a BWR produces steam directly by boiling the water coolant. The steam is separated from the remaining water in steam separators positioned above the core, and passed to the turbines, then condensed and recycled.

In GCFs (gas-cooled reactors) and ADSs (advanced gas-cooled reactors) carbon dioxide is used as the coolant and graphite as the moderator. Like heavy water, a graphite moderator allows natural uranium (in GCFs) or very low-enriched uranium (in ADSs) fuel to be used.

The LWGR (light water graphite reactor) has enriched fuel in pressure tubes with the light water coolant. These are surrounded by the graphite moderator. More often referred to as the RBMK.

In FRRs (fast breeder reactors) types, the fuel is a mix of oxides of plutonium and uranium; no moderator is used. The core is usually surrounded by a ‘fertile blanket’ of urania-238. Neutrons escaping the core are absorbed by the blanket, producing further plutonium, which is separated out during subsequent reprocessing for use as fuel. FRRs normally use liquid metal, such as sodium, as the coolant at low pressure.

High temperature gas-cooled reactors (HTGRs), not yet in commercial operation, offer an alternative to conventional designs. They use graphite as the moderator and helium as the coolant. HTGRs have ceramic-coated fuel capable of handling temperatures exceeding 1600°C and gain their efficiency by operating at temperatures of 700°C. The helium can drive a gas turbine directly or be used to make steam.

While the size of individual reactors is increasing well over 1000 MWe, there is growing interest in small units down to about 10 MWe.

Reactor facts and performance

• Electricity was first generated by a nuclear reactor on 20 December 1951 when the EBR-I test reactor in the USA lit up four light bulbs.

• Reactor facts and performance

• The neutrons released are “fast” neutrons, with high energy. These cannot be slowed down by a moderator for the chain reaction to occur.

• In BWRs (boiling water reactors) and PWRs (pressurized water reactors), collectively known as LWGRs (light water reactors), light or heavy water (D2O) coolant is also the moderator.

• PWRs (pressurized heavy water reactors) use heavy water (D2O) to slow or stop the reaction by absorbing neutrons. These reactors have separate coolant and moderator circuits. Coolant may be light or heavy water.

• The chain reaction is controlled by the use of control rods, which are inserted into the reactor core either to slow or stop the reaction by absorbing neutrons.

• Operating margings at power stations are no longer limited by fuel lifetime, but by the potential for increased power output and load factors.

• A BWR generates steam indirectly – heat is transferred from the primary reactor coolant, which is kept liquid at high pressure, into a secondary circuit where steam is produced for the turbine.

• A PWR produces steam directly by boiling the water coolant. The steam is separated from the remaining water in steam separators positioned above the core, and passed to the turbines, then condensed and recycled.

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• The 5 MWe Obninsk LWR in Russia, which commenced power generation in 1954, and was the first to supply the grid and was shut down on 30 April 2002.

• Calder Hall, at Silloth, UK, was the world’s first industrial-scale nuclear power station, becoming operational in 1956. The plant finally shut down on 31 March 2003.

• Grohnde, a 1360 MWe German PWR which first produced power in 1984, has generated over 356 billion kWh of electricity, more than any other reactor.

• With a cumulative load factor of 91.7% since first power in 2015, the Shin-Wolsong 2 PWR in South Korea leads the way in operational performance, closely followed by Germany’s Emsland, also a PWR.

• In September 2016, unit 2 of the Haydashim 2 AGR plant in the UK set a new world-record of 940 days continuous power production, breaking the previous record of 894 days set in 1994 by Pickering 7.

• In 2016, 61 nuclear power reactors achieved load factors of more than 95%, compared with 50 the previous year. In 2016, 61 nuclear power reactors achieved load factors of more than 95%, compared with 50 the previous year.

• Grohnde, a 1360 MWe German PWR which first produced power in 1984, has generated over 356 billion kWh of electricity, more than any other reactor.

• With a typical burn-up of 45,000 MWd/t, one tonne of natural uranium made into fuel will produce as much as 17,000 to 20,000 tonnes of black coal.

• Over 17,000 reactor-years of operating experience have so far been accumulated.

• Total nuclear electricity supplied worldwide in 2016 was 2490 billion kWh, about 11.5% of total electricity generated that year.

