Why the U.S. needs nuclear power production

Robert Gallagher proves that nuclear power is not only safe, but indispensable to meet the energy requirements of the future.

After Soviet Russia launched an international propaganda campaign against nuclear power, through its activation of the Green Party to shut down 16% of West Germany's electrical generating capacity, some observers were surprised when Moscow TV announced June 3 that the two undamaged reactors at Chernobyl would be back on line as early as October. The Chernobyl accident has in no way altered the Soviet commitment to nuclear power development. Despite their disregard for safety, the Kremlin leaders understand that nuclear power is inherently superior to any form of electric power generation based on the combustion of coal, oil, or natural gas.

The success of the environmentalists in the United States in destroying our nuclear power construction program, has led the United States to the brink of economic disaster. The potential relative population density of the United States has declined over the past decade as a result. Per capita electric power production leveled off in the late 1970s and has actually declined since President Ronald Reagan's election in 1980, for the first time since Herbert Hoover was President (**Figure 1**).

Preceeding this decline, electric power output per powerplant production worker peaked in 1970 and has dropped 10% since. This stagnation and then collapse in productivity followed closely on the heels of the decline in the rate of growth of the energy flux density applied in fossil fuel-fired power plants in the mid-1960s. (Energy-flux density measures the intensity of the application of energy through a work surface, and thus measures the ability to perform work.)

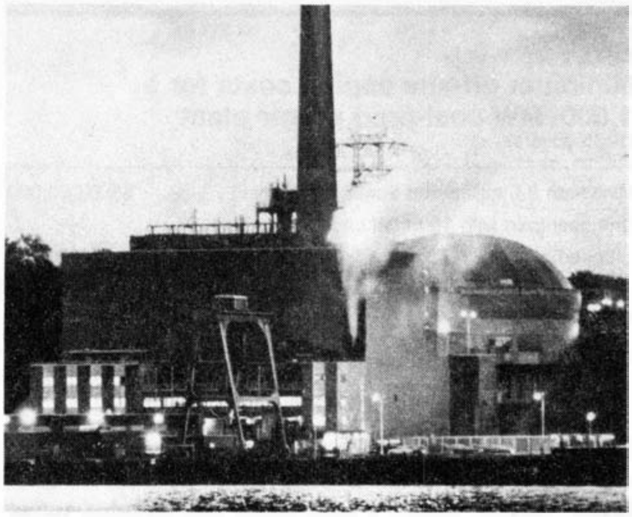
To comprehend the enormity of the problem we face, consider the energy requirements for U.S. economic growth between now and the end of the century. The Department of Energy admits that the nation will require 50% more electrical generating capacity by the year 2000; but *EIR*'s October 15, 1985 *Quarterly Economic Report* estimated that turn-of-the-century needs will really be double today's capacity.

These discouraging trends could have been prevented, or at least reversed, by a determined effort to "go nuclear" in the 1970s and 1980s. Productivity at nuclear power plants is over 10 times greater than conventional generating stations. Nuclear plants generate steam to drive turbines by applying an energy-flux density approximately 10 times greater than that of fossil fuel-fired plants.

Why nuclear energy is superior

Nuclear power's advantage today derives from the more advanced physical principle, by which it even generates steam. Power plants that burn fuels are limited in the energy-flux density they may apply to produce steam. Water in a boiler would be subjected to the highest energy-flux density (for a moment), if it simply flowed over the burning coals. Unfortunately, this would extinguish the fire in the furnace. As a result, all fossil-fuel fired power plants must separate the heat source and the heat-carrying water medium, with boiler tubing. This tubing must be strong enough to resist the corrosive action of superheated steam, yet thin enough to permit efficient heat transfer across its surface. These boundary conditions place limits on the flame temperatures that can be applied to boiler tubes.

In nuclear light-water reactors, the heat-carrying water medium circulates around and over the heat source, zirconium-clad uranium fuel elements, and thus the boundary conditions on energy-flux density that limit fossil-fuel fired plants are removed. This permits the order-of-magnitude leap in



Consolidated Edison

New York's Indian Point nuclear plant.

energy-flux density achievable with nuclear power.

