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NUCLEAR POWER

Nuclear power is a relatively recent energy source, beginning approximately half a century ago with both civilian and military applications. Currently, nuclear power is generated through atomic fission (a nuclear reaction that splits the nucleus of the atom into smaller, energized components), but new technologies are being developed to make nuclear power development safer and more controllable. In comparison to fossil-fuel based energy sources, nuclear power has relatively low carbon emissions and, as such, is regarded as a green energy source. However, accidents such as the 1986 Chernobyl disaster and the growing problems of radioactive waste management contribute to maintaining a public fear around the widespread development of nuclear power plants. These civic concerns coupled with a spatially and temporally limited uranium supply do not make nuclear power a renewable nor sustainable energy source.

History

Both the energy and military nuclear power stories follow one single path: since the discovery of radium by Pierre and Marie Curie, scientists, experts, politicians, and industries have always contributed to the development of nuclear power. By nuclear power, we mean here civil nuclear power, excluding military nuclear power and naval and space propulsion.

According to the International Atomic Energy Agency (IAEA), the 436 operational nuclear reactors in the world provide 18,368 TWh (18,368 billion kWh). This represents 14.2 percent of the world's electricity production and somewhere between two to six percent of the total global energy production. The greater part of electricity is provided by thermal power stations through the use of coal, petrol, or gas.

The first atomic cell, as a micro nuclear power generator, was built by Enrico Fermi and Lea Szilard in 1942. It was called "Chicago Pile 1" and provided power of only 0.5 W but was mainly used to contribute to the Manhattan Project and the development of the Hiroshima and Nagasaki nuclear bombs. French scientists Lew Kowarski and Frédéric Joliot-Curie also developed an atomic cell in 1948, called Zoé, with the same goal—to anticipate military nuclear application.

After the end of World War II, the "Atoms for Peace" discourse, announced in December 1953 by President Dwight Eisenhower, furthered the use of nuclear power for energy, not only for war. The United States had already built a nuclear reactor capable of generating electricity in December 1951, but the Soviet Union's Obninsk nuclear power plant was the first to provide an electricity grid in 1954, with a capacity of 5 MWh. Then other nuclear plants opened: in 1956, Marcoule (France) and Sellafield (Great Britain) were the first commercial plants, followed by Shippingport (United States) one year later; 1957 also saw the creation of the International Atomic Energy Agency (IAEA), which compiles data on nuclear development. The IAEA's Power Reactor Information System, for example, presents data on quantity and evolution of the whole world reactor set. The IAEA's Incident Reporting System compiles information on both technical and human factors related to events of safety significance that occur at nuclear plants.

The Framatome organization, created in 1958, is also an important organization, showing the early links between the two countries highest in number of nuclear power plants—the United States and France, now with, respectively, 104 and 59 operational reactors. The so-called "Franco-Américaine de construction atomique" gets together engineers of the four mother companies. Nowadays, it is part of the French AREVA multinational industrial conglomerate.

Power Capacity and Operating Cycle

IAEA's data illustrate the growth of the development of nuclear capacity from almost nothing in 1960 (1 GW or less) to 100 GW by 1980, to 300 GW by 1990 and to approximately 400 GW presently. This increase was made possible by the development of second-generation reactors. After the first attempts during the 1950s and 1960s (atomic cell and reactor of the first generation), a new wave of nuclear technologies was developed (second-generation reactor), mostly represented by pressurized water reactors (about 85 percent of reactors) and, at a lower level, by boiled water reactors and Russian high-power channel-type reactors.

As thermal power stations use fossil fuels to heat up water and activate turbines, nuclear power plants use controlled nuclear chain reactions to generate steam to make turbines and generators run to produce electricity. Nuclear chain reactions result from fission of the atomic nucleus, generally uranium-235, by the absorption of a neutron. Fission divides an atom into two or more smaller nuclei and releases other free neutrons. These neutrons can be absorbed by other fissile atoms and create more fission. Nuclear technology is no more than the use of this chain reaction: the controlled chain reaction is used for nuclear power plants while the uncontrolled version is used for nuclear bombs. Such fission produces a very high quantity of energy: about 20 Mega eV (electronvolt, an energy measure) resulting from the fissile products' kinetic energy (the kinetic energy of new neutrons and new nuclei resulting from fission). This kinetic energy produces the very heat used in the reactor to pressurize or boil water in another closed circuit, depending on the selected technology. Turbines are then activated by pressurized or boiled water and active generators that produce electricity.

