Nuclear Power Plants

NUCLEAR POWER PLANTS

Nuclear power plants use the heat generated from nuclear fission in a contained environment to convert water to steam, which powers generators to produce electricity. Nuclear power plants operate in most states in the country and produce about 20 percent of the nation's power. Nearly 3 million Americans live within 10 miles of an operating nuclear power plant.

Although the construction and operation of these facilities are closely monitored and regulated by the Nuclear Regulatory Commission (NRC), accidents are possible. An accident could result in dangerous levels of radiation that could affect the health and safety of the public living near the nuclear power plant.

Local and state governments, federal agencies, and the electric utilities have emergency response plans in the event of a nuclear power plant incident. The plans define two "emergency planning zones." One zone covers an area within a 10-mile radius of the plant, where it is possible that people could be harmed by direct radiation exposure. The second zone covers a broader area, usually up to a 50-mile radius from the plant, where radioactive materials could contaminate water supplies, food crops and livestock.

The potential danger from an accident at a nuclear power plant is exposure to radiation. This exposure could come from the release of radioactive material from the plant into the environment, usually characterized by a plume (cloud-like formation) of radioactive gases and particles. The major hazards to people in the vicinity of the plume are radiation exposure to the body from the cloud and particles deposited on the ground, inhalation of radioactive materials and ingestion of radioactive materials.

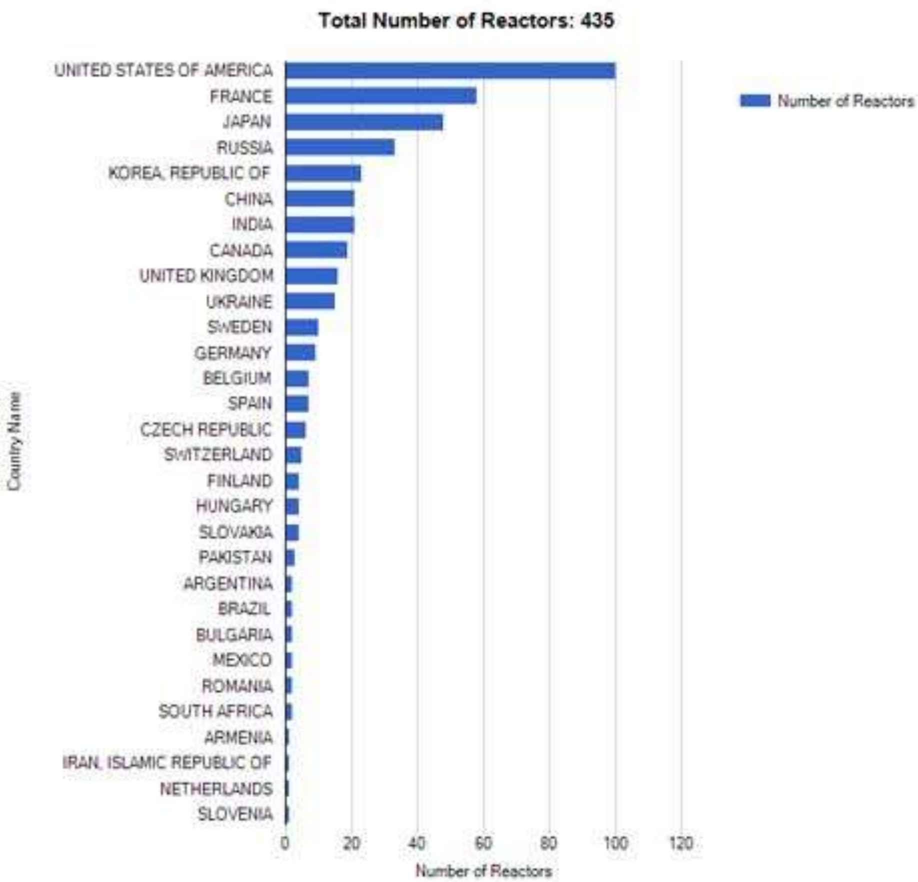
Radioactive materials are composed of atoms that are unstable. An unstable atom gives off its excess energy until it becomes stable. The energy emitted is radiation. Each of us is exposed to radiation daily from natural sources, including the Sun and the Earth. Small traces of radiation are present in food and water. Radiation also is released from man-made sources such as X-ray machines, television sets and microwave ovens. Radiation has a cumulative effect. The longer a person is exposed to radiation, the greater the effect. A high exposure to radiation can cause serious illness or death.

2012.

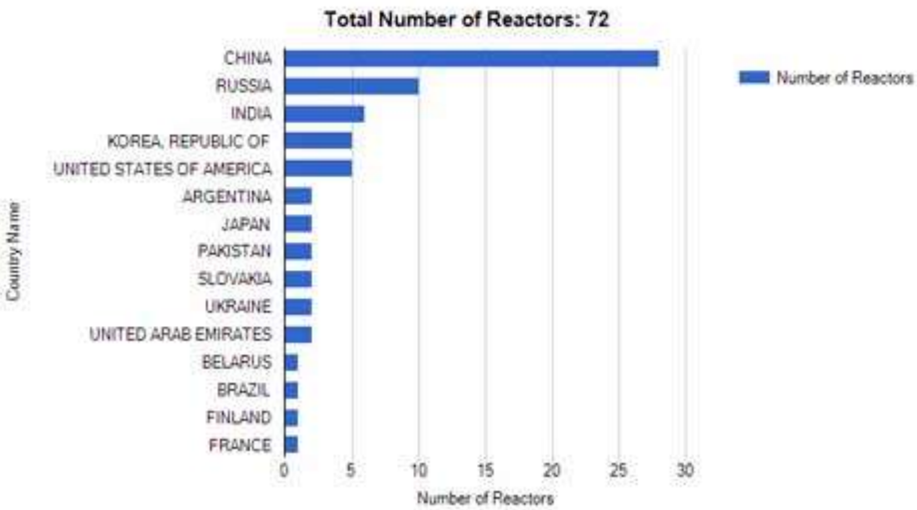
Country	In operation		Under construction	
	Number	Electr. net output MW	Number	Electr. net output MW
Argentina	2	935	2	717
Armenia	1	375	-	-
Belarus	-	-	1	1.109
Belgium	7	5,927	-	-
Brazil	2	1,884	1	1,245
Bulgaria	2	1,906	-	-
Canada	19	13,500	-	-
China (6 reactors in Taiwan)	21	16,890	28	27,756
Czech Republic	6	3,804	-	-
Finland	4	2,752	1	1,600
France	58	63,130	1	1,600
Germany	9	12,068	-	-
Hungary	4	1,889	-	-
India	21	5,308	6	3,907
Iran	1	915	-	-
Japan	48	42,388	2	1.325
Korea, Republic	23	20,710	5	6,370
Mexico	2	1,330	-	-
Netherlands	1	482	-	-
Pakistan	3	690	2	630
Romania	2	1,300	-	-
Russian Federation	33	23,643	10	8,382
Slovakian Republic	4	1,815	2	880
Slovenia	1	688	-	-
South Africa	2	1,860	-	-
Spain	7	7,121	-	-
Sweden	10	9,474	-	-
Switzerland	5	3,308	-	-
Ukraine	15	13,107	2	1,900

United Arab Emirates	-	-	2	2,690
United Kingdom	16	9,231	-	-
USA	104	101,465	5	5,633
Total	**435**	**372,022**	**72**	**68,344**

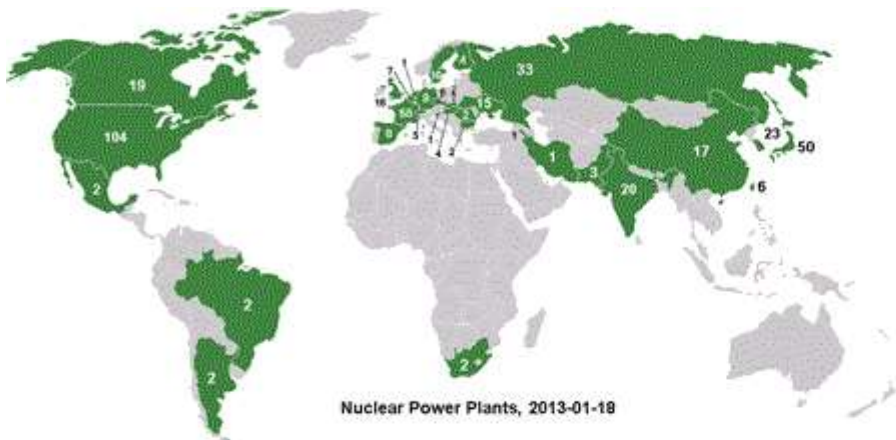
Nuclear power plants world-wide, in operation and under construction, IAEA as of 11 March 2014