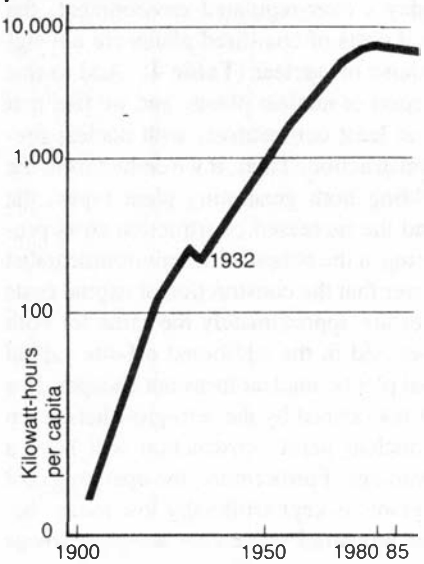
This, and the fact that nuclear power plants do not require hundreds of miners and railroad workers to fuel them, produces the tremendous increase in productivity.

With this background, it perhaps seems odd that accountants and environmentalists are perpetrating the myth that nuclear power is a greater cost to the national economy than coal-fired power plants of equal generating capacity. From a bookkeeping standpoint, it may appear, at least for some utilities close to significant, cheap coal deposits, that this is true. Coal appears cheaper only because of the significantly larger financing and re-engineering costs now applied to the construction of a nuclear plant, because of regulatory measures and construction stretch-out resulting from re-design of the plant during construction. Over the past decade, the average lead time for construction of a U.S. nuclear plant has doubled, from 60 months to 120 months, and costs have soared. Today, the total capital cost of a nuclear plant of 1 gigawatt capacity ranges from $2 billion to $5 billion, most of which is related to increased costs from time delays and changes required by Nuclear Regulatory Commission regulations.

From the standpoint of physical economy, there is absolutely no truth to the assertion that electricity generated from coal is cheaper than nuclear. Nuclear power stations compress a huge amount of labor, capital equipment, and resources into a small space relative to that required for coal-fired power generation. In this way, they demonstrate the fundamental principle of economy: the application of higher ordering principles to lower the cost of production.

FIGURE 1

U.S. electric power production

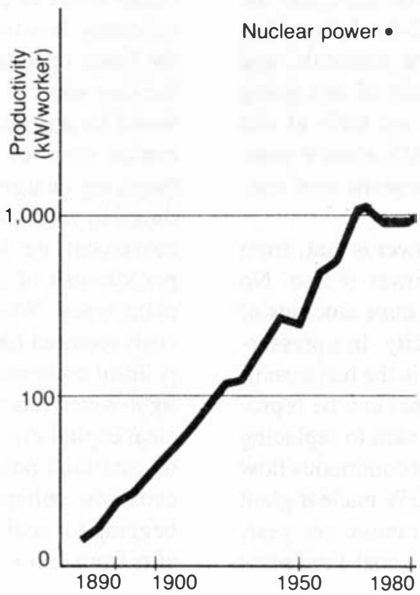


Per capita electric power production in the United States has declined since President Reagan's election, for the first time since the Hoover administration.

Note: All graphs are drawn to logarithmic scales

FIGURE 2

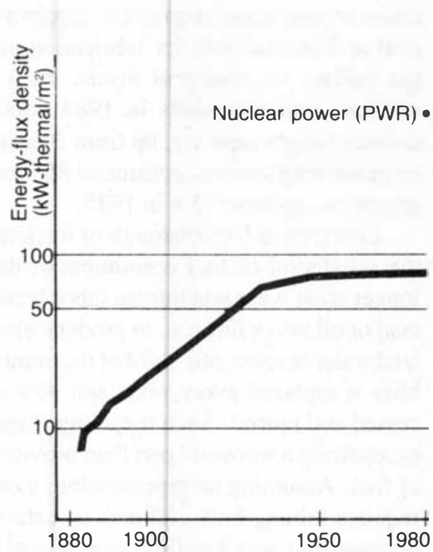
Productivity in U.S. electric power generation



Until 1965, there was an exponentially increasing productivity in U.S. electric power generation.

FIGURE 3a

Energy flux density in U.S. power production



Energy flux density through the heat transfer surface of steam boilers increased exponentially in power generation until 1930.

TABLE 1
Labor requirements for a 1,000-MW power plant

	Coal	Nuclear
Off-site		
miners	751	negligible
transport	254	negligible
On-site		
plant operatives	200	96
Total production workers	1,205	96

Sources: Statistical Abstract of the U.S.; Waterford Nuclear Power Plant, Louisiana; CSX, Inc.