As a consequence, nuclear power plants need a source of cool water that will be heated again by the reactor. This is the purpose of the enormous concrete aerorefrigerated towers that are the most recognized aspect of nuclear power plants. The towers use ambient air to cool primary circuit water, inducing a lot of evaporation. Other sources of cooling can be used, such as a river, and still remain radioactive fall-out free. Moreover, water coolant systems induce cooling of the reactor, which reduces the speed of neutrons' interactions with uranium-235 and maintains a relatively controllable chain reaction.

Third and fourth generation reactors are also being developed. Reactors of the third generation will still use fission-produced electricity, such as the European pressurized water reactor (EPR) under construction in France and a similar project in Finland under STUK (the Finnish Radiation and Nuclear Authority). These newer reactors will have a capacity of 1,600 MW—one of the highest production capacities to date. In contrast to earlier generation reactors, fourth generation nuclear reactors propose to use controlled fusion energy. Whereas fission splits the atom, fusion assembles two atomic nuclei to form a heavier nucleus, with extraordinary energy liberation. Using "tokamak" technology, the fourth-generation ITER corporation prototype project may show a controlled fusion use in order to fuel a new nuclear reactor. According to the American National Science Foundation, "proposed advanced (generation IV) nuclear power plants aim to incorporate a suite of new technologies that will produce nuclear power in a manner that is sustainable, economical, safe, reliable, and proliferation resistant, [but] additional research, development, and analysis of advanced nuclear power is needed". The Generation IV International Forum (GIF) website provides detailed information on these projects, explaining six others technologies planned for development.

Controversies and Nuclear Fear

All these new technologies have also known failures. The examples of the Three Mile Island and Chernobyl accidents are well known. The Three Mile Island (Pennsylvania, United States) reactor number two, a PWR type, was subject to a partial fusion of its central core on March 28, 1979. This provoked an important contamination within the confinement enclosure. However, radioactive rejects were limited and seemed not to affect the population or the environment. The Chernobyl nuclear reactor incident would not be though, and would not be without severe consequences.

On April 26, 1986, the Soviet-era RMBK Chernobyl (modern Ukraine) reactor number four, as a consequence of technical and human failure, had an exceptional jump rise in its power output (about a 100-fold increase in four minutes) that resulted in multiple explosions and long-lasting fires. The heart of the reactor burned for six days, engendering a radioactive cloud containing mainly iodine-131 and cesium-137. According to Marie-Hélène Labbé, some 600,000 to 800,000 "liquidators" were recruited to stop the fire and shut down the reactor, but they were not equipped to not be irradiated—or even not contaminated. Then the radioactive cloud drifted over Europe, provoking a still-ongoing controversy over its effects. For example, French authorities announced that fallout of cesium-137 was no more than 5,400 becquerels (radiation unit of measure) in countries to the east and southeast, while the independent French Commission for the Independent Research and Information on Radioactivity (CRIIRAD) expertise revealed 30,000 to 35,000 becquerels per square meter.

After the first period of production of electricity by nuclear power, the Chernobyl accident has applied a relative brake on nuclear plants' extension. Indeed, a relative decline of production is characteristic of the period from the late 1980s until now. Since 2006 and 2007, however, Chinese demand for nuclear power has reactivated construction of reactors and new grid connections. Consequently, the attention has recently focused on present and potential radioactive resource reserves, primarily uranium. In 2007, this necessitated some 70,000 metric tons of uranium extracted from mines, but also from nuclear stock and military resources. World production of uranium was about 41,000 metric tons in 2006, which represents an increase of 14 percent in comparison with 2000 or 2001. Uranium is mostly extracted from Canada (10,000 metric tons), Australia (7,500 metric tons), and Kazakhstan (5,500 metric tons). Uranium reserves area estimated at 5.5 million metric tons with a supplementary potential of 10 million metric tons were already detected. However, consumption will rapidly grow to 94,000 to 122,000 metric tons, depending on the scenario, and the IAEA only plans for one century of reserve. Some nongovernmental organizations, though, think that this resource will be more rapidly used by 2030.