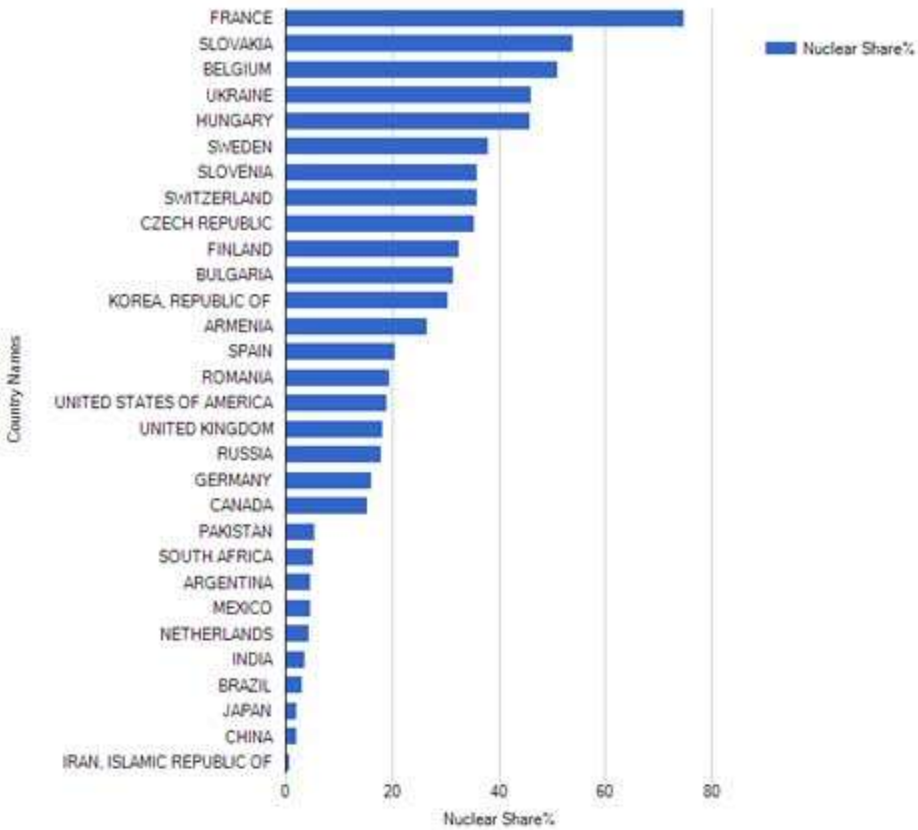


Number of reactors in operation, worldwide, 2014-03-11 (IAEA 2014)

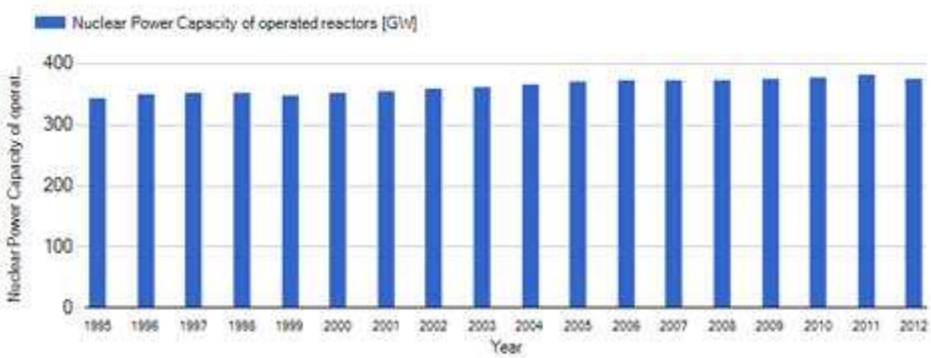


Number of reactors under construction, 2014-03-11 (IAEA 2014)

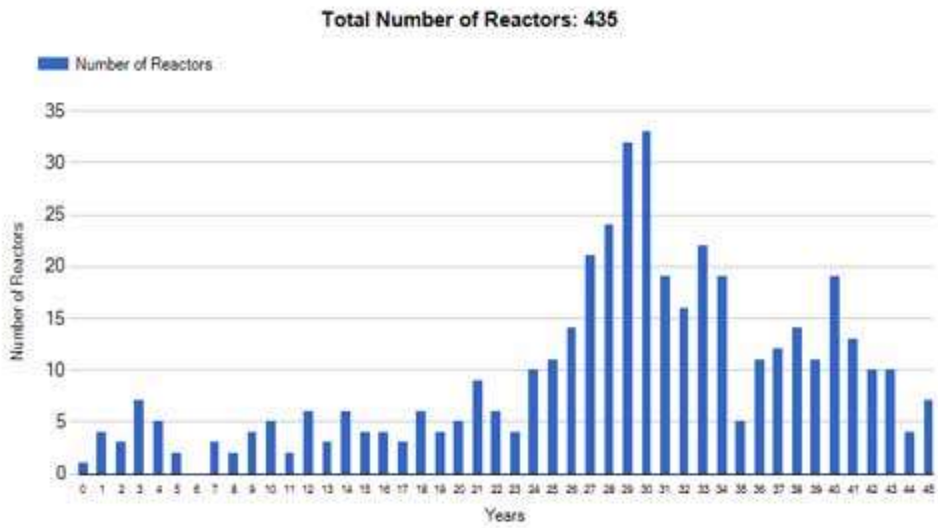




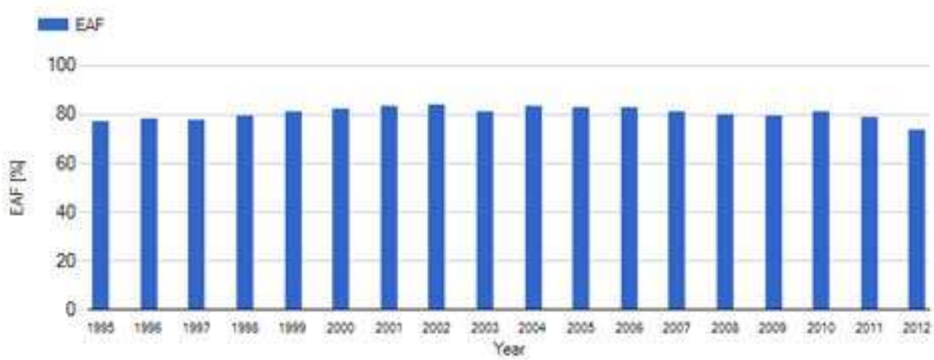
Nuclear share in electricity generation, 2012 (IAEA 2014)



Nuclear Power Plants, nuclear power capacity 1995 - 2012 (IAEA 2014)



Number of nuclear reactors worldwide by age as of 2014-03-11 (IAEA 2014)



Nuclear Power Plants, energy availability factor 1995 - 2012 (IAEA 2014)

back

How Do Nuclear Plants Work?

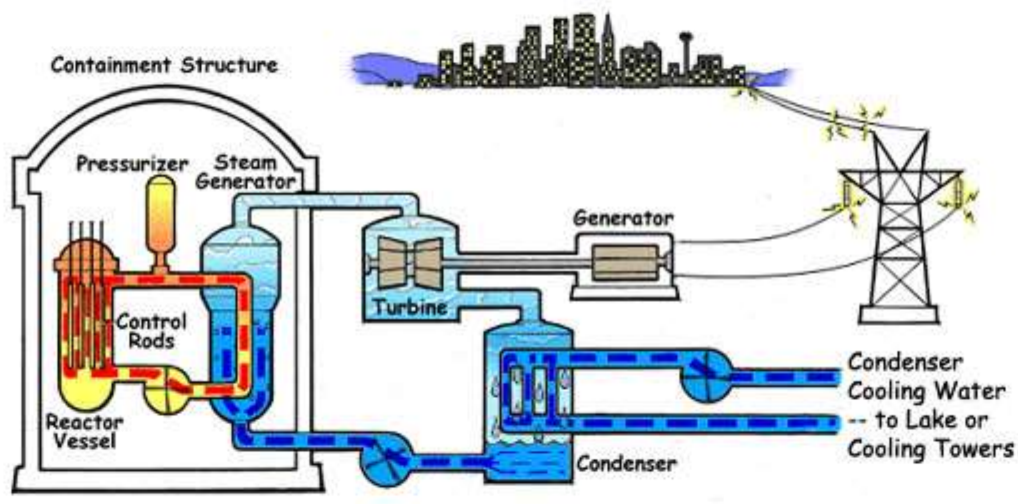
In a nuclear-fueled power plant – much like a fossil-fueled power plant – water is turned into steam, which in turn drives turbine generators to produce electricity. The difference is the source of heat. At nuclear power plants, the heat to make the steam are created when uranium atoms split – called fission. There is no combustion in a nuclear reactor. Here's how the process works.

There are two types of nuclear reactors in the United States:

Pressurized Water Reactor

Pressurized Water Reactors (also known as PWRs) keep water under pressure so that it heats, but does not boil. This heated water is circulated through tubes in steam generators, allowing the water in the steam generators to turn to steam, which then turns the turbine generator. Water from the reactor and the water that is turned into steam are in separate systems and do not mix.