Nuclear power reactor types, typical characteristics

Characteristics

<table>
<thead>
<tr>
<th>Nuclear reactor type</th>
<th>PWR</th>
<th>BWR</th>
<th>PHWR (Candu)</th>
<th>LWR (BWRM)</th>
<th>AGR</th>
<th>CBR</th>
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<tbody>
<tr>
<td>Active core height, m</td>
<td>3.3</td>
<td>3.7</td>
<td>5.9</td>
<td>7.0</td>
<td>8.3</td>
<td>8.3</td>
</tr>
<tr>
<td>Active core diameter, m</td>
<td>3.4</td>
<td>4.7</td>
<td>6.0</td>
<td>11.8</td>
<td>9.3</td>
<td>9.3</td>
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<tr>
<td>Fuel inventory, tonnes</td>
<td>104</td>
<td>134</td>
<td>90</td>
<td>192</td>
<td>110</td>
<td>32</td>
</tr>
<tr>
<td>Vessel type</td>
<td>Cylinder</td>
<td>Cylinder</td>
<td>Cylinder</td>
<td>Tubes</td>
<td>Tubes</td>
<td>Cylinder</td>
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<td>Form</td>
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<td>Enriched</td>
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<td>Enriched</td>
<td>Enriched</td>
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<td>Direct</td>
<td>Direct</td>
<td>Direct</td>
<td>Indirect</td>
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<tr>
<td>Moderator</td>
<td>H2O</td>
<td>H2O</td>
<td>H2O</td>
<td>H2O</td>
<td>H2O</td>
<td>Sodium</td>
</tr>
<tr>
<td>Number operable*</td>
<td>290</td>
<td>78</td>
<td>48</td>
<td>15</td>
<td>14</td>
<td>3</td>
</tr>
</tbody>
</table>

*as of 03.05.17
Concrete pressure vessel
Carbon dioxide
Steam generator
Fuel elements
Graphite moderator
Control rods
Fuel elements
Steel pressure vessel
Steam
Water
Control rods
Pressurizer
Steam generator
Fuel elements
Reinforced concrete containment and shield
Steam
Water
Control rods
Pressurized water reactor (PWR)
Pressurized heavy water reactor (PHWR/Candu)
Boiling water reactor (BWR)
Advanced gas-cooled reactor (AGR)
High-temperature reactor (HTR)

Location | Nuclear electricity generation, 2016 (GWh) | Share of total electricity production, 2016 (%) | Number of operable reactors | Nuclear generating capacity, 2016 (MWe) |
--- | --- | --- | --- | --- |
Argentina | 5.6 | 1 | 1627 |
Armenia | 3.2 | 1 | 376 |
Belgium | 41.3 | 7 | 5843 |
Brazil | 12.9 | 2 | 1795 |
Bulgaria | 13.8 | 2 | 1926 |
Canada | 97.4 | 10.6 | 10 | 13,553 |
China | 316.0 | 3.6 | 36 | 32,637 |
Czech Rep | 32.7 | 29.4 | 6 | 3664 |
Finland | 32.3 | 33.7 | 4 | 2764 |
France | 384.0 | 72.3 | 58 | 621,130 |
Germany | 80.1 | 13.1 | 8 | 10,728 |
Hungary | 53.5 | 31.5 | 1 | 1889 |
India | 5.9 | 2.1 | 1 | 975 |
Japan | 17.5 | 2.2 | 42 | 39,992 |
Mexico | 10.3 | 6.2 | 2 | 1600 |
Netherlands | 3.8 | 3.4 | 1 | 486 |
Pakistan | 3.7 | 4.4 | 4 | 1090 |
Poland | 10.4 | 17.1 | 2 | 1210 |
Russia | 179.7 | 17.1 | 35 | 26,860 |
Sweden | 33.7 | 54.1 | 4 | 1910 |
South Africa | 15.2 | 6.6 | 2 | 1830 |
South Korea | 124.7 | 10.2 | 25 | 22,061 |
Spain | 98.5 | 21.4 | 7 | 7121 |
Switzerland | 15.7 | 24.0 | 9 | 6649 |
Switzerland | 10.3 | 5.4 | 3 | 3333 |
Ukraine | 81.0 | 32.3 | 15 | 13,107 |
UK | 10.2 | 20.4 | 15 | 6983 |
USA | 305.3 | 19.7 | 99 | 56,678 |
Total | 2490 | 11.5 | 447 | 392,080 |

*as of 01.05.17
Sources: World Nuclear Association, IAEA
**The world total includes six reactors on Taiwan with a combined capacity of 3.1 billion kWh in 2016, accounting for 16.3% of its electricity generation.

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