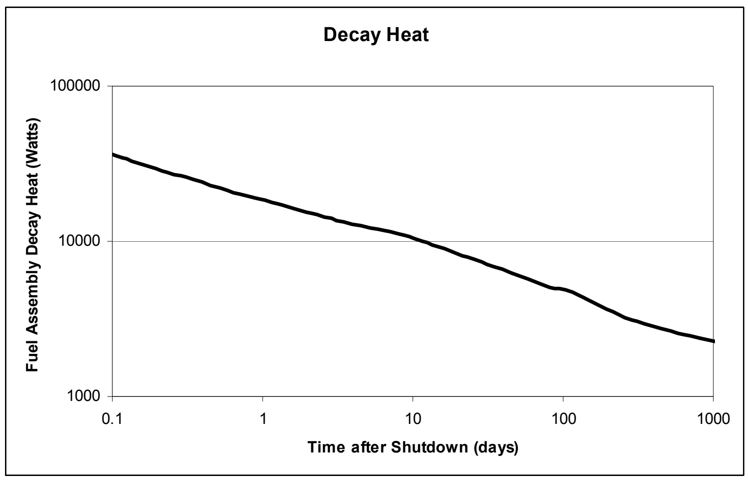
Energy Engineering and
Systems Analysis

Spent Fuel

Spent nuclear fuel is removed from a reactor and placed in the spent fuel pool for storage. The spent fuel produces decay heat and it is rejected using a heat removal system. The Nuclear Regulatory Commission has ordered licensees to develop guidance and strategies to maintain and restore spent fuel pool cooling.

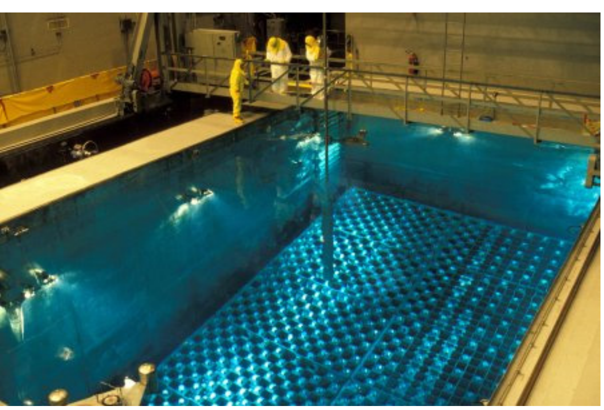
Decay Heat

When a nuclear reactor has been shut down, and nuclear fission is not occurring at a large scale, the major source of heat production will be due to the beta decay of fission fragments. At the moment of reactor shutdown the decay heat is about 6.5% of the previous core power if the reactor has had a long and steady power history. About 1 hour after shutdown, the decay heat will be about 1.5% of the previous core power. After a day, the decay heat falls to 0.4%, and after a week it falls to 0.2%.



Decay Heat for Representative BWR Assembly

While there is a large decrease in decay heat after a reactor is shut down, the used nuclear fuel in a reactor core must be continually cooled. This is why all reactors have systems that remove decay heat after a reactor shut down. These are powered by the off-site electricity grid, back-up diesel generators in the event that off-site power is lost, and stand-by back-up batteries. The beyond design basis events at affected the Fukushima Daiichi destroyed their capability to remove this decay heat.


Spent Fuel Pool

Spent Fuel Management

Spent nuclear fuel is removed from the reactor and placed in the spent fuel pool for storage. Spent fuel pools contain enormous amounts of water and are strong structures constructed of very thick steel-reinforced concrete walls with stainless steel liners located inside protected areas. Spent fuel pools are typically 40 or more feet deep, with the bottom 14 feet equipped with storage racks designed to hold fuel assemblies removed from the reactor. Many fuel pools are located below ground level, many are shielded by other structures, and many have intervening walls that would obstruct an aircraft or other object impact.

The spent fuel produces decay heat and it is rejected using a heat removal system. The beyond design basis events that affected the Fukushima Daiichi also destroyed their capability to remove this decay heat. The cooling of the spent fuel pools at the Fukushima Daiichi may have also been affected by the hydrogen explosions that occurred. In the U.S, the Nuclear Regulatory Commission has ordered licensees to develop guidance and strategies to maintain and restore spent fuel pool cooling using existing or available resources if cooling is lost for any reason.[1] For many events, U.S. plant operators would have significant time to correct a problem, or implement fixes to restore cooling.

1. www.nrc.gov/reading-rm/doc-collections/fact-sheets/storage-spent-fuel-fs.html

Spent Fuel Pool

In the early 1980s, utilities began looking at options for increasing spent fuel storage capacity. Current regulations permit re-racking (placing fuel rod assemblies closer together in spent fuel pools) and fuel rod consolidation, subject to U.S. Nuclear Regulatory Commission review and approval, to increase the amount of spent fuel that can be stored in the pool. Both of these methods are constrained by the size of the pool.


Dry Storage Facilities

An option for increasing capacity that is being used by several nuclear utilities is dry storage in an independent spent fuel storage installation (ISFSI) at the reactor site. Dry storage casks typically consist of a sealed metal cylinder containing the spent fuel enclosed within a metal or concrete outer shell. In some designs, casks are placed horizontally; in others, they are set vertically on a concrete pad. The U.S. Nuclear Regulatory Commission reviews and approves the designs for spent fuel dry storage systems to ensure that the dry storage system will protect public health and safety and the environment.

Dry Storage of Spent Nuclear Fuel

The table below shows the number of fuel assemblies in storage at each nuclear power plant in Illinois. In the U.S., there is no disposition pathway for discharged nuclear fuel. All discharged fuel is stored on-site either in the spent fuel pools or in dry storage facilities pending future decisions regarding the disposition pathway.

Plant	Type	Capacity (MW)	Wet Storage[a]	Dry Storage[a]
Zion	PWR (2)	510 each (shutdown)	2,227	0
Quad Cities	BWR (2)	870 each	6,355	1,700
LaSalle	BWR (2)	1,138 and 1,150	6,408	204
Dresden	BWR (3)	867 each (2) 210 (shutdown)	5,933	2,924
Clinton	BWR (1)	1,043	2,732	0
Byron	PWR (2)	1,168 each	2,471	192
Braidwood	PWR (2)	1,165 each	2,462	0

[a]Chicago Tribune, March 20, 2011.

[b]Note that a BWR fuel assembly contains about 40% as much fuel material as a PWR fuel assembly (~0.2 MT vs. ~0.5 MT).