View animated image of a Pressurized Water Reactor



Source: Nuclear Regulatory Commission

PWR Nuclear Power Plant (3 Building)

a. Containment Structure (Reactor, Steam Generators [usually two, three or four] & Reactor Coolant Pumps [usually two, three or four] & one Pressurizer)

b. Auxiliary Building which seats next to Containment Structure & houses related nuclear equipment that needs to be shielded from radiation exposure to the public.

c. Turbine Building houses the Turbine/Generator, Condenser & Condensate Pumps. Its location is as closed to the Containment Structure & Auxiliary Building as practical to reduce the length of Main Steam Piping from Steam Generators to Steam Turbine & the Condensate piping back to the Steam Generators.

d. The remaining buildings, equipment (both Mechanical & Electrical), falls under the heading of Balance-of-Plant or BOP.

Detailed description of Process

1. The Fuel

the fuel used in nuclear generation is primarily uranium 235. It is manufactured as small round fuel pellets. A single pellet is less than an inch long, but produces the energy equivalent to a ton of coal. The pellets are placed end-to-end into fuel rods that are 12 feet long. Over 200 of these rods are grouped into what is known as a fuel assembly.

2. Reactor

The process of producing electricity begins when uranium atoms are split (i.e., fission) by particles known as neutrons. Uranium 235 has a unique quality that causes it to break apart when it collides with a neutron. Once an atom of uranium 235 is split, neutrons from the uranium atom are free to collide with other uranium 235 atoms. A chain reaction begins, producing heat. This reaction is controlled in several ways, including by control rods which absorb neutrons.
Control rods are inserted among the fuel assembly rods that hold the uranium pellets. When they are in place, they absorb the atomic particles that would normally initiate the chain reaction. When they are withdrawn from the fuel assembly, fission is allowed to occur.

3. Pressurizer

the heat produced in the reactor is transferred to the first of three water systems: the primary coolant. The primary coolant is heated to over 600 degrees Fahrenheit. In a pressurized water reactor, a pressurizer keeps the water under pressure to prevent it from boiling.

4. Steam Generator

The hot, pressurized water passes through thousands of tubes in nearby steam generators. These tubes are surrounded by another water system called the secondary coolant. The heat from the primary coolant is transferred to the secondary coolant, which then turns into steam.
The primary and secondary systems are closed systems. This means that the water flowing through the reactor remains separate and does not mix with the water from the other system or the lake.

5. Turbine

The steam is piped from the containment building into the turbine building to push the giant blades of a turbine. The turbine is connected to an electric generator by a rotating shaft. As the turbine blades begin to spin, a magnet inside the generator also turns to produce electricity.

6. Condenser Coolant

after turning the turbines, the steam is cooled by passing it over tubes carrying a third water system, called the condenser coolant or lake water. The steam is cooled so it condenses back into water and is returned to the steam generator to be used again and again.

7. Lake or Cooling Towers

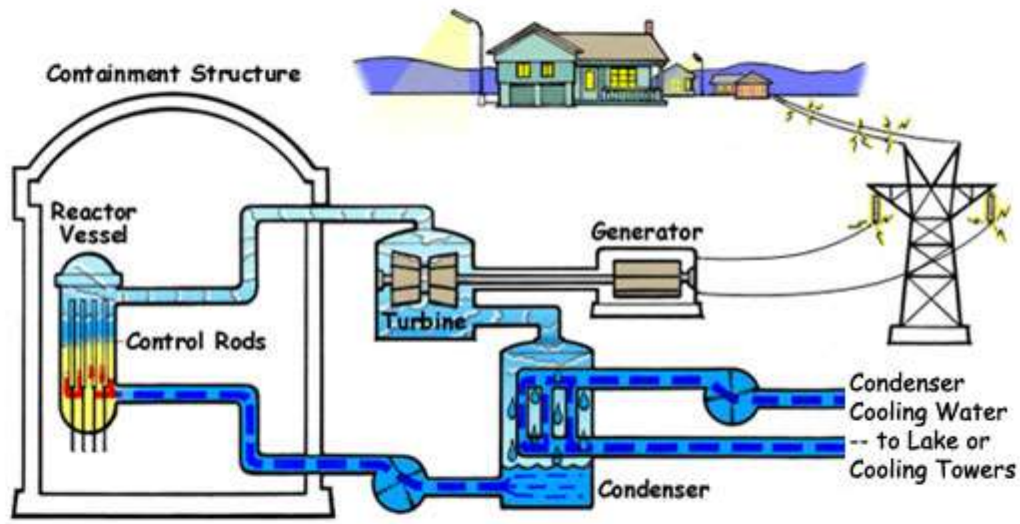
At some nuclear stations, lake water flows through thousands of condenser tubes to condense steam back to water. It is then discharged down a long canal (for cooling) and eventually enters the main part of the lake.

At other plants, the condenser cooling water is circulated through cooling towers to remove the extra heat it has gained. The water is pumped to the top of the cooling towers and is allowed to pour down through the structure. At the same time, a set of fans at the top of each tower pulls air up through the condenser water. This lowers the temperature of the water. After it is cooled, the condenser water flows back into the turbine building to begin its work of condensing steam again.

Boiling Water Reactor

In Boiling Water Reactors (also known as BWRs), the water heated by fission actually boils and turns into steam to turn the turbine generator. In both PWRs and BWRs, the steam is turned back into water and can be used again in the process.

View animated image of a Boiling Water Reactor



Source: Nuclear Regulatory Commission

BWR Nuclear Power Plant (3 Building)

e. Containment Structure (Reactor, Steam Generator (inside reactor vessel)

f. Auxiliary Building which seats next to Containment Structure & houses related nuclear equipment that needs to be shielded from radiation exposure to the public.

g. Turbine Building houses the Turbine/Generator, Condenser & Condensate Pumps. Its location as closed to the Containment Structure & Auxiliary Building as practical to reduce the length of Main Steam Piping from Steam Generators to Steam Turbine & the Condensate piping back to the Steam Generators. Also, BWR's the steam piping contains radioactive steam & this steam to Turbine Building & back to Containment Structure must be shielded to protect the public safety.

h. On BWR's the three main structures use shielding of reinforce concrete using the following ratio: 1" of Lead = 1' of Steel = 3'of reinforce concrete. Because of weight lead & steel usually aren't used, but reinforce concrete shielding is the most practical application for engineering & construction.

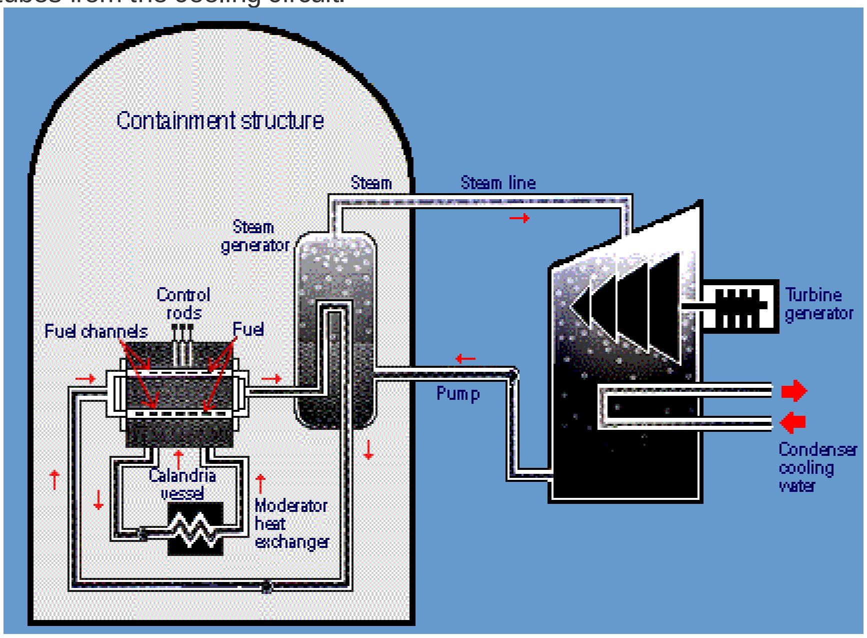
i. The remaining buildings & equipment (both Mechanical & Electrical), falls under the heading of Balance-of-Plant or BOP, which will be located within the plant property & these elements don't represent any danger to the public.

Pressurised Heavy Water Reactor (PHWR or CANDU)

j. The PHWR reactor design has been developed since the 1950s in Canada as the CANDU, and more recently also in India. PHWRs generally use natural uranium (0.7% U-235) oxide as fuel, hence needs a more efficient moderator, in this case heavy water (D_2O).** The PHWR produces more energy per kg of mined uranium than other designs.

k. ** with the CANDU system, the moderator is enriched (ie water) rather than the fuel, - a cost trade-off.

l. The moderator is in a large tank called a calandria, penetrated by several hundred horizontal pressure tubes which form channels for the fuel, cooled by a flow of heavy water under high pressure in the primary cooling circuit, reaching 290°C. As in the PWR, the primary coolant generates steam in a secondary circuit to drive the turbines. The pressure tube design means that the reactor can be refuelled progressively without shutting down, by isolating individual pressure tubes from the cooling circuit.

m. 