TABLE 2
Minimum off-site capital costs for a 1,000- MW coal-fired power plant
(1985 dollars)

Mine with 3.5 million-ton annual capacity	$350,000,000
Unit coal train with 100 coal cars	
Locomotive	1,500,000
110 coal cars (@$35,000 ea.)	4,000,000
TOTAL	$355,500,000
Additions to capital costs per kW	
Coal mine	$350
Two trains	11
TOTAL	$361

Sources: Statistical Abstract of the U.S., National Coal Association, Association of American Railways, Thrall Manufacturing.

Tables 1 and **2** show the tremendous off-site labor, capital, and coal requirements for only a single 1-gigawatt coal-fired power plant. (Corresponding costs for nuclear plants are negligible on a per kilowatt basis.) When the labor required to mine and haul the coal to the plant is counted, the labor productivity in nuclear power is at least 10 times greater than that of coal-fired power (**Table 3**). In other words, the portion of the labor force required to produce U.S. power needs, is 14 times greater for coal than for nuclear. With a nuclear power grid, the potential relative population density of the United States is correspondingly higher. This indicates the true saving of "going nuclear," and the true cost of not doing so.

With nuclear, we do not require the coal mine and the coal-carrying trains required to supply a coal-fired plant. The coal is then available for fabrication of new materials, and the railcars for transport needs. As a result of not going nuclear, coal shipments in 1984 gobbled up 40% of our railway freight capacity, up from 29% in 1975; electric power-generating stations consumed 85% of domestic coal consumption, up from 73% in 1975.

One critical breakthrough of nuclear power is that, from the standpoint of fuel consumption, the power is free. No longer must we waste human labor feeding huge amounts of coal or oil into a furnace, to produce electricity. In a pressurized water reactor, one-third of the uranium in the fuel assemblies is replaced every year, and 96% of that can be reprocessed and reused. Such recycling is more akin to replacing or repairing a worn-out part than providing a continuous flow of fuel. Assuming no reprocessing, a one-GW nuclear plant requires mining only 133 tons of natural uranium per year, compared to over 3 million tons of coal for a coal-fired plant of the same power output.

The most elementary thermodynamic parameters of the real physical economy, demonstrate this natural superiority of nuclear power over coal-fired power production methods. The elementary data of energy-flux density, electric power output per unit of thermal energy generated, and power output per production worker, shown in Table 3, cry out for the nuclear age. All issues of safety and "waste disposal" aside, nuclear power today in its infancy, is an order of magnitude superior to fossil fuel-fired power plants in energy-flux density and labor productivity, and competitive in energy efficiency. With the development of more advanced materials, nuclear power's efficiency could soon exceed 50%, were the technology not being sabotaged by the Congress and Nuclear Regulatory Commission.

When the additional costs to the nation of coal-fired power are counted in figuring the comparative costs of coal and nuclear, even in today's over-regulated environment, the construction or capital costs of coal-fired plants are not significantly less than those of nuclear (**Table 4**). Add to this the lower operating costs of nuclear plants, and we find that the two sources are at least competitive, with nuclear preferred for any new construction. Then, if we deduct from the capital costs of building both generating plant types, the financing charges and the increased construction costs produced by re-engineering at the behest of the environmentalist movement, we discover that the construction or capital costs per kilowatt of power are approximately the same for both plant types. When we add in the additional off-site capital costs required for coal plants, nuclear turns out cheaper. In a political environment not defined by the zero-growthers, even light-water reactor nuclear plant construction will have a clear capital-cost advantage. Furthermore, the operating cost of coal-fired power plants is kept artificially low today, because the collapse of industrial commerce leaves railroads begging for coal transport contracts. The coal consumer benefits from today's depressed economic conditions.

