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Standardization of power-plant output required to meet the world's needs

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The United States of America's 1950s "Atoms for Peace" program had as its major objective the provision of high-quality electric power and heat for the modern industrial development of the underdeveloped world. If a New World Economic Order is organized for a recovery from the current world depression, the ambitious nuclear-electricity production goals of Atoms for Peace could still be achieved, despite the 15-year U.S. default on its nuclear exports promises.

This is the conclusion of a current Fusion Energy Foundation review of the potential new reactor and fuel technologies and reactor production methods of the immediate future through the end of the century. Standardized, "mass production" capabilities for nuclear reactors, now emerging in several nations including the United States, show the potential to make up for 20 years of neglect.

The FEF survey found that by full utilization of the standardization methods they have been developing, the world's five leading nuclear-producing nations would turn out the equivalent of 1,300 gigawatts (GWe) electric power (one gigawatt is roughly the size of a modern full-sized, 1,000 megawatt plant) by the end of the century, from (France excepted) what is a virtual standing start (see Figure 1). Such an achievement would fall short by nearly 50 percent of meeting minimum power needs of modern industrial and

Figure 1
Accumulated nuclear plant production capacities
(in GWe's by nation)

	1990						2000					
	Stnd. Plnt.*		Flt. Plnt.†		Tot. Plnts.‡		Stnd. Plnt.		Flt. Plnt.		Tot. Plnts.	
Nation	GWe	GWe/yr	GWe	GWe/yr	GWe	GWe/yr	GWe	GWe/yr	GWe	GWe/yr	GWe	GWe/yr
United States	182	20/yr	8	4/yr	190	24/yr	446	32/yr	216	24/yr	662	56/yr
U.S.S.R.	73	8/yr	—	—	73	8/yr	153	8/yr	60	8/yr	213	16/yr
France	52	3/yr	—	—	52	3/yr	90	5/yr	60	8/yr	150	13/yr
Germany	37	3/yr	—	—	37	3/yr	82	5/yr	60	8/yr	142	13/yr
Japan	42	2/yr	—	—	42	2/yr	78	5/yr	60	8/yr	138	13/yr
Nation Total	386	37/yr	8	4/yr	394	40/yr	849	55/yr	456	56/yr	1305	111/yr
INFCE/Seaborg World Requirements					600	70/yr					1510	110/yr

Summary of accumulated major component production capacity—five nation totals

	1990						2000					
	Stnd. Plnt.		Flt. Plnt.		Tot. Plnts.		Stnd. Plnt.		Flt. Plnt.		Tot. Plnts.	
Component type	#	Rate	#	Rate	#	Rate	#	Rate	#	Rate	#	Rate
Reactor pressure vessels	386	37/yr	8	4/yr	394	40/yr	849	55/yr	456	56/yr	1305	111/yr
Steam generators	772	74/yr	16	8/yr	788	80/yr	1689	110/yr	912	112/yr	2610	222/yr
Primary coolant pumps	1158	111/yr	24	12/yr	1182	120/yr	2547	165/yr	1368	168/yr	3915	333/yr
Turbine-generators	386	37/yr	8	4/yr	394	40/yr	849	55/yr	456	56/yr	1305	111/yr

Source: Fusion Energy Foundation, 1982.
*Standard Plant
†Floating plant
‡Total plants

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agricultural standards in the Third World—the basic task of decolonization. But if India, Sweden, and other nuclear producers whose programs have been conceived only for their own use, develop export capacities as well, the year 2010 might see the achievement of such "modern" (i.e., 1980) standards of power use for the entire world.

Thus, ten years later, the nations of the 21st century could achieve the levels, and the purposes, of nuclear power use set forth in global planning documents of the mid-1960s. The clearest and best-known of those was authored by former Atomic Energy Commissioner Glenn T. Seaborg, a physicist who discovered several transuranic elements.

What are these standards? Seaborg's book *Man and Atom,* aimed at worldwide electricity use of 6,000 kilowatt-hours (kwh) per capita, by the year 2000. For comparison, current U.S. standards are over 10,000 kwh per capita per year. European standards average about 5,000 kwh per capita inclusive of less-industrialized European areas like the Iberian peninsula. In stark contrast, Third World electricity-use standards today are typified by Egypt's 335 kwh per capita annually. The vast energy gap Seaborg saw, and aimed to close with nuclear power, is not only as wide as ever, but both advanced and underdeveloped nations have stagnated since 1979 in this crucial parameter.