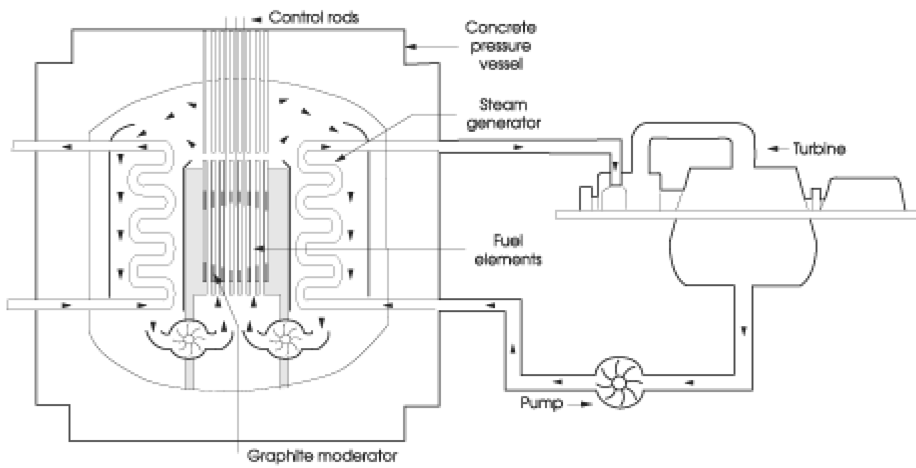
n. A CANDU fuel assembly consists of a bundle of 37 half metre long fuel rods (ceramic fuel pellets in zircaloy tubes) plus a support structure, with 12 bundles lying end to end in a fuel channel. Control rods penetrate the calandria vertically, and a secondary shutdown system involves adding gadolinium to the moderator. The heavy water moderator circulating through the body of the calandria vessel also yields some heat (though this circuit is not shown on the diagram above).

o. Newer PHWR designs such as the Advanced Candu Reactor (ACR) have light water cooling and slightly-enriched fuel.

p. CANDU reactors can readily be run on recycled uranium from reprocessing LWR used fuel, or a blend of this and depleted uranium left over from enrichment plants. About 4000 MWe of PWR can then fuel 1000 MWe of CANDU capacity, with addition of depleted uranium. Thorium may also be used in fuel.

q. **Advanced Gas-cooled Reactor (AGR)**

r. These are the second generation of British gas-cooled reactors, using graphite moderator and carbon dioxide as primary coolant. The fuel is uranium oxide pellets, enriched to 2.5-3.5%, in stainless steel tubes. The carbon dioxide circulates through the core, reaching 650°C and then past steam generator tubes outside it, but still inside the concrete and steel pressure vessel (hence 'integral' design). Control rods penetrate the moderator and a secondary shutdown system involves injecting nitrogen to the coolant.



s.

t. The AGR was developed from the Magnox reactor, also graphite moderated and CO_2 cooled, and one of these is still operating in UK to late 2014. They use natural uranium fuel in metal form. Secondary coolant is water.

Light water graphite-moderated reactor (RBMK)

u. This is a Soviet design, developed from plutonium production reactors. It employs long (7 metre) vertical pressure tubes running through graphite moderator, and is cooled by water, which is allowed to boil in the core at 290°C, much as in a BWR. Fuel is low-enriched uranium oxide made up into fuel assemblies 3.5 metres long. With moderation largely due to the fixed graphite, excess boiling simply reduces the cooling and neutron absorbtion without inhibiting the fission reaction, and a positive feedback problem can arise, which is why they have never been built outside the Soviet Union. See appendix on RBMK Reactors for more detail.

Advanced reactors

v. Several generations of reactors are commonly distinguished. Generation I reactors were developed in 1950-60s and only one is still running today. They mostly used natural uranium fuel and used graphite as moderator. Generation II reactors are typified by the present US fleet and most in operation elsewhere. They typically use enriched uranium fuel and are mostly cooled and moderated by water. Generation III are the Advanced Reactors evolved from these, the first few of which are in operation in Japan and others are under construction and ready to be ordered. They are developments of the second generation with enhanced safety. There is no clear distinction Gen II to Gen III.

w. Generation IV designs are still on the drawing board and will not be operational before 2020 at the earliest, probably later. They will tend to have closed fuel cycles and burn the long-lived actinides now forming part of spent fuel, so that fission products are the only high-level waste. Of seven designs under development, 4 or 5 will be fast neutron reactors. Four will use fluoride or liquid metal coolants, hence operate at low pressure. Two will be gas-cooled. Most will run at much higher temperatures than today's water-cooled reactors. See Generation IV Reactors paper.

x. More than a dozen (Generation III) advanced reactor designs are in various stages of development. Some are evolutionary from the PWR, BWR and CANDU designs above, some are more radical departures. The former include the Advanced Boiling Water Reactor, a few of which are now operating with others under construction. The best-known radical new design has the fuel as large 'pebbles' and uses helium as coolant, at very high temperature, possibly to drive a turbine directly.

y. Considering the closed fuel cycle, Generation 1-3 reactors recycle plutonium (and possibly uranium), while Generation IV are expected to have full actinide recycle.

Fast neutron reactors (FNR)

z. Some reactors (only one in commercial service) do not have a moderator and utilise fast neutrons, generating power from plutonium while making more of it from the U-238 isotope in or around the fuel. While they get more than 60 times as much energy from the original uranium compared with the normal reactors, they are expensive to build. Further development of them is likely in the next decade, and the main designs expected to be built in two decades are FNRs. If they are configured to produce more fissile material (plutonium) than they consume they are called Fast Breeder Reactors (FBR). See also Fast Neutron Reactors and Small Reactors papers.

Floating nuclear power plants

aa. Apart from over 200 nuclear reactors powering various kinds of ships, Rosatom in Russia has set up a subsidiary to supply floating nuclear power plants ranging in size from 70 to 600 MWe. These will be mounted in pairs on a large barge, which will be permanently moored where it is needed to supply power and possibly some desalination to a shore settlement or industrial complex. The first has two 40 MWe reactors based on those in icebreakers and will operate at a remote site in Siberia. Electricity cost is expected to be much lower than from present alternatives.

bb. The Russian KLT-40S is a reactor well proven in icebreakers and now proposed for wider use in desalination and, on barges, for remote area power supply. Here a 150 MWt unit produces 35 MWe (gross) as well as up to 35 MW of heat for desalination or district heating. These are designed to run 3-4 years between refuelling and it is envisaged that they will be operated in pairs to allow for outages, with on-board refuelling capability and used fuel storage. At the end of a 12-year operating cycle the whole plant is taken to a central facility for 2-year overhaul and removal of used fuel, before being returned to service. Two units will be mounted on a 21,000 tonne barge. A larger Russian factory-built and barge-mounted reactor is the VBER-150, of 350 MW thermal, 110 MWe. The larger VBER-300 PWR is a 325 MWe unit, originally envisaged in pairs as a floating nuclear power plant, displacing 49,000 tonnes. As a cogeneration plant it is rated at 200 MWe and 1900 GJ/hr. See also Nuclear Power in Russia paper.

Alphabetical List of U.S. Operating Nuclear Power Reactors by Name

A - C

- Arkansas Nuclear 1
- Arkansas Nuclear 2
- Beaver Valley 1
- Beaver Valley 2
- Braidwood 1
- Braidwood 2
- Browns Ferry 1
- Browns Ferry 2
- Browns Ferry 3
- Brunswick 1
- Brunswick 2
- Byron 1
- Byron 2
- Callaway
- Calvert Cliffs 1
- Calvert Cliffs 2
- Catawba 1
- Catawba 2
- Clinton
- Columbia Generating Station
- Comanche Peak 1
- Comanche Peak 2
- Cooper

D - L

- D.C. Cook 1
- D.C. Cook 2
- Davis-Besse
- Diablo Canyon 1
- Diablo Canyon 2
- Dresden 2
- Dresden 3
- Duane Arnold
- Farley 1
- Farley 2
- Fermi 2
- FitzPatrick
- Fort Calhoun
- Ginna
- Grand Gulf 1
- Harris 1
- Hatch 1
- Hatch 2
- Hope Creek 1
- Indian Point 2
- Indian Point 3
- La Salle 1
- La Salle 2
- Limerick 1
- Limerick 2

M - Q

- McGuire 1
- McGuire 2
- Millstone 2
- Millstone 3
- Monticello
- Nine Mile Point 1
- Nine Mile Point 2
- North Anna 1
- North Anna 2
- Oconee 1
- Oconee 2
- Oconee 3
- Oyster Creek
- Palisades
- Palo Verde 1
- Palo Verde 2
- Palo Verde 3
- Peach Bottom 2
- Peach Bottom 3
- Perry 1
- Pilgrim 1
- Point Beach 1
- Point Beach 2
- Prairie Island 1
- Prairie Island 2
- Quad Cities 1
- Quad Cities 2

R - W

- River Bend 1
- Robinson 2
- Saint Lucie 1
- Saint Lucie 2
- Salem 1
- Salem 2
- Seabrook 1
- Sequoyah 1
- Sequoyah 2
- South Texas 1
- South Texas 2
- Summer
- Surry 1
- Surry 2
- Susquehanna 1
- Susquehanna 2
- Three Mile Island 1
- Turkey Point 3
- Turkey Point 4
- Vermont Yankee
- Vogtle 1
- Vogtle 2
- Waterford 3
- Watts Bar 1
- Wolf Creek 1

US Nuclear Power Plants

General U.S. Nuclear Info

U.S. electricity from nuclear energy in 2012: 19.0 percent, with 769.3 billion kilowatt-hours generated.