The historical record

The thermodynamic history of electric power production, shows that the intrinsic physical-geometric tendency of power production technology in the United States contains an

TABLE 3

Economic parameters of power production

	Energy flux density (kW−t/m²) (a)	(b)	Transformation rate (kWh-e/kWh−t)	Kilowatts-electric per worker: plant workers only	including miners	including railroad workers
Coal plant	82.0	10,300	0.342	5,000	1,051	830
Nuclear (PWR)	704	360,000	0.32	10,000	10,000	10,000

Notes: (a) is energy flux density through heat transfer area; (b) is energy flux density through cross-section of furnace. Coal data are 1982 industry averages. Note that some coal plants have achieved efficiencies of 0.4. PWR = pressurized water reacter. kW − t = kilowatt thermal; kWh-t = kilowatt-hour thermal; kWh − e = kilowatt-hour electric.

Sources: Combustion Engineering; Statistical Abstract of U.S.; Waterford Nuclear Power Plant, Louisiana; Frank J. Rahn et al., *A Guide to Nuclear Power Technology,* Wiley, New York, 1984.

impetus towards conversion to nuclear. Around 1970, this development was thrown off the track, and the physical economy of power production began to collapse as a result.

Figure 2 shows the rise in continuous electric power output per production worker (in kilowatts per worker) for coal-fired power production from 1890 to 1982. Productivity is shown on a logarithmic scale, because all growth in nature is self-similar. The fact that productivity growth generally follows a straight line from 1895 to 1965 in this logarithmic graph, shows that the growth was exponential over this time period. Note the leveling-off that occurs after this.

Figure 2 indicates a representative data point for nuclear power, in this case, the much-maligned pressurized water reactor (PWR)—"off the chart" compared to fossil-fuel methods. Since the necessary operating labor of these coal-fired plants includes hundreds of coal miners (see Table 1), the productivity of labor at them is calculated with the entire necessary production labor force included.

The primary questions are: 1) What produced the exponential growth in productivity from 1895 to 1965? 2) What aborted this growth thereafter?

All power plants installed over the past century generate electricity by boiling water, to produce steam, and using the steam to drive steam engines or turbines that turn large electromagnets. The effective energy-fluxes occur across the heat-transfer surface of the steam generator (that is, the surface of the tubes carrying water in a water boiler) and through the cross-sectional area of the boiler as a whole (the cross-sectional area of the furnace in a coal plant). The energy tolerance of the materials composing the first surface, determine the maximum flux that may be applied to the boiling water. The energy-flux through the cross-section of the boiler, identifies the scale of steam generation: It increases with the height of the boiler. Both measures inform us about the efficiency of steam generation.

Figures 3a and **3b** show the development of energy-flux density (in kilowatts per square meter, on a logarithmic scale) in fossil fuel-fired boilers, calculated through both surfaces. Figure 3a shows the development of energy-flux density through the heat-transfer surface of the boiler tubes, while Figure 3b shows the flux density through a cross-section of the furnace. The figures indicate representative data for nuclear power. A graph of the development of the energy transformation rate, or efficiency of power production with steam boilers (**Figure 4**), shows that both of these measures are relevant.

There have been two significant declines in the rate of increase of the efficiency of power production in coal-fired plants. The first, as shown in Figure 4, occurred between 1930 and 1940; the second, between 1960 and 1970. In the first period, the growth of the energy-flux density through the heat-transfer surface of the boiler tubes leveled off, as shown in Figure 3a, and reached the limit attainable with chemical combustion systems: The material requirements of having flame on the exterior of a few-millimeters thin boiler tube and highly corrosive steam on the inside, became insurmountable. Advances to a new type of energy source were

TABLE 4

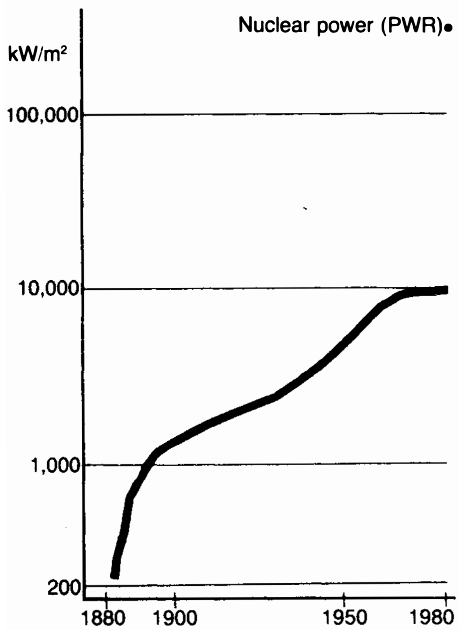
Capital costs per kilowatt for 1,000-MW coal plant and 1,000-MW pressurized water reacter

	Under today's regulations: Total today	Plus off-site	Under sensible regulations: Basic cost	Plus off-site
Coal	$2,300-2,600	$2,660-2,960	$1,200	$1,560
PWR	3,000	3,000*	1,200	1,200*

*Off-site additions to cost are negligible per kilowatt of power for nuclear.

