

Estimates of the amount of steel required for a 1,100 megawatt-electric (MWe) unit, according to industry data supplied by Westinghouse in 1977, are as follows:

Low-grade steel	43,000 tons
Stainless steel	4,000 tons
Equipment steel	50,000 tons
Total	100,000 tons per reactor

Now, taking the requirements of building even 75 reactors in Europe, this will mean a demand increase alone of 7.5 million tons of steel consumption. If we say 250 units, that will require 25 million tons of steel of these qualities.

Energy requirements for the 'Triangle'

Parallel with the building-up of a new, highly efficient transport infrastructure, the energy economy of Europe will undergo fundamental changes. Electricity use will increase to 30% or more of total energy consumption, and nuclear energy will displace coal almost entirely in the production of electricity as well as becoming an important source of district heat and industrial process heat.

The most dramatic changes will occur in Eastern Europe, where large-scale application of nuclear energy will end the heavy dependence on coal, especially low-quality brown coal and lignite, which has caused disastrous pollution and low economic productivity. The mode of nuclear development will also switch from the very large light-water reactor units which were the predominant trend so far, to increasing use of smaller, more flexible and inherently safe second-generation units based on the high-temperature gas-cooled reactor (HTR) technology. At the same time, industries will move toward higher qualities of energy, replacing most present uses of chemical combustion-heat by electricity-based technology (including lasers, radio frequency, microwave, and plasma devices).

Fundamental parameters of energy supply

The most important parameter governing the relationship between energy use and economic growth is the *density of useful energy per capita and per square kilometer*. Subsumed under the concept of "density of useful energy" is not only the differentiation between nominal energy quantity and the quantity of energy which actually ends up doing work (as opposed to such things as waste heat), but also the technical quality of the energy. The latter is approximately measured by the energy flux-density, in watts per unit area, which characterizes the various phases of transport and application of a particular energy form within a given energy system.

Oil, for example, is generally superior to coal as a fuel, having 40-45% higher energy content per ton than anthracite coal. Consider the difference between coal and oil in transport. A single oil pipeline of 1 meter diameter can transport up to 20 million tons of oil per year. That corresponds to an average power flow of about 25 Gigawatts. Approximately the same power flow would be reached by a rail line carrying 75 trains every day, each moving 1,000 tons of coal. Compare the expenditure of effort, in manpower, energy, and capital investment.

While electricity might appear comparable or even inferior to oil and gas in terms of investment required for high-voltage lines (present technology), and while each has its particular advantages and disadvantages in various applications, electricity possesses one very crucial advantage: The energy flux-densities which can be reached in applications of electrical energy are relatively unlimited, while oil, gasoline, and gas are bound to the limitations of chemical combustion processes. Thus, for example, an oil or gas flame never reaches above 2,500°C, while plasma arcs easily reach 5,000-15,000°C. If we convert electricity to laser light, we can generate much higher temperatures, reaching all the way up to tens of millions of degrees in laser fusion experiments. Another decisive advantage of electricity is its unique capability to generate a magnetic field, and, related to this, the potentially much higher power density of electric motors compared to internal combustion engines. This distinction will be greatly enhanced through the new superconducting materials.

The advantages of electricity do not imply that it replaces other energy forms, but rather that it plays an increasingly dominant role within a harmonious system of various forms in an economy. Thus, although electricity has not replaced natural gas, the high productivity of natural gas use today is only possible in the context of a developed electricity system.

Energy flux-density is also crucial to the economics of electricity generation. Key to the unique advantages of nuclear technology, is the much higher power density compared with all conventional power sources. For the same electric power output, a nuclear plant consumes 75,000 times less weight in fuel than a coal power station.