- U.S. Nuclear Generating Statistics (1971 - 2012)
- State Fact Sheets

Number of states with operating reactors: 31, including seven states where nuclear makes up the largest percentage of the electricity generated.

- State Electricity Generation Fuel Shares (2012)
- U.S. Electricity Generation Fuel Shares (1973 - 2012)

Nuclear industry capacity factor (2012): 86 percent.

- U.S. Capacity Factors by Fuel Type
- U.S. Nuclear Industry Capacity Factors (1971 - 2012)
- U.S. Nuclear Industry Capacity Factors by Quartile (2007 - 2012)

Average refueling outage duration (2012): 46 days.

- U.S. Nuclear Refueling Outage Days (Average, 1990-2012)

Nuclear safety performance:

- U.S. Nuclear Industrial Safety Accident Rate
- Significant Events at U.S. Nuclear Plants
- U.S. Nuclear Industry Scram Trend

U.S. Nuclear Plant Stats

Number of operating reactors: 100, with 35 boiling water reactors (BWRs) and 65 pressurized water reactors (PWRs).

- 14 BWR plants have one reactor; nine have two reactors; one has three reactors
- 13 PWR plants have one reactor; 23 have two reactors; two have three reactors
- U.S. Nuclear Operating Plant Basic Information
- Nuclear Plants in Regulated and Deregulated States

Longest operating period between refueling outages: LaSalle 1 (Illinois); 739 days; February 2006.

Most electricity generated in a year: 11.8 billion kilowatt-hours at South Texas Project 2 in Texas in 2007.

Largest U.S. nuclear plant: Palo Verde (Arizona), three reactors at 1,311; 1,314; and 1,312 megawatts each, for a total of 3,937 megawatts.

Smallest nuclear plant: Fort Calhoun (Nebraska), one reactor at 478 megawatts.

Newest nuclear plant: Watts Bar 1 (Tennessee), operating license issued June 1996.

Oldest operating nuclear plant: Oyster Creek (New Jersey), operating license issued April 1969.

Nuclear plants under construction: Five, including Summer 2 and 3 (South Carolina); Vogtle 3 and 4 (Georgia); Watts Bar 2 (Tennessee).

- New Nuclear Plant Status

Nuclear plant sales: Ownership shares of all or part of 30 nuclear units have been sold since 1999.

- U.S. Nuclear Plant Sales

License renewal: 73 reactors have received 20-year license renewals to operate for a total of 60 years, 30 reactors have applied for or announced intentions to renew their licenses for another 20 years.

- U.S. Nuclear License Renewal Filings

- U.S. Nuclear Plant License Information

Nuclear power uprates: More than 6,900 megawatts of power uprates have been approved by the NRC since 1977. That is the equivalent of adding seven reactors to the electric grid.

- U.S. Nuclear Power Uprates by Plant
- U.S. Nuclear Industry Yearly Power Uprates (1977-2013)
- U.S. Nuclear Expected Power Uprates
- Cumulative Capacity Additions at U.S. Nuclear Facilities (1977 - 2017)

Amount of electricity generated by a 1,000-megawatt reactor at 90 percent capacity factor in one year: 7.9 billion kilowatt-hours—enough to supply electricity for 690,000 households. If generated by other fuel sources, it would require:

- Oil: 13.7 million barrels – 1 barrel yields 576 kWh
- Coal: 3.4 million short tons – 1 ton yields 2,297 kWh
- Natural Gas: 65.8 billion cubic feet – 100 cubic feet yields 12 kWh

(based on average conversion rates from the Energy Information Administration)

First commercial nuclear plant decommissioned: Shippingport in Pennsylvania began operation in December 1957, shut down in 1982.

- Locations of Power Reactor Sites Undergoing Decommissioning
- Decommissioning Status for Shutdown U.S. Power Reactors

U.S. Nuclear Electric Companies

Nuclear plant owners: 81

Nuclear plant operators: 32

- U.S. Nuclear Power Plant Owners, Operators and Holding Companies

Mergers and Acquisitions:

- Duke Energy merged with Progress Energy in July 2012. The merged company is called Duke Energy and includes Progress Energy's ownership of five reactors: Brunswick 1 and 2, Crystal River 3, Robinson and Shearon Harris.
- Exelon Corporation merged with Constellation Energy in March 2012. The merged company is called Exelon Corporation. As a result of this transaction, Exelon acquired Constellation's 50.01 percent ownership of Constellation Energy Nuclear Group (CENG), which operates five nuclear plants (Calvert Cliffs 1 & 2, Ginna, Nine Mile Point 1 & 2). EDF owns the remaining 49.99 percent of CENG.
- TXU Corp./Texas Energy Future Holdings Limited Partnership (TEF), October 2007, 2 reactors total; TXU Corp's new name is Energy Future Holdings Corp. The power generation entity under the merged company is Luminant, which owns and operates the two reactors at Comanche Peak.
- NRG Energy Inc. purchased Texas Genco LLC in February 2006. They own and operate the two reactors total at South Texas Project.
- Exelon purchased British Energy's 50 percent interest in AmerGen in December 2003 to operate three reactors: Clinton, Oyster Creek and Three Mile Island.

Consolidations:

- Nuclear Management Co. was formed in February 1999 to operate six plants: Duane Arnold (Iowa), Point Beach (Wis.), Kewaunee (Wis.), Prairie Island (Minn.), Monticello (Minn.) and Palisades (Mich.) Since then, FPL Group (now called NextEra Energy Inc.) acquired and now owns Duane Arnold and Point Beach, operating them through a subsidiary, NextEra Energy Resources LLC. Dominion owns Kewaunee (now shutdown), and Entergy owns and operates Palisades. Xcel Energy's subsidiary, Northern States Power Co., operates Prairie Island and Monticello.

Nuclear power plant

From Wikipedia, the free encyclopedia
Jump to: navigation, search
This article is about electricity generation from nuclear power. For the general topic of nuclear power, see Nuclear power.

A nuclear power station (Grafenrheinfeld Nuclear Power Plant, Grafenrheinfeld, Bavaria, Germany). The nuclear reactor is contained inside the spherical containment building in the center - left and right are cooling towers which are common cooling devices used in all thermal power stations, and likewise, emit water vapor from the non-radioactive steam turbine section of the power plant.

Nuclear power plant in Jaslovské Bohunice in Slovakia.

A **nuclear power plant** is a thermal power station in which the heat source is a nuclear reactor. As is typical in all conventional thermal power stations the heat is used to generate steam which drives a steam turbine connected to a generator which produces electricity. As of 16 January 2013, the IAEA report there are 439 nuclear power reactors in operation[1] operating in 31 countries.[2]

Nuclear power plants are usually considered to be base load stations, since fuel is a small part of the cost of production.[3]

Contents

[hide]

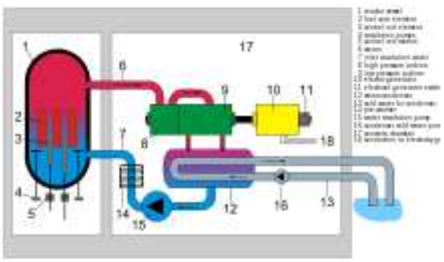
History[edit]

The control room at an American nuclear power plant.

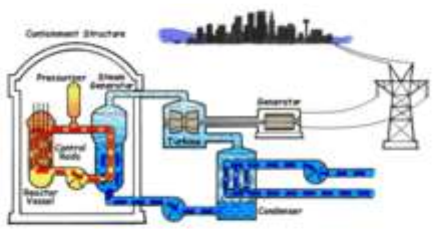
For more history, see nuclear reactor, nuclear power and nuclear fission.

Electricity was generated by a nuclear reactor for the first time ever on September 3, 1948 at the X-10 Graphite Reactor in Oak Ridge, Tennessee in the United States, and was the first nuclear power plant to power a light bulb.[4][5][6] The second, larger experiment occurred on December 20, 1951 at the EBR-I experimental station near Arco, Idaho in the United States. On June 27, 1954, the world's first nuclear power plant to generate electricity for a power grid started operations at the Soviet city of Obninsk.[7] The world's first full scale power station, Calder Hall in England opened on October 17, 1956.[8]

Systems[edit]



BWR schematic.