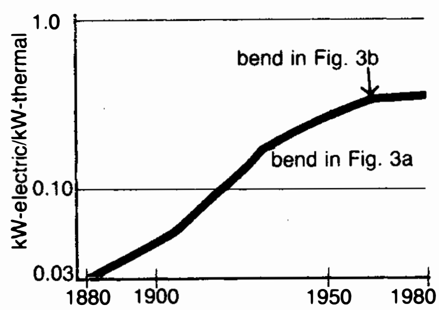
Sources: Department of Energy, Nuclear Power Database, June 1985; Electric Power Research Institute, Handbook.

FIGURE 3b



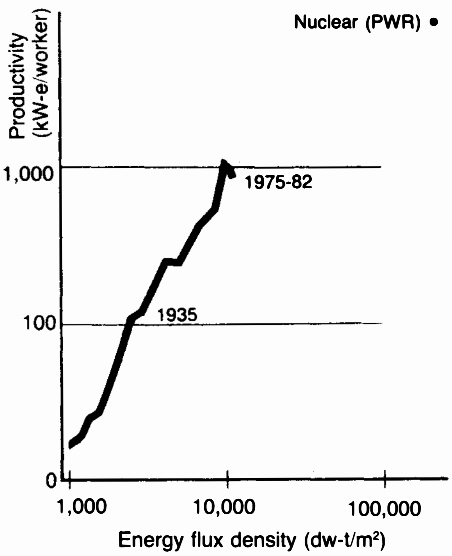
Energy flux density through a cross-section of steam boilers increased at an increasing rate since 1960.

FIGURE 4
U.S. power output



Power output per unit of coal consumption increased until 1965; its rate of increase had slowed around 1930.

FIGURE 5
Correlation of productivity with energy flux density



Increases in energy flux density through a cross-sectional area of steam boilers correlates with productivity increases from 1895-1970.

required already in the mid-1930s. This dating actually coincides with the demonstration of the feasibility of nuclear power by Otto Hahn. The leveling-off of growth in Figure 3a displays classical hyberbolic exhaustion of a process because of the failure to solve technological problems.

After the leveling-off in energy-flux density through the heat-transfer surface, the steam power output of boilers was increased primarily by making them larger and adding more tubes, with the effect of increasing only the energy-flux density through the furnace cross-section. A dramatic increase in unit size of boiler-turbine steam generators occurred in the 1960s.

The second decline in the rate of growth of efficiency coincides with stagnation in the growth of the energy-flux density through the furnace cross-section, as boiler unit size leveled-off around 1970. The fall in productivity shown in Figure 2 followed thereafter.

If increases in energy-flux density reflect technological development that caused, or enabled productivity increases to occur, there should be an inherent geometric relationship between increases in flux density and increases in productivity. Figure 5 shows the productivity data of Figure 2, plotted against the energy-flux density data of Figure 3b, to determine to what extent there is a close correlation between the two. The graph demonstrates that a correlation exists. In both, the correlation is very good during the periods of continuous exponential increase in energy-flux density: 1895 to 1965. In other words, productivity increases are usually accompanied by increases in energy-flux density. The directionality of these charts tends toward the higher productivities and energy-flux densities possible only with nuclear technology.

One of the fantastic results of the increases in energy-flux density in power production over the period from 1890 to 1965, is that the cost of electricity declined in actual dollars over the entire period.

The dramatic compression in scale introduced by nuclear power will produce unpredictable savings to industry. Since we are today only in the infancy of nuclear technology, we can only say for certain, that it will provide a pathway toward putting greater reducing power at the disposal of man. It is clearly a boon to nations with little or no coal reserves, but just how it will affect industry overall is not yet appreciated. The next obvious step to take in industrial development—requiring nuclear—is to continue the electrification of industry begun in the 1890s, by powering all high-temperature thermal processes, such as steel-making, with the electric-powered plasma torch.