Competent studies repeatedly demonstrate that electricity growth must "lead" economic growth by at least 50 percent; all attempts to "decouple" the two have been fraudulent substitutions of distorted GNP or money-supply figures for real economic growth.

Nuclear construction worldwide has equalled less than one-third of even the "first-stage" goals of Seaborg's study, and U.S. capacities have fallen into complete disuse. Thus the importance of the FEF survey's finding that a "last chance" still exists for a nuclear production drive which might approximate what has been known for 20 years to be necessary.

While France has achieved in practice the closest and most effective approximation of rapid, nationally standardized production of nuclear reactor units, the United States, the U.S.S.R., and Japan are all converging on extremely similar large-sized, optimally efficient standard unit designs, and all have greater ultimate capacities for mass-production than France despite its successful experience, because of their much greater industrial depth. The United States is actually by far the closest to an actual mass-production capacity for completely-assembled reactors. The "floating plant" production facility pioneered by Offshore Power Systems in Ft. Lauderdale, Florida, is now nearing final licensing by the Nuclear Regulatory Commission, although it is without orders from anywhere in the world at the depth of the current depression.

Standardized reactor construction

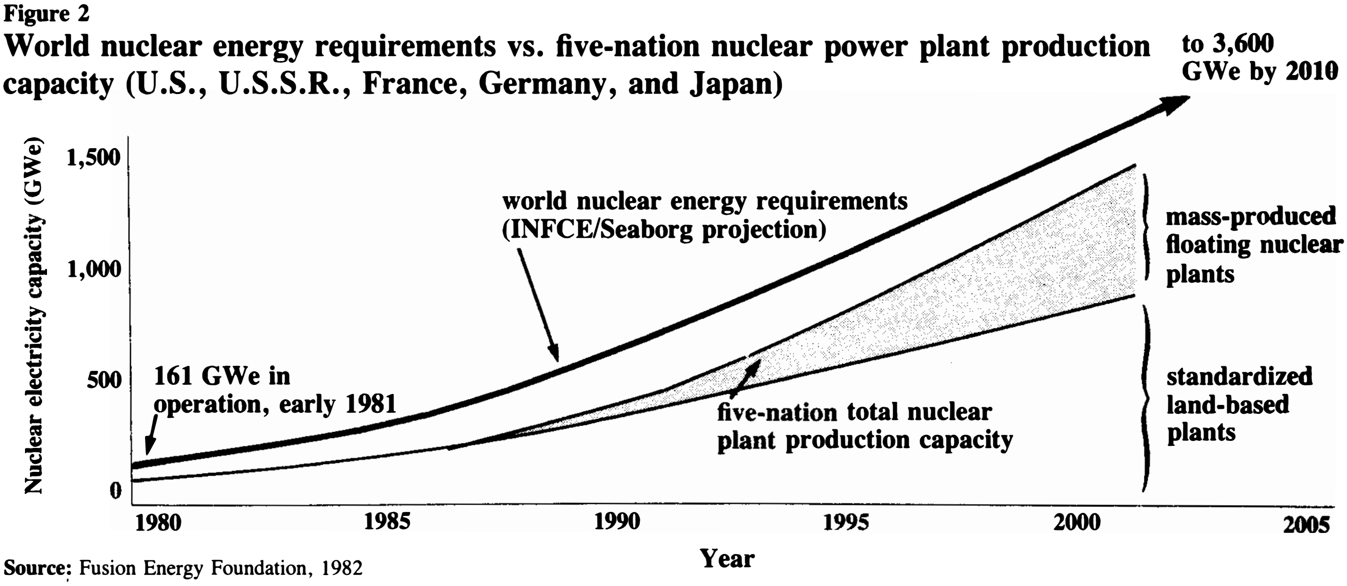
Figure 2 shows that this total potential for the leading nuclear-producing nations over the next 20 years is increased by nearly 50 percent (the shaded area) because of the promise of standardized reactor-production methods by the mid-to late-1980s.

Figure 3 demonstrates that by far the largest block of essential nuclear production capability remained in the United States as of the end of the 1970s; by 1982 the U.S. program's goals have dropped by nearly 50 percent in three years (unlike those of France, Japan, and the Soviet Union, whose domestic production goals remained near their maximum capacities.)