Pressurized water reactor

This section has recently been translated from the German Wikipedia.

The conversion to electrical energy takes place indirectly, as in conventional thermal power plants. The heat is produced by fission in a nuclear reactor (a light water reactor). Directly or indirectly, water vapor (steam) is produced. The pressurized steam is then usually fed to a multi-stage steam turbine. Steam turbines in Western nuclear power plants are among the largest steam turbines ever. After the steam turbine has expanded and partially condensed the steam, the remaining vapor is condensed in a condenser. The condenser is a heat exchanger which is connected to a secondary side such as a river or a cooling tower. The water is then pumped back into the nuclear reactor and the cycle begins again. The water-steam cycle corresponds to the Rankine cycle.

Nuclear reactors[edit]

Main article: Nuclear reactor

A **nuclear reactor** is a device to initiate and control a sustained nuclear chain reaction. The most common use of nuclear reactors is for the generation of electric energy and for the propulsion of ships.

The nuclear reactor is the heart of the plant. In its central part, the reactor core's heat is generated by controlled nuclear fission. With this heat, a coolant is heated as it is pumped through the reactor and thereby removes the energy from the reactor. Heat from nuclear fission is used to raise steam, which runs through turbines, which in turn powers either ship's propellers or electrical generators.

Since nuclear fission creates radioactivity, the reactor core is surrounded by a protective shield. This containment absorbs radiation and prevents radioactive material from being released into the environment. In addition, many reactors are equipped with a dome of concrete to protect the reactor against both internal casualties and external impacts.[9]

In nuclear power plants, different types of reactors, nuclear fuels, and cooling circuits and moderators are used.

Steam turbine[edit]

Main article: Steam turbine

The purpose of the steam turbine is to convert the heat contained in steam into mechanical energy. The engine house with the steam turbine is usually structurally separated from the main reactor building. It is so aligned to prevent debris from the destruction of a turbine in operation from flying towards the reactor.[*citation needed*]

In the case of a pressurized water reactor, the steam turbine is separated from the nuclear system. To detect a leak in the steam generator and thus the passage of radioactive water at an early stage, an activity meter is mounted to track the outlet steam of the steam generator. In contrast, boiling water reactors pass radioactive water through the steam turbine, so the turbine is kept as part of the control area of the nuclear power plant.

Generator[edit]

Main article: Electric generator

The generator converts kinetic energy supplied by the turbine into electrical energy. Low-pole AC synchronous generators of high rated power are used.

Cooling system[edit]

A cooling system removes heat from the reactor core and transports it to another area of the plant, where the thermal energy can be harnessed to produce electricity or to do other useful work. Typically the hot coolant is used as a heat source for a boiler, and the pressurized steam from that boiler powers one or more steam turbine driven electrical generators.[10]

Safety valves[edit]

In the event of an emergency, two independent safety valves can be used to prevent pipes from bursting or the reactor from exploding. The valves are designed so that they can derive all of the supplied flow rates with little increase in pressure. In the case of the BWR, the steam is directed into the condensate chamber and condenses there. The chambers on a heat exchanger are connected to the intermediate cooling circuit.

Feedwater pump[edit]

The water level in the steam generator and nuclear reactor is controlled using the feedwater system. The feedwater pump has the task of taking the water from the condensate system, increasing the pressure and forcing it into either the steam generators (in the case of a pressurized water reactor) or directly into the reactor vessel (for boiling water reactors).

Emergency power supply[edit]

Most nuclear plants require two distinct sources of offsite power feeding station service transformers that are sufficiently separated in the plant's switchyard and can receive power from multiple transmission lines. In addition in some nuclear plants the turbine generator can power the plant's house loads while the plant is online via station service transformers which tap power from the generator output bus bars before they reach the step-up transformer (these plants also have station service transformers that receive offsite power directly from the switchyard.) Even with the redundancy of two power sources total loss of offsite power is still possible. Nuclear power plants are equipped with emergency power systems to maintain safety in the event of unit shutdown and loss of offsite power. Batteries provide uninterruptible power to instrumentation, control systems, and valves. Emergency diesel generators provide direct AC power to charge the batteries and to provide power to systems requiring AC power such as motor driven pumps. The emergency diesel generators do not power all plant systems, only those required to shut the reactor down safely, remove decay heat from the reactor, provide emergency core cooling, and, in some plants, spent fuel pool cooling. The large power generation pumps such as the main feedwater, condensate, circulating water, and (in pressurized water reactors) reactor coolant pumps are not backed up by the diesels.

People in a nuclear power plant[edit]

- Nuclear engineers
- Reactor operators
- Health physicists
- Emergency response team personnel
- Nuclear Regulatory Commission Resident Inspectors

In the United States and Canada, workers except for management, professional (such as engineers) and security personnel are likely to be members of either the International Brotherhood of Electrical Workers (IBEW) or the Utility Workers Union of America (UWUA), or one of the various trades and labor unions representing Machinist, laborers, boilermakers, millwrights, iron workers etc.

Economics[edit]

The Bruce Nuclear Generating Station, the largest nuclear power facility in the world[11]
Main article: Economics of new nuclear power plants

The economics of new nuclear power plants is a controversial subject, and multi-billion dollar investments ride on the choice of an energy source. Nuclear power plants typically have high capital costs, but low direct fuel costs, with the costs of fuel extraction, processing, use and spent fuel storage internalized costs. Therefore, comparison with other power generation methods is strongly dependent on assumptions about construction timescales and capital financing for nuclear plants. Cost estimates take into account plant decommissioning and nuclear waste storage or recycling costs in the United States due to the Price Anderson Act. With the prospect that all spent nuclear fuel/"nuclear waste" could potentially be recycled by using future reactors, generation IV reactors, that are being designed to completely close the nuclear fuel cycle.

On the other hand, construction, or capital cost aside, measures to mitigate global warming such as a carbon tax or carbon emissions trading, increasingly favor the economics of nuclear power. Further efficiencies are hoped to be achieved through more advanced reactor designs, Generation III reactors promise to be at least 17% more fuel efficient, and have lower capital costs, while futuristic Generation IV reactors promise 10000-30000% greater fuel efficiency and the elimination of nuclear waste.

In Eastern Europe, a number of long-established projects are struggling to find finance, notably Belene in Bulgaria and the additional reactors at Cernavoda in Romania, and some potential backers have pulled out.[12] Where cheap gas is available and its future supply relatively secure, this also poses a major problem for nuclear projects.[12]

Analysis of the economics of nuclear power must take into account who bears the risks of future uncertainties. To date all operating nuclear power plants were developed by state-owned or regulated utility monopolies[13] where many of the risks associated with construction costs, operating performance, fuel price, and other factors were borne by consumers rather than suppliers. Many countries have now liberalized the electricity market where these risks, and the risk of cheaper competitors emerging before capital costs are recovered, are borne by plant suppliers and operators rather than consumers, which leads to a significantly different evaluation of the economics of new nuclear power plants.[14]

Following the 2011 Fukushima I nuclear accidents, costs are likely to go up for currently operating and new nuclear power plants, due to increased requirements for on-site spent fuel management and elevated design basis threats.[15] However many designs, such as the currently under construction AP1000, use passive nuclear safety cooling systems, unlike those of Fukushima I which required active cooling systems, this largely eliminates the necessity to spend more on redundant back up safety equipment.

Safety[edit]

There are trades to be made between safety, economic and technical properties of different reactor designs for particular applications. Historically these decisions were often made in private by scientists, regulators and engineers,[*citation needed*] but this may be considered problematic, and since Chernobyl and Three Mile Island, many involved now consider informed consent and morality to be primary considerations.[16]

Complexity[edit]

Nuclear power plants are some of the most sophisticated and complex energy systems ever designed.[17] Any complex system, no matter how well it is designed and engineered, cannot be deemed failure-proof.[18] Veteran anti-nuclear activist and author Stephanie Cooke has argued:

The reactors themselves were enormously complex machines with an incalculable number of things that could go wrong. When that happened at Three Mile Island in 1979, another fault line in the nuclear world was exposed. One malfunction led to another, and then to a series of others, until the core of the reactor itself began to melt, and even the world's most highly trained nuclear engineers did not know how to respond. The accident revealed serious deficiencies in a system that was meant to protect public health and safety.[19]

The 1979 Three Mile Island accident inspired Perrow's book *Normal Accidents*, where a nuclear accident occurs, resulting from an unanticipated interaction of multiple failures in a complex system. TMI was an example of a normal accident because it was "unexpected, incomprehensible, uncontrollable and unavoidable".[20]

Perrow concluded that the failure at Three Mile Island was a consequence of the system's immense complexity. Such modern high-risk systems, he realized, were prone to failures however well they were managed. It was inevitable that they would eventually suffer what he termed a 'normal accident'. Therefore, he suggested, we might do better to contemplate a radical redesign, or if that was not possible, to abandon such technology entirely.[21] .