As a result, uranium is now a strategic resource for nuclear countries. For example, France is very dependent on uranium and tries to ensure continued supplies to produce its electricity and export it. Recently, France has invested in mines in the Congo. China also tries to predict its future growth of uranium consumption, also looking in the direction of its African and Asiatic neighbors' reserves.

Uranium consumption is also problematic regarding its waste production. In fact, nuclear wastes have always been paradoxical: Since nuclear production in the 1970s, production of waste has only grown, but no stocking solution was chosen, revealing the complexity of the problem. In fact, only a specific kind of waste is really problematic: high-level waste, or waste of category C. Although category C wastes are only 1 percent of the total volume of radioactive waste, they represent 95 percent of total radioactive waste activity of all categories. Depending on experts, the decrease of its radioactivity will be effective in 1,000 to 10,000 years. This kind of waste must be isolated from humans and their environment. If waste reprocessing permits limiting their quantity, this cannot be considered to be an optimal solution because of the incapability to reprocess all wastes. Moreover, waste reprocessing plants seem to have effects on their environment, as some studies show concerning, for example, the La Hague complex in France.

Technical characteristics and decision-making difficulties concerning wastes permit the introduction of opacity about decisions on nuclear issues. Since the first elaborations of atomic cells and bombs, "secret" seems to be a necessary step for each nuclear development. The effect of Chernobyl has been convincing people that public stakeholders are sometimes hiding facts. For example, French authorities have tried to persuade their citizens that the westward spread of the Chernobyl radioactive cloud stopped at the Franco-German border.

On a broader scale, Marie-Hélène Labbé indicates that, associated with its military use, the nuclear "big fear" is linked to four elements relative to nuclear essence: atoms' smallness, their invisibility, their almost unlimited lifetime, and the easiness of their propagation. Such characteristics call to mind other big fears such as biological terrorism. Experts consider that high-level accidents such as Chernobyl have a probability of 1/100,000 by year and by reactor (it was 1/10,000 20 years ago), and technical or human-induced incidents are counted each year. If they represent mostly limited dangers for the population and for workers, they constantly remind individuals of the possibility of a Chernobyl-like accident. Paradoxically, studies have shown that the nearer people live to a nuclear power plant, the less they are afraid of a probable accident. Françoise Zonabend says residents near nuclear plants live in "the land of the denied death," acting in everyday life as if the nuclear plant were not there and trying to never name it. In a similar way, nuclear station workers claim their risk-taking as an occupational hazard that reinforces their identity and their symbolic vision of their work.

All of this refers to the modernity dialectic: on one hand, postindustrial modernity pursues its complex scientific and technical development, trying to provide a better quality of life, while on the other hand, uncontrolled, unlimited, thoughtless progress and uncertainty engender risk, undesirable effects, and unexpected feedback. Nuclear power is also nuclear weakness. Preoccupation with prolongation of the life of nuclear reactors from 20 years to 40 years in spite of some recurring problems, or with the continued existence of Chernobyl-like reactors or other unsafe reactors (such as the Russian VVER 230, a Pressure-Water Reactor), which have to be secured, calls to mind these weaknesses and maintains the population's faith in its fear of nuclear energy.