Standardized reactor construction involves choosing one plant type and size, or perhaps two sizes, that have already been built successfully several times, and tooling up the supporting component manufacturing industry to continuously reproduce components for these reactors only. Based

Figure 2

World nuclear energy requirements vs. five-nation nuclear power plant production capacity (U.S., U.S.S.R., France, Germany, and Japan)



Source: Fusion Energy Foundation, 1982

on world experience to date, that single-sized reactor is approximately 1,000 to 1,200 MWe and is either a pressurized water reactor (PWR) or a boiling water reactor (BWR), which are both classified as light water reactors (LWRs). This large size has been chosen based on the optimum for the combustion temperatures characteristic of current nuclear fuels. The reactor type LWR produces electricity most economically relative to other types of reactors available today. For export to developing nations, however, a smaller 300 to 500 MWe size will probably be chosen as the most economically feasible, since many regions cannot handle the output of the larger reactor in one location, and will not be able to for years to come.

Another big advantage in addition to the advantage of efficiency in the production of components for such plants, is in licensing the plants. That is, if exactly the same plant has already been licensed before, its duplicates could be licensed almost automatically since every safety feature had already been previously approved by the licensing agencies. The only differences would be in the site-related considerations. However, standard plants will literally take years off both construction and licensing time.

U.S. nuclear production capacity

As of early 1979, all four reactor manufacturers in the United States were offering utility companies standard plants of the 1,000 MWe size, and gearing up their component production facilities for mass production. In fact, according to an Atomic Industrial Forum (AIF) study released that year, the U.S. nuclear industry would have the capability to produce 25 to 30 full-size 1,000 MWe nuclear power plants per year when geared up to full capacity, then planned for about 1985. This means an industry capable of *producing annually,* 30 reactor pressure vessels, 50 steam generators (BWRs don't need steam generators), 90 primary coolant pumps, 30 complete reactor internals and 30 turbine/generator units, just to mention a few major components. Uranium mining, enrichment services, and fuel fabrication facilities could also be geared up to these production levels by that time, according to AIF.

But since 1979, much of this capacity has been put in mothballs or diverted, as in the case of pressure vessel/steam generator manufacturing capacity recently producing large tanks and equipment for the oil industry. Of course, some of this capacity has since shut down completely and no longer exists because the companies have gone out of business, or at least out of that business. Under conditions of economic recovery and a "great projects" infrastructure-building effort worldwide, it will take on the order of three to five years to replace that once-existing capacity and gear up to those production levels again.

Production capacity outside the U.S.

A look at the current and future construction programs of the other four leading nations revealed the following. The U.S.S.R., which just recently put into operation its Atommash reactor-component mass-production facilities on the Volga River, will soon have the means to produce components for four 1,000 MWe PWRs per year, increasing to eight per year by 1986. France, on the other hand, made a decision nearly ten years ago to produce a standard 1,000 MWe PWR and over the past two to three years has begun to start up some of these plants. The French plan to continue bringing these plants on-line at a rate of three to four per year over the next two decades, and could easily increase this to six per year if the demand existed. West Germany and Japan are just beginning to standardize, but both will soon have the capacity to produce large PWRs at a rate of three per year, with the capability to increase this to five or six per year by 1990 if the market existed.

The floating nuclear plant

To actually be capable of mass producing the entire nuclear power plant, not just its components as is currently done in the standard plant concept, would be the most efficient, productive, and economic way of building nuclear power stations. This involves the old tried-and-proven American concept of assembly-line production, with the final product coming off at the end of the line. For a product as large as nuclear power station, this represents a great advance in assembly-line practices. However, we already know that it can be done, and how it can be done.

Over ten years ago Westinghouse proposed that an assembly-line-based mass-production facility be studied and built if feasible, which would produce floating nuclear plants. This would work in much the same manner as some production plants that have already been built by the Japanese and others. These, such as desalination plants and some petrochemical facilities, are built on floating barges and towed to the purchasing country. In fact, floating nuclear plants, although smaller in size, have been around for a long time—since the first nuclear submarine, the Nautilus was launched in 1955—and there are now several hundred scattered around the world in submarines and aircraft carriers.

However, in Westinghouse's proposal, an actual production-line fabrication plant would be set up and continuously produce FNPs on a several-per-year basis. The feasibility study proved out the concept, and in 1975 Westinghouse began construction of a manufacturing facility in Jacksonville, Florida.

In this facility, which is located in a bay off the Atlantic Ocean, an entire PWR nuclear power station will be assembled on a floating barge-like structure, which can then be towed by tug-boat to any offshore, bay, or river location in the world to provide electricity where needed. The standard size of the plants produced is to be 1,150 MWe, enough to provide electricity to a city of 600,000 people. With some modification, a smaller unit could be produced if the demand were there, especially from the developing nations. The 1,150 MWe plant itself is 400 feet square in area and sinks to a depth of about 44 feet when floating; thus it has the capability of being towed into relatively shallow water, including some rivers.

