# Plans For New Reactors Worldwide

*(Updated August 2010)*

- **Nuclear power capacity worldwide is increasing steadily but not dramatically, with almost 60 reactors under construction in 15 countries.**
- **Most reactors on order or planned are in the Asian region, though there are major plans for new units in Europe, the USA and Russia.**
- **Significant further capacity is being created by plant upgrading.**
- **Plant life extension programs are maintaining capacity, in USA particularly.**

Today there are some 440 nuclear power reactors operating in 30 countries plus Taiwan, with a combined capacity of over 376 GWe. In 2009 these provided 2560 billion kWh, about 15% of the world's electricity.

About 58 power reactors are currently being constructed in 14 countries plus Taiwan (see Table below), notably China, South Korea and Russia.

The International Atomic Energy Agency in its 2009 report significantly increased its projection of world nuclear generating capacity. It now anticipates at least 73 GWe in net new capacity by 2020, and then 511 to 807 GWe in place in 2030 - very much more than projected previously, and 37% to 116% more than the 327.5 GWe actually operating in 2009. OECD estimates range up to 680 GWe in 2030. The change is based on specific plans and actions in a number of countries, including China, India, Russia, Finland and France, coupled with the changed outlook due to the Kyoto Protocol. The IAEA projections would give nuclear power a 13.5 to 14.6% share in electricity production in 2020, and 12.6 to 15.9 % in 2030. The fastest growth is in Asia.

It is noteworthy that in the 1980s, 218 power reactors started up, an average of one every 17 days. These included 47 in USA, 42 in France and 18 in Japan. These were fairly large - average power was 923.5 MWe. So it is not hard to imagine a similar number being commissioned in a decade after about 2015. But with China and India getting up to speed with nuclear energy and a world energy demand double the 1980 level in 2015, a realistic estimate of what is possible (but not planned at this stage) might be the equivalent of one 1000 MWe unit worldwide every 5 days.

See also *Nuclear Renaissance* paper for the factors driving the increase in nuclear power capacity, and also WNA's Nuclear Century Outlook.

## Increased Capacity

Increased nuclear capacity in some countries is resulting from the uprating of existing plants. This is a highly cost-effective way of bringing on new capacity.

Numerous power reactors in USA, Belgium, Sweden and Germany, for example, have had their generating capacity increased. In **Switzerland**, the capacity of its five reactors has been increased by 12.3%. In **the USA**, the Nuclear Regulatory Commission has approved 126 uprates totalling some 5600 MWe since 1977, a few of them "extended uprates" of up to 20%.

**Spain** has had a program to add 810 MWe (11%) to its nuclear capacity through upgrading its nine reactors by up to 13%. Some 519 MWe of the increase is already in place. For instance, the

Almarez nuclear plant is being boosted by more than 5% at a cost of US$ 50 million.

**Finland** Finland boosted the capacity of the original Olkiluoto plant by 29% to 1700 MWe. This plant started with two 660 MWe Swedish BWRs commissioned in 1978 and 1980. It is now licensed to operate to 2018. The Loviisa plant, with two VVER-440 (PWR) reactors, has been uprated by 90 MWe (10%).

**Sweden** is uprating Forsmark plant by 13% (410 MWe) over 2008-10 at a cost of EUR 225 million, and Oskarshamn-3 by 21% to 1450 MWe at a cost of EUR 180 million.

## Nuclear Plant Construction

Most reactors currently planned are in the Asian region, with fast-growing economies and rapidly-rising electricity demand.

Many countries with existing nuclear power programs (Argentina, Armenia, Brazil, Bulgaria, Canada, China, Czech Rep., France, India, Japan, Pakistan, Romania, Russia, Slovakia, South Korea, South Africa, Ukraine, UK, USA) have plans to build new power reactors (beyond those now under construction).

In all, over 150 power reactors with a total net capacity of almost 170,000 MWe are planned and over 340 more are proposed. Rising gas prices and greenhouse constraints on coal, coupled with energy security concerns, have combined to put nuclear power back on the agenda for projected new capacity in both Europe and North America.

In the **USA** there are proposals for over twenty new reactors and the first 17 combined construction and operating licences for these have been applied for. All are for late third-generation plants, and a further proposal is for two ABWR units.  it is expected that 4 to 8 new  reactors will be on line by 2020.

In **Canada** there are plans to build up to 3500 MWe of new capacity in Ontario, and proposals for similar capacity in Alberta and one large reactor in New Brunswick.

In **Finland**, construction is now under way on a fifth, very large reactor which will come on line in 2012, and plans are firming for another large one to follow it.

**France** is building a similar 1600 MWe unit at Flamanville, for operation from 2012, and a second is to follow it at Penly.

In the **UK**, four similar 1600 MWe units are planned for operation by 2019, and a further 6000 MWe is proposed.

**Romania**'s second power reactor istarted up in 2007, and plans are being implemented for two further Canadian units to operate by 2017.

**Slovakia** is completing two 470 MWe units at Mochovce, to operate from 2011-12.

**Bulgaria** is planning to start building two 1000 MWe Russian reactors at Belene.

In **Russia**, ten large reactors are under active construction, one being a large fast neutron reactor. Seven further reactors are then planned to replace some existing plants, and by 2016 ten new

reactors totalling at least 9.8 GWe should be operating. Further reactors are planned to add new capacity by 2020. This will increase the country's present 21.7 GWe nuclear power capacity to 43 GWe about 2020. In addition about 5 GW of nuclear thermal capacity is planned. A small floating power plant is expected to be completed by 2012 and others are planned to follow.