Moreover, this fear is reactivated during nuclear waste transportation, with the help of antinuclear movements that draw media attention to this specific point. Nuclear waste transports between Germany and France, for example, regularly see protestors halt movement by chaining themselves to the railway tracks. One of nuclear wastes' main problems is its long lifetime. Although reprocessing enables the minimization of long-term radioactive waste (category C waste), the potential for radioactive pollution resulting from the remaining waste cannot be excluded. Two main solutions are advocated: (very) long-term stocking, planning on the difficulty of reprocessing this waste in the future and on the decrease of their radioactivity in about 10,000 years, depending on prediction. The U.S. debate on underground storage at Yucca Mountain comes under this kind of solution. Located approximately 90 miles northwest of Las Vegas in Nye County, Nevada, Yucca Mountain is a long-term repository for spent nuclear fuel and high-level radioactive waste, particularly from used fuel rods from nuclear reactors. President Barack Obama has proposed to eliminate federal funding for Yucca Mountain and investigate alternative solutions for nuclear waste management; however, the nearby Waste Isolation Pilot Plant in Carlsbad, New Mexico would remain a functioning long-term repository. Yucca Mountain and other places that stock nuclear waste are in remote or less desirable locations, chosen from the NIMBY(Not In My Backyard) mentality, and as such, the nuclear waste will likely remain rather than be transported elsewhere. That is why, in this perspective, wastes are only stocked for a few years and remain easily accessible when science and technology will be able to use them. However, such a vision is a promethean one: science will not necessarily be able to find a solution, and nuclear waste will be a preoccupation—if not an important problem—for the next generations.

Works of Hans Jonas may be taken into account: the German philosopher explains that we have to choose a responsibility principle coupled with a fear ethic, avoiding displacing our responsibility on the next generation. That is the main point that antinuclear movements criticize, because of the strong responsibility that falls to future generations.

Is Nuclear a Green, Sustainable, or Renewable Energy?

Green energies are generally characterized by their non-emission of carbon dioxide (CO_2), the primary greenhouse gas responsible for recent climate change, and their long-term resource capability. The nuclear lobby has profited from the new, big environmental problem since the 1990s—greenhouse gases—calling to mind its ecological aspects, its power, and its security, avoiding debates on wastes or plant incidents. Moreover, some NGOs would like to take into account in the carbon balance the transport of resources and waste, which is important. However, regarding the future of energy, most experts think only nuclear plants will be able to provide enough power for the third millennium.

Looking now in terms of sustainable energies, we introduce a social dimension that cannot be associated with nuclear energy. The anthropological fear evoked here and the responsibility that falls to future generations avoid any attempt to make nuclear energy sustainable. Nuclear capacity necessitates a high level of technology that is controlled only by specialist engineers and technicians and is impossible to develop at the local level that is preferred by sustainable principles. On a global scale, controversies about the potential use of nuclear power by countries such as Iran or Pakistan underline the considerable gap between already nuclearized countries and the rest of the world. There is also a significant amount of cement used in nuclear power plant construction and cement production is a significant source of carbon dioxide emissions.

Finally, the question most asked remains this one: Is nuclear energy a renewable energy or not? It is often put forward that there is huge resource of uranium, as well as of tritium, for future-generation reactors. However, using a strict definition, is it a renewable resource or an energy that is inexhaustible? Nuclear energy uses a limited resource, and there is no complete waste reprocessing. As uranium or other nuclear fuel remains not considered as a renewable resource, experts and NGOs generally consider nuclear power as nonrenewable.

The fascination that surrounds the nuclear question cannot erase difficulties in controlling its extremely complex mechanism nor erase problems too often neglected, such as the probability of accidents and waste management. But the actual energy consumption of mostly northern and rich countries does not permit us to go without nuclear power. However, as renewable and sustainable energies are more and more developed, one can see a departure. Even if energy policies are quite independent of such questions, the 2008 financial crisis calls to mind the better short-term profitability of these new energies, while nuclear power necessitates a long-term investment. If nuclear human experience is a relative progress, contemporary reflexivity and caution principles will probably encourage forsaking such fantastic power, even if it necessitates a significant reduction of energy consumption.

See Also: Chernobyl; Non-Renewable Energy Resources; Nuclear Proliferation; Power and Power Plants; Three Mile Island; Uranium; Yucca Mountain.

Further Readings

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