Once shipped to its final location, in most cases a man-made island located two to three miles offshore, all that will be necessary to deliver electricity will be to plug the plant into the existing grid via a cable connection, and turn on the reactor. Since the bulk of the world's population and industry is located on or near coastlines or major rivers, a large portion of the world's future electricity requirements can be provided by these mass-produced reactors.

Westinghouse's production plant in Florida could be in full operation if a three-year concentrated construction effort were undertaken. By 1989, it could be mass producing its first completed units. The initial rate of production will be four nuclear plants per year. However, with further modifications, this facility could reach a maximum production capacity of eight plants per year.

All of Westinghouse's existing orders for floating nuclear plants were cancelled in 1978, due to the then-worsening economic depression and the drop in electricity demand. Since then, Westinghouse has kept a small staff on site which has continued a low-key effort to obtain a manufacturing license from the Nuclear Regulatory Commission. It was recently announced that the license is six to eight months from final approval, much to the consternation of many advocates of the shutdown of the U.S. nuclear industry.

Westinghouse's is, of course, just one of several mass-production facilities that could be in operation during the next two decades if the appropriate economic and political climate existed now. The three other major U.S. nuclear reactor manufacturers were considering the building of mass-production plants several years ago, and these efforts could be rather quickly reactivated. Likewise, the U.S.S.R., France, Japan, and Germany would also be capable of building a mass production facility if the appropriate incentive existed, and could be producing nuclear plants of this type by the early 1990s.

What can be achieved?

With the existing nuclear manufacturing capacity plus an added margin from the introduction of floating nuclear plant production facilities over the next two decades, the world should have most of the capability necessary for carrying out the much-too-long delayed world electrification program, and therefore the major nation-building projects of a "Great Enterprises" program.

The assumptions of Figure 1 and Figure 2 are as follows.

In 1989, the Jacksonville facility will begin producing floating nuclear plants at 4 per year, increasing to 8 per year by 1993. Two additional mass-production facilities will be added in the United States, one on the East Coast and another on the West Coast, which will begin producing four plants per year each in 1992, increasing to eight floating plants per year each by 1994. A third increment of mass-produced floating plants will be added in the U.S.S.R., France, Germany, and Japan with all four producing floating plants at a rate of four per year each in 1992, increasing to eight per year in each country by 1996.

The total production capacity of all five nations combined, both land-based and floating, by 1990 will be 394 GWe, while by 2000 it will be 1,305 GWe. The INFCE/Seaborg world requirements for those years are 600 and 1,510 GWe respectively. Obviously the projected capacity as represented by these five nations will not be sufficient to close the gap on the world energy requirements by the year 2000 time frame. Even after the production capacity of the remaining 15 percent of the nations with nuclear capability is added, including Canada, the United Kingdom, Sweden, Italy, and Belgium, the total is expected to fall at least 100 GWe short by 2000, and probably more.

However, it can also be observed from the figure, that the gap between required energy and production capacity will begin to close by the year 2000 such that by the year 2010 or so it should be possible to "catch up" and reach 3,600 GWe installed capacity. This was Seaborg's original goal for the year 2000. By this time, total production will also include significant contributions from some developing nations, such as India, Brazil, Korea, Taiwan, Argentina, and Mexico, as well as additional production capacity in the advanced sector nations.

Thus in the year 2010, approximately ten years behind schedule, the goal of the original "Atoms for Peace" program could be met, with over 50 percent of the world's electricity *capacity* being provided by nuclear power. In terms of electricity *consumption*, this will represent nearly 65 percent of the total, since the cheaper nuclear electricity will be 'based-loaded' and run continuously, with the more expensive oil and coal capacity held in reserve and used for peak loading.

Figure 3

Nuclear power plants in operation, under construction, or on order by nation of manufacture, in 1979

Nation	**Production goal** (MWe)	**% of total**
United States	219,254	52.1
U.S.S.R.	45,758	10.9
West Germany	36,976	8.8
France	36,324	8.6
Japan	18,857	4.5
Subtotal	357,169	84.9
Canada	18,277	4.3
U.K.	11,581	2.7
Sweden	8,280	2.0
Belgium	6,518	1.6
Italy	4,880	1.2
Others	13,787	3.3
Total	420,482	100.0

Source: Fusion Energy Foundation, 1982.