These distinctions are important to bear in mind in examining future energy policy for Europe. We see, for example, that the nominal per capita energy consumption of the G.D.R. is 25% higher than in the F.R.G. The reality behind this figure is that the G.D.R. has a much lower living standard and productivity than the F.R.G., and also a highly inefficient energy system. Thus, the per capita consumption of *useful* energy is much lower in the G.D.R. The energy economy of the G.D.R. is nearly entirely based upon the use of brown coal, which is the least efficient form of fossil fuel. This brown coal has approximately half the heat value per ton of the anthracite coal used in some power plants in the F.R.G. One-third of the rail capacity of the G.D.R. must be devoted to moving this low-value coal—more than 90 million tons per year. In addition, the brown coal burns less well, generates more ash and pollution. A similar situation, though less drastic, holds for Czechoslovakia, which obtains 61% of its primary energy from brown coal.

At the other end of the spectrum we have France, which derives 70% of its electricity from nuclear energy. The French nuclear energy program led to a dramatic saving of transport capacity on the French railways. Furthermore, France used the lower cost of nuclear-supplied electricity (30-50% cheaper than coal power) to increase the use of electricity in industry to 51% of total industrial energy consumption (compared to 28% in the F.R.G. and less than 15% in the G.D.R.). At the same time, French industry reduced the oil component of its energy consumption from 39% to 22%.

France's benefit from nuclear energy would be greatly enhanced if its population and industry were more densely concentrated, as in West Germany and Japan. Although the distribution of electricity by a well-maintained network involves relatively low losses in energy terms, the investment in construction and maintenance of the distribution network is large. For a given total energy throughput, these costs are inversely related to the density of consumption. Thus, the cost to deliver 1 GW of average power to an industrial city of 1 million inhabitants, is much less than the cost to deliver that same amount of power to the same population and industry distributed uniformly over several hundred square kilometers. The advantages of district heating can, of course, only be enjoyed in towns and cities.

The optimum arrangement, discussed in the 1960s and 1970s as the "nuplex concept," is to cluster industry and population around thermal electric stations (preferably nuclear) and along the main lines of power distribution. In this way, we obtain an optimum use of electricity and heat. Such clustering permits various advantageous forms of recycling and complementary use of materials among industries. The most energy-intensive activities are to be located in complexes proximate to the main lines, in such a way that the relatively largest portion of total energy is consumed within the relatively smallest area of the grid. If a portion of excess heat from an electric power station can be utilized as industrial process heat and for district heating, that heat is no longer "waste heat," and the productivity of the plant increases accordingly.

Second-generation nuclear technology: the HTR

The light water reactor (LWR) technology used in France and Germany has gained a secure place in Europe's energy supplies; over the last 20 years, however, second-generation technology has been developed, in particular the high temperature gas-cooled reactor (HTR), which offers important advantages over existing LWR technology in many applications. This reactor type employs ceramic-coated spherical

TABLE 2

Brown coal electricity production to be replaced by nuclear*

	Production TWh	Installation capacity GWe
G.D.R.	114	23
Czechoslovakia	86	18
Hungary	13	3
Yugoslavia	30	6
Total	243	50

*The capacity estimates here assume a proportion of 1:1.8 between average electricity production and nominal installed capacity, as existed in the Federal Republic of Germany at the beginning of the 1970s.

fuel-elements, cooled by inert helium gas with an exit temperature of 900-1,000°C. Unlike the LWR, which only generates electricity, the HTR can also serve as an economical source of process heat and district heating.

Here, in summary, are advantages of the HTR:

1) By operating at a higher temperature, the HTR achieves significantly higher efficiencies in electricity production than the LWR (6% higher with standard steam generation, and as much as 10% higher with direct helium turbine).

2) Because of the higher operating temperature in the primary circuit, low-temperature waste heat from the HTR can be used for district heating without reducing the electricity production. This unique "co-generation" capability means that an HTR facility can "pay for itself twice," and operate at a far higher overall effficiency.

3) With its 900-1,000°C operating range, the HTR can serve as a heat source for a variety of industrial processes, including coal gasification, thermocatalytic hydrogen production, hydrocarbon cracking, and other processes in the chemical industry, and desalination of sea water.

4) The HTR has the special property, that its reactivity decreases with increasing temperature. Even under conditions of total loss of coolants, the reactor shuts down by itself. The high thermal capacity of the fuel system precludes a "meltdown," as could hypothetically occur with the LWR. Furthermore, new coatings developed for the fuel pellets constitute a "containment building," preventing the escape of radioactive material. The HTR is so safe, that it can be built and operated in the middle of a city. It may even be possible to eliminate the expensive concrete containment wall needed for LWRs, thus cutting down substantially on cost.