A fundamental issue contributing to a nuclear power system's complexity is its extremely long lifetime. The timeframe from the start of construction of a commercial nuclear power station through the safe disposal of its last radioactive waste, may be 100 to 150 years.[17]

Failure modes of nuclear power plants[edit]

There are concerns that a combination of human and mechanical error at a nuclear facility could result in significant harm to people and the environment:[22]

Operating nuclear reactors contain large amounts of radioactive fission products which, if dispersed, can pose a direct radiation hazard, contaminate soil and vegetation, and be ingested by humans and animals. Human exposure at high enough levels can cause both short-term illness and death and longer-term death by cancer and other diseases.[23]

It is impossible for a commercial nuclear reactor to explode like a nuclear bomb since the fuel is never sufficiently enriched for this to occur.[24]

Nuclear reactors can fail in a variety of ways. Should the instability of the nuclear material generate unexpected behavior, it may result in an uncontrolled power excursion. Normally, the cooling system in a reactor is designed to be able to handle the excess heat this causes; however, should the reactor also experience a loss-of-coolant accident, then the fuel may melt or cause the vessel in which it is contained to overheat and melt. This event is called a nuclear meltdown.

After shutting down, for some time the reactor still needs external energy to power its cooling systems. Normally this energy is provided by the power grid to which that plant is connected, or by emergency diesel generators. Failure to provide power for the cooling systems, as happened in Fukushima I, can cause serious accidents.

Nuclear safety rules in the United States "do not adequately weigh the risk of a single event that would knock out electricity from the grid and from emergency generators, as a quake and tsunami recently did in Japan", Nuclear Regulatory Commission officials said in June 2011.[25]

Vulnerability of nuclear plants to attack[edit]

Nuclear reactors become preferred targets during military conflict and, over the past three decades, have been repeatedly attacked during military air strikes, occupations, invasions and campaigns:[26]

- In September 1980, Iran bombed the Al Tuwaitha nuclear complex in Iraq, in Operation Scorch Sword.
- In June 1981, an Israeli air strike completely destroyed Iraq's Osirak nuclear research facility.
- Between 1984 and 1987, Iraq bombed Iran's Bushehr nuclear plant six times.
- On 8 January 1982, Umkhonto we Sizwe, the armed wing of the ANC, attacked South Africa's Koeberg nuclear power plant while it was still under construction.
- In 1991, the U.S. bombed three nuclear reactors and an enrichment pilot facility in Iraq.
- In 1991, Iraq launched Scud missiles at Israel's Dimona nuclear power plant.
- In September 2007, Israel bombed a Syrian reactor under construction.[26]

In the U.S., plants are surrounded by a double row of tall fences which are electronically monitored. The plant grounds are patrolled by a sizeable force of armed guards.[27] The NRC's "Design Basis Threat" criteria for plants is a secret, and so what size of attacking force the plants are able to protect against is unknown. However, to scram (make an emergency shutdown) a plant takes fewer than 5 seconds while unimpeded restart takes hours, severely hampering a terrorist force in a goal to release radioactivity.

Attack from the air is an issue that has been highlighted since the September 11 attacks in the U.S. However, it was in 1972 when three hijackers took control of a domestic passenger flight along the east coast of the U.S. and threatened to crash the plane into a U.S. nuclear weapons plant in Oak Ridge, Tennessee. The plane got as close as 8,000 feet above the site before the hijackers' demands were met.[28][29]

The most important barrier against the release of radioactivity in the event of an aircraft strike on a nuclear power plant is the containment building and its missile shield. Current NRC Chairman Dale Klein has said "Nuclear power plants are inherently robust structures that our studies show provide adequate protection in a hypothetical attack by an airplane. The NRC has also taken actions that require nuclear power plant operators to be able to manage large fires or explosions—no matter what has caused them."[30]

In addition, supporters point to large studies carried out by the U.S. Electric Power Research Institute that tested the robustness of both reactor and waste fuel storage and found that they should be able to sustain a terrorist attack comparable to the September 11 terrorist attacks in the U.S. Spent fuel is usually housed inside the plant's "protected zone"[31] or a spent nuclear fuel shipping cask; stealing it for use in a "dirty bomb" would be extremely difficult. Exposure to the intense radiation would almost certainly quickly incapacitate or kill anyone who attempts to do so.[32]

Plant location[edit]

Fort Calhoun Nuclear Generating Station surrounded by the 2011 Missouri River Floods on June 16, 2011

In many countries, plants are often located on the coast, in order to provide a ready source of cooling water for the essential service water system. As a consequence the design needs to take the risk of flooding and tsunamis into account. The World Energy Council (WEC) argues disaster risks are changing and increasing the likelihood of disasters such as earthquakes, cyclones, hurricanes, typhoons, flooding.[33] High temperatures, low precipitation levels and severe droughts may lead to fresh water shortages.[33] Seawater is corrosive and so nuclear energy supply is likely to be negatively affected by the fresh water shortage.[33] This generic problem may become increasingly significant over time.[33] Failure to calculate the risk of flooding correctly lead to a Level 2 event on the International Nuclear Event Scale during the 1999 Blayais Nuclear Power Plant flood,[34] while flooding caused by the 2011 Tōhoku earthquake and tsunami lead to the Fukushima I nuclear accidents.[35]

The design of plants located in seismically active zones also requires the risk of earthquakes and tsunamis to be taken into account. Japan, India, China and the USA are among the countries to have plants in earthquake-prone regions. Damage caused to Japan's Kashiwazaki-Kariwa Nuclear Power Plant during the 2007 Chūetsu offshore earthquake[36][37] underlined concerns expressed by experts in Japan prior to the Fukushima accidents, who have warned of a *genpatsu-shinsai* (domino-effect nuclear power plant earthquake disaster).[38]

Multiple reactors[edit]

The Fukushima nuclear disaster illustrated the dangers of building multiple nuclear reactor units close to one another. This proximity triggered[*citation needed*] the parallel, chain-reaction accidents that led to hydrogen explosions damaging reactor buildings and water draining from open-air spent fuel pools -- a situation that was potentially more dangerous than the loss of reactor cooling itself. Because of the closeness of the reactors, Plant Director Masao Yoshida "was put in the position of trying to cope simultaneously with core meltdowns at three reactors and exposed fuel pools at three units".[39]

Nuclear safety systems[edit]

Main article: Nuclear safety systems

The three primary objectives of nuclear safety systems as defined by the Nuclear Regulatory Commission are to shut down the reactor, maintain it in a shutdown condition, and prevent the release of radioactive material during events and accidents.[40] These objectives are accomplished using a variety of equipment, which is part of different systems, of which each performs specific functions.

Routine emissions of radioactive materials[edit]

For the controversial debate on the health effects by the routine emissions, see Nuclear power debate#Health effects on population near nuclear power plants and workers and Environmental impact of nuclear power#Risk of cancer.

During everyday routine operations, emissions of radioactive materials from nuclear plants are released to the outside of the plants although they are quite slight amounts.[41][42][43][44] The daily emissions go into the air, water and soil.[42][43]

NRC says, "nuclear power plants sometimes release radioactive gases and liquids into the environment under controlled, monitored conditions to ensure that they pose no danger to the public or the environment",[45] and "routine emissions during normal operation of a nuclear power plant are never lethal".[46]

According to the United Nations (UNSCEAR), regular nuclear power plant operation including the nuclear fuel cycle amounts to 0.0002 mSv (milli-Sievert) annually in average public radiation exposure; the legacy of the Chernobyl disaster is 0.002 mSv/yr as a global average as of a 2008 report; and natural radiation exposure averages 2.4 mSv annually although frequently varying depending on an individual's location from 1 to 13 mSv.[47]

The Japanese myth of absolute safety[edit]

In Japan, many government agencies and nuclear companies have promoted a public myth of "absolute safety" that nuclear power proponents had nurtured over decades.[48] The tsunami that began the Fukushima nuclear disaster could have been anticipated[49][*verification needed*] and in March 2012, Prime Minister Yoshihiko Noda acknowledged that the Japanese government shared the blame for the Fukushima disaster, saying that officials had been blinded to the country's "technological infallibility", and were all too steeped in a "safety myth".[50]

In Japan, a national program to develop robots for use in nuclear emergencies was terminated in midstream because it "smacked too much of underlying danger". Japan, supposedly a major power in robotics, had none to send in to Fukushima during the disaster. Similarly, Japan’s Nuclear Safety Commission stipulated in its safety guidelines for light-water nuclear facilities that “the potential for extended loss of power need not be considered.” However, it was exactly such an extended loss of power to the cooling pumps that caused the meltdown at the Fukushima nuclear facilities.[51]

Controversy[edit]

Main article: Nuclear power debate

The abandoned city of Prypiat, Ukraine, following the Chernobyl disaster. The Chernobyl nuclear power plant is in the background.

The nuclear power debate is about the controversy[52][53][54][55] which has surrounded the deployment and use of nuclear fission reactors to generate electricity from nuclear fuel for civilian purposes. The debate about nuclear power peaked during the 1970s and 1980s, when it "reached an intensity unprecedented in the history of technology controversies", in some countries.[56][57]

Proponents argue that nuclear power is a sustainable energy source which reduces carbon emissions and can increase energy security if its use supplants a dependence on imported fuels.[58] Proponents advance the notion that nuclear power produces virtually no air pollution, in contrast to the chief viable alternative of fossil fuel. Proponents also believe that nuclear power is the only viable course to achieve energy independence for most Western countries. They emphasize that the risks of storing waste are small and can be further reduced by using the latest technology in newer reactors, and the operational safety record in the Western world is excellent when compared to the other major kinds of power plants.[59]

Opponents say that nuclear power poses many threats to people and the environment. These threats include health risks and environmental damage from uranium mining, processing and transport, the risk of nuclear weapons proliferation or sabotage, and the unsolved problem of radioactive nuclear waste.[60][61][62] They also contend that reactors themselves are enormously complex machines where many things can and do go wrong, and there have been many serious nuclear accidents.[63][64] Critics do not believe that these risks can be reduced through new technology.[65] They argue that when all the energy-intensive stages of the nuclear fuel chain are considered, from uranium mining to nuclear decommissioning, nuclear power is not a low-carbon electricity source.[66][67][68]

Reprocessing[edit]

Main article: Nuclear reprocessing

Nuclear reprocessing technology was developed to chemically separate and recover fissionable plutonium from irradiated nuclear fuel.[69] Reprocessing serves multiple purposes, whose relative importance has changed over time. Originally reprocessing was used solely to extract plutonium for producing nuclear weapons. With the commercialization of nuclear power, the reprocessed plutonium was recycled back into MOX nuclear fuel for thermal reactors.[70] The reprocessed uranium, which constitutes the bulk of the spent fuel material, can in principle also be re-used as fuel, but that is only economic when uranium prices are high or disposal is expensive. Finally, the breeder reactor can employ not only the recycled plutonium and uranium in spent fuel, but all the actinides, closing the nuclear fuel cycle and potentially multiplying the energy extracted from natural uranium by more than 60 times.[71]

Nuclear reprocessing reduces the volume of high-level waste, but by itself does not reduce radioactivity or heat generation and therefore does not eliminate the need for a geological waste repository. Reprocessing has been politically controversial because of the potential to contribute to nuclear proliferation, the potential vulnerability to nuclear terrorism, the political challenges of repository siting (a problem that applies equally to direct disposal of spent fuel), and because of its high cost compared to the once-through fuel cycle.[72] In the United States, the Obama administration stepped back from President Bush's plans for commercial-scale reprocessing and reverted to a program focused on reprocessing-related scientific research.[73]

Accident indemnification[edit]

The Vienna Convention on Civil Liability for Nuclear Damage puts in place an international framework for nuclear liability.[74] However states with a majority of the world's nuclear power plants, including the U.S., Russia, China and Japan, are not party to international nuclear liability conventions.

In the U.S., insurance for nuclear or radiological incidents is covered (for facilities licensed through 2025) by the Price-Anderson Nuclear Industries Indemnity Act.

Under the Energy policy of the United Kingdom through its Nuclear Installations Act of 1965, liability is governed for nuclear damage for which a UK nuclear licensee is responsible. The Act requires compensation to be paid for damage up to a limit of £150 million by the liable operator for ten years after the incident. Between ten and thirty years afterwards, the Government meets this obligation. The Government is also liable for additional limited cross-border liability (about £300 million) under international conventions (Paris Convention on Third Party Liability in the Field of Nuclear Energy and Brussels Convention supplementary to the Paris Convention).[75]

Decommissioning[edit]

Main article: Nuclear decommissioning

Nuclear decommissioning is the dismantling of a nuclear power plant and decontamination of the site to a state no longer requiring protection from radiation for the general public. The main difference from the dismantling of other power plants is the presence of radioactive material that requires special precautions.

Warranty period of operation of nuclear power plants is 30 years.[76] One from factors wear is the destruction of the reactors shell under the action of ionizing radiation.[76]

Generally speaking, nuclear plants were designed for a life of about 30 years.[citation needed] Newer plants are designed for a 40 to 60-year operating life.[citation needed]

Decommissioning involves many administrative and technical actions. It includes all clean-up of radioactivity and progressive demolition of the plant. Once a facility is decommissioned, there should no longer be any danger of a radioactive accident or to any persons visiting it. After a facility has been completely decommissioned it is released from regulatory control, and the licensee of the plant no longer has responsibility for its nuclear safety.

Historic accidents[edit]

The 2011 Fukushima Daiichi nuclear disaster in Japan, the worst nuclear accident in 25 years, displaced 50,000 households after radiation leaked into the air, soil and sea.[77] Radiation checks led to bans of some shipments of vegetables and fish.[78]
Main article: Nuclear power accidents by country

The nuclear industry says that new technology and oversight have made nuclear plants much safer, but 57 small accidents have occurred since the Chernobyl disaster in 1986 until 2008. Two thirds of these mishaps occurred in the US.[79] The French Atomic Energy Agency (CEA) has concluded that technical innovation cannot eliminate the risk of human errors in nuclear plant operation.[citation needed]

According to Benjamin Sovacool, an interdisciplinary team from MIT in 2003 estimated that given the expected growth of nuclear power from 2005 – 2055, at least four serious nuclear accidents would be expected in that period.[79] However the MIT study Benjamin Sovacool references does not state this, instead the authors of the MIT study acknowledge that this estimated accident number does not take into account the existing, as of the time of publishing in 2003, and future, improvements in safety,[80] with the authors basing this assumed high accident rate, cited by Sovacool, only if none of the improvements in safety technology from 1970 to 2003 were implemented.[81] Therefore the figure the MIT team suggest, by their own account, would only be possible if the world nuclear fleet were to continue to operate and build old Generation II reactors and not learn from past mistakes, and that the world fleet would not include any of the presently (as of 2013) built, Generation III or in design phase Generation IV nuclear power plants between 2005 and 2055. The interdisciplinary team from MIT also went on to endorse that it was possible to make nuclear power safe,[81] going on to state that the substantial safety features of then under construction Generation III reactors appear "plausible" at reducing the serious accident rate to near zero with, amongst other features, the use of passive nuclear safety features, which are now part of the state of the art in nuclear reactor safety.[81]

Flexibility of nuclear power plants[edit]

It is often claimed that nuclear stations are inflexible in their output, implying that other forms of energy would be required to meet peak demand. While that is true for the vast majority of reactors, this may no longer true of at least some modern designs.[82]

Nuclear plants are routinely used in load following mode on a large scale in France, although "it is generally accepted that this is not an ideal economic situation for nuclear plants."[83] Unit A at the German Biblis Nuclear Power Plant is designed to in- and decrease its output 15% per minute between 40 and 100% of its nominal power.[84] Boiling water reactors normally have load-following capability, implemented by varying the recirculation water flow.[*citation needed*]

Future power plants[edit]

A number of new designs for nuclear power generation, collectively known as the Generation IV reactors, are the subject of active research and may be used for practical power generation in the future. Many of these new designs specifically attempt to make fission reactors cleaner, safer and/or less of a risk to the proliferation of nuclear weapons. Passively safe plants (such as the ESBWR) are available to be built[85] and other designs that are believed to be nearly fool-proof are being pursued.[86] Fusion reactors, which may be viable in the future, diminish or eliminate many of the risks associated with nuclear fission.[87]

The 1600 MWe European Pressurized Reactor reactor is being built in Olkiluoto, Finland. A joint effort of French AREVA and German Siemens AG, it will be the largest reactor in the world. In December 2006 construction was about 18 months behind schedule so completion was expected 2010-2011.[88][89]

As of March 2007, there are seven nuclear power plants under construction in India, and five in China.[90]

In November 2011 Gulf Power stated that by the end of 2012 it hopes to finish buying off 4000 acres of land north of Pensacola, Florida in order to build a possible nuclear power plant.[91]

Russia has begun building the world's first floating nuclear power plant. The £100 million vessel, the *Lomonosov*, is the first of seven plants that Moscow says[*who?*] will bring vital energy resources to remote Russian regions.[92]

By 2025, Southeast Asia nations would have a total of 29 nuclear power plants, Indonesia will have 4 nuclear power plants, Malaysia 4, Thailand 5 and Vietnam 16 from nothing at all in 2011.[93]

Expansion at two Nuclear Power Plants in the United States, Plant Vogtle and V. C. Summer Nuclear Power Plant, located in Georgia and South Carolina, respectively, are scheduled to be completed between 2016 and 2019. The two new Plant Vogtle reactors, and the two new reactors at Virgil C. Summer Nuclear Plant, represent the first nuclear power construction projects in the United States since the Three Mile Island nuclear accident in 1979.