5) Small modular HTR units have been developed which can be mass-produced and rapidly assembled in groups to give any desired output power. This permits great flexibility not possible with the gigantic LWR plants. Thus, in areas which lack the built-up power grid for a large plant, one or two modules could be installed first, and further modules added as the grids expand. General Atomics projects that with mass production of 135 MWe units of American design, a multi-unit HTR plant could be built in 27 months. HTR GmbH in Germany (a joint venture formed in 1988 by Asea-Brown Boveri and Siemems-KWU/Interatom) is developing 320 MWe HTR modules based on the German "pebble-bed" design. A four-module 1,300 MWe plant could be assembled in 48 months, counted from receipt of the construction permit. The French company Framatom alone could produce enough reactor vessels for 18 modules of 320 MWe every year.

6) The HTR can be used to breed thorium into fissionable uranium-233, thus more than doubling the nuclear energy fuel base even without the fast breeder reactor.

In view of these advantages, it is reasonable to project that the HTR will play an increasingly dominant role in the expansion of Europe's nuclear energy supply.

Bottlenecks and potentials for the future

Given the greater flexibility permitted by shorter licensing and construction times for the smaller, modular reactors, it is not necessary to set a rigid schedule for energy development in the Triangle and its spiral arms. What is important now is to know within which approximate limits new construction will occur, in order to insure that sufficient production capacities are there, and permit the various nations to plan their own programs in a harmonious manner.

The most urgent immediate task, which sets a lower limit on new construction, is to rebuild the collapsing electrical energy supplies of the eastern side of the Triangle, while virtually eliminating the combustion of brown coal and lignite for electricity and heat. This involves the approximate magnitudes shown in **Table 2.**

In addition to this, Poland is experiencing a serious energy crisis, associated with the accelerating collapse of oil supplies from the U.S.S.R. and a high investment cost required to increase its anthracite coal production. Eighty percent of Poland's primary energy comes from coal, and any increased use of brown coal and lignite is a harmful dead-end. The official plan already calls for installation of 6 GWe of nuclear power by the year 2000. In light of the poor condition of many of the present power plants, this figure should be revised upward to a minimum of 10 GWe as an immediate, emergency measure.

The special situation of Ukraine should also be mentioned. The RBMK reactor type used in Chernobyl could never have been licensed in the West, nor for that matter could any of the nuclear reactors now operating in the U.S.S.R. Understandably, Ukrainians are unhappy about the continued operation of these reactors, especially the three 1,000 MWe RBMKs still running in Chernobyl. In addition, there are a number of pressurized water reactors in Ukraine, including six blocks at Zaporozhe south of Dnepropetrovsk, several additional blocks at Khmelnitsky in western Ukraine and near the Black Sea. Already, the Crimean station and unit four of the South Ukraine plant have been abandoned under public pressure. Electricity production has had to be raised at conventional power stations, resulting in 5.6 million more tons of fossil fuel more than originally planned. Because of these problems, strict limits are being placed on electricity use, and certain areas are already experiencing power cuts.

Rebuilding Ukraine's power supply based on the inherently accident-proof HTR technology is a crucial facet of an urgently needed program to modernize the Ukrainian economy. The immediate priority is to replace capacity which has been, or is being, taken out of service for reasons of obsolescence and lack of safety. This would amount to an estimated 10 GWe for the immediate future. Total electricity production in Ukraine is 315 terawatt-hours (TWh) per year, larger than all the European nations except France and Germany.

Romania already declared an energy emergency in 1985, when the entire power sector was taken over by the military. This crisis was brought on by the decline of Romania's oil production, together with inadequate development of coal production. Rather than launch a huge expansion of relatively inefficient coal power generation, the solution for this desparately poor nation is to go nuclear. Immediate requirements to meet the energy crisis are estimated at 4 GWe nuclear capacity.

Within Western Europe, a disastrous energy bottleneck has arisen through the sabotage of nuclear energy in Italy. Brownouts and blackouts are now a regular feature of life, not only in the South of Italy, but increasingly in the North, too. Lack of energy is strangling Italian industry and exacerbating the chronic underdevelopment of the Mezzogiorno. This is occurring even though Italy imports increasing amounts of nuclear-produced electricity from France. On this background, the proposal of the European Labor Party for construction of 30 GWe of nuclear power capacity in Italy is hardly exaggerated. The approximate doubling of Italy's present electricity production which this measure would permit, would simply bring Italy's per capita electricity production to the level of France and Germany today. Of that 30 GWe, the first 10 GWe must be installed on an emergency basis, as an absolute minimum to prevent a devastating loss of Italy's industrial potential.

Adding up only the most urgent requirements to avoid an energy disaster within the area of the Triangle and its spiral arms, we arrive at 84 GWe. This is a minimum value, to be realized by the end of this century at the latest.

An optimal program

We turn now from emergency measures to the requirements for optimal economic development as called for by the Triangle program. For a first approximation, we have used the following four assumptions:

1) The average density of useful energy delivered per square kilometer shall increase throughout the Triangle and its spiral arms, to the present density values for West Germany, and beyond these at a rate not less than 8% per year. This expansion is driven by the economic reconstruction of Eastern Europe and a rapid increase in exports of high-technology capital goods from Europe to the developing sector.

2) The single most efficient means to accomplish this densification process is to increase the role of electricity in industry and transportation, parallel with rapid growth of productivity in those sectors. It is reasonable to assume that as plasma and coherent-energy processing replace many of today's heat-based processes, electricity will rise to account for at least 60% of industrial energy consumption. Meanwhile, the transportation system's consumption of oil and gasoline will stabilize at a value significantly less than that in West Germany today, with the increased movement of materials, goods, and passengers being carried by mainly electricity-based rail and maglev systems for long-distance and urban transport. Combined with increased utilization of Europe's unique inland water infrastructure, these measures will reduce the average energy cost of transport per ton-kilometer and passenger-kilometer to less than half the present value.

3) Nuclear energy will increasingly displace fossil fuel combustion in the "heat market"—particularly for heating of residential areas and industrial facilities, and as a process heat source in the chemical industry. In a preliminary phase employing present-generation HTR technology, we can reasonably expect to cover 5% of the "heat market" around the turn of the century. Then, on the basis of operational experience and perfected technology, that percentage will expand to as much as 30%.

4) With increasing electrification, the demand for process heat at temperatures below 1,000°C will grow more slowly than industrial production as a whole. Two important exceptions to this, however, may develop over the coming years: coal gasification and thermocatalytic generation of hydrogen. The HTR has already been studied in connection with both these applications, and economically viable technology is already available for the first one. HTR-based brown coal/lignite gasification facilities should be included among the first phase indicated above. The areas of choice include Poland and other increasingly gas- and oil-starved nations of Eastern Europe, which possess large reserves of coal that are best exploited in the indicated way.

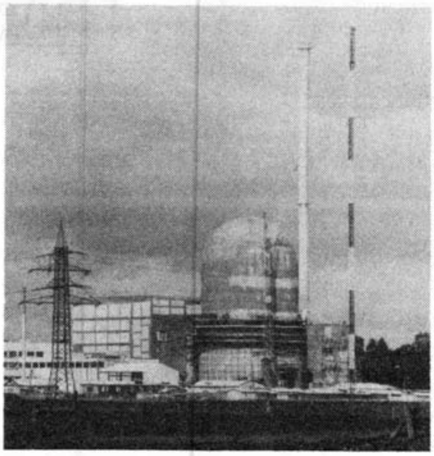
Based upon these assumptions, we arrive at the rough estimates of requirements for electricity alone, shown in **Table 3.**

The lower figure corresponds to only a slight increase above present values. The core area is approximately at the given value today, while the spiral arms fall short by approximately 500 TWh (corresponding to an additional required capacity of about 100 GWe, an increase of 20% for the whole system). At this lowest variant, the Triangle and its spiral arms consume about the same amount of electrical energy as

TABLE 3

Electricity requirements for the European Triangle

	30% of industrial energy use from electricity	50% of industrial energy use from electricity	60% of industrial energy use from electricity
Average electric power per km^2	194 KW/km^2	250 KW/km^2	300 KW/km^2
Core region of the Triangle	560 TWh	720 TWh	860 TWh
Installed capacity required	115 GWe	148 GWe	178 GWe
Core region plus spiral arms	2,428 TWh	3,120 TWh	3,740 TWh
Installed capacity required	499 GWe	641 GWe	770 GWe



Office of European Atomic Energy Commission (URATOM)

Gundremminger nuclear power plant in West Germany on the Danube.

the United States today, on one-seventh the land area.

Assuming that, as in France, 70% of electricity production is to be based upon nuclear energy, the lowest variant calls for some 350 Gigawatts of nuclear capacity in the Triangle and its spiral arms. This is somewhat larger than the present nuclear capacity of the *entire world* (311 GWe), and about three times the present installed nuclear capacity of Europe (not including the U.S.S.R.). The 350 GWe would consist of an existing approximately 115 GWe of nuclear capacity, plus 100 GWe nuclear to be added, plus replacing 135 GWe of existing fossile fuel plants by nuclear. This 135 GWe might seem rather high at first glance, but it includes 74 GWe already mentioned as emergency replacement requirements for Eastern Europe. Add to this the obsolescence of most of the power generating equipment in Eastern Europe and the replacement requirements of Western Europe due to depreciation (average lifetime of 30 years, requiring replacement of one-third of all equipment every 10 years) and technological obsolescence (including environmental considerations). We see that 100+135 GWe=235 GWe is not an unrealistic demand to be met over the next 10 years. It will, of course, require an unprecedented nuclear construction program, but one which is well within the grasp of the industrial regions included in the system.

In terms of process heat, we can use the combustion fuels consumption of West German industry as a comparison; it runs at approximately 720 TWh per year, of which 38% is in the chemical industry. To supply 5% of that by nuclear process heat around the turn of the century, would mean an average thermal power level of about 4 GW. A reasonable estimate for the Triangle and its spiral arms would be about three times this, or 12 gigawatts-thermal. This does not take account of the perspectives of nuclear coal gasification, however. As part of a first phase, pilot plants should be set up in some of the main brown coal producing regions, to perfect the technology and gain operational experience. An HTR complex of 1 GW(th) can produce 1.2 billion cubic meters of methane per year, with a heat value of about 1.4 GW.

Nuclear energy is one key to reducing the dependence of Eastern European nations upon oil and gas imports from the U.S.S.R. The other decisive measure is to set up adequate infrastructure, giving those nations access to the Western European petroleum network. This does not mean ending all imports of fuel from the U.S.S.R., but eliminating the condition of total dependence which is incompatible with the sovereignty of the nations of Eastern Europe, and increasingly risky in view of technical and other problems in the U.S.S.R. Meanwhile, Western technology, including the HTR, can greatly benefit the extraction and exploitation of Russia's vast mineral reserves, as well as upgrade the safety and performance of nuclear power in the U.S.S.R.

As we proceed with the indicated energy buildup, revolutionary new technologies are appearing on the horizon: "hot" nuclear fusion is nearing the point of scientific breakeven, and pilot fusion power plants could be built in the early years of the next century. Using fusion, the deuterium contained in one liter of sea water can provide the energy equivalent of 300 liters of gasoline. Even before "pure" fusion plants come on line for commercial power production, the so-called fission-fusion hybrid reactor could be employed to breed fission fuel. This technology employs fusion reactions as a source of neutrons for the breeding process, and offers considerable safety and other advantages over present breeder reactor technology. Even more revolutionary are the implications of the peculiar phenomena observed in electrolytic cells using heavy water, the phenomena referred to as "cold fusion." Here much more research is required, but those controversial observations point toward the existence of new types of nuclear processes which might be exploited in technology of the future.