**Poland** is planning some nuclear power capacity, and may also join a project in Lithuania, with Estonia and Latvia.

**Italy** is planning to build substantial nuclear capacity and have 25% of its electricity from nuclear power by 2030, which will require 8 to 10 large new reactors by then.

**South Korea** plans to bring a further eight reactors into operation by 2016, giving total new capacity of 9200 MWe. Of the first six, now under construction, four are improved OPR-1000 designs. Then come Shin-Kori-3 & 4 and Shin-Ulchin 1&2, the first of the Advanced PWRs of 1400 MWe, to be in operation by 2016. These APR-1400 designs have evolved from a US design which has US NRC design certification, and have been known as the Korean Next-Generation Reactor. Four further APR-1400 units are planned, and the design has been sold to the UAE (see below).

**Japan** has two reactors under construction and another three likely to start building by mid 2011. It also has plans and, in most cases, designated sites and announced timetables for a further nine power reactors, totalling over 13,000 MWe which are expected to come on line by 2022.

In **China**, now with 13 operating reactors on the mainland, the country is well into the next phase of its nuclear power program. Some 23 reactors are under construction and ten more are likely to be so by the end of 2010. Those under construction include the world's first Westinghouse AP1000 units and a demonstration high-temperature gas-cooled reactor plant. Many more units are planned, with construction due to start within three years. But most capacity under construction will be the largely indigenous CPR-1000. China aims at least to quadruple its nuclear capacity from that operating and under construction by 2020.

On Taiwan, Taipower is building two advanced reactors (ABWR) at Lungmen.

**India** has 19 reactors in operation, and four under construction (two expected to be completed by 2010). This includes two large Russian reactors and a large prototype fast breeder reactor as part of its strategy to develop a fuel cycle which can utilise thorium. Twenty further units are planned. Ten further units are planned, and proposals for more - including western and Russian designs - are taking shape following the lifting of trade restrictions.

**Pakistan** has a second 300 MWe reactor under construction at Chasma, financed by China. There are plans for two more Chinese power reactors.

In **Kazakhstan**, a joint venture with Russia's Atomstroyexport envisages development and marketing of innovative small and medium-sized reactors, starting with a 300 MWe Russian design as baseline for Kazakh units.

In **Iran** nuclear power plant construction was suspended in 1979 but in 1995 Iran signed an agreement with Russia to complete a 1000 MWe PWR at Bushehr. Fuel is being loaded for late 2010 start-up.

The **United Arab Emirates** has awarded a $20.4 billion contract to a South Korean consortium to

build four 1400 MWe reactors by 2020.

**Jordan** has committed plans for its first reactor to be operating by 2020, and is developing its legal and regulatory infrastructure.

**Turkey** has contracts signed for Russian nuclear plants at one site and is planning Soputh Korean units at another. Its legal and regulatory infrastructure is well-developed.

**Vietnam** has committed plans for its first reactors at two sites (2x2000 MWe), to be operating by 2020, and is developing its legal and regulatory infrastructure. The first plant will be a turnkey project built by Atomstroyexport.

**Indonesia** plans to construct 6000 MWe of nuclear power capacity by 2025.

**Thailand** plans to start constructing an initial nuclear power station in 2014.

Fuller details of all the above contries curently without nuclear power are in country papers or the paper on *Emerging Nuclear Energy Countries.*

## Plant Life Extension and Retirements

Most nuclear power plants originally had a nominal design lifetime of 25 to 40 years, but engineering assessments of many plants have established that many can operate longer. In the USA some 60 reactors have been granted licence renewals which extend their operating lives from the original 40 out to 60 years, and operators of most others are expected to apply for similar extensions. Such licence extensions at about the 30-year mark justify significant capital expenditure for replacement of worn equipment and outdated control systems.

In France, there are rolling ten-year reviews of reactors. In 2009 the Nuclear Safety Authority (ASN) approved EdF's safety case for 40-year operation of the 900 MWe units, based on generic assessment of the 34 reactors. In Japan, plant lifetimes up to 70 years re envisaged.

When some of the first commercial nuclear power stations in the world, Calder Hall and Chapelcross in the UK, were built in the 1950s they were very conservatively engineered, though it was assumed that they would have a useful lifetime of only 20-25 years. They were then authorised to operate for 50 years, but due to economic factors closed earlier. Most other Magnox plants are licensed for 40-year lifetimes.

The Russian government is extending the operating lives of many of the country's reactors from their original 30 years, for 15 years. However, 25-year licence extensions are likely for the newer VVER-1000 units, with significant upgrades.

The technical and economic feasibility of replacing major reactor components, such as steam generators in PWRs and pressure tubes in CANDU heavy water reactors, has been demonstrated. The possibilities of component replacement and licence renewals extending the lifetimes of existing plants are very attractive to utilities, especially in view of the public acceptance difficulties involved in constructing replacement nuclear capacity.

On the other hand, economic, regulatory and political considerations have led to the premature closure of some power reactors, particularly in the United States, where reactor numbers have fell

from 110 to 104, and in eastern Europe.

It should not be assumed that reactors will close when their licence is due to expire, since licence renewal is now common. However, new plants coming on line are balanced by old plants being retired. Over 1996-2009, 43 reactors were retired as 49 started operation. There are no firm projections for retirements over the next two decades, but WNA estimates that at least 60 of those now operating will close by 2030, most being small plants. The 2009 WNA Market Report reference case has 143 reactors closing by 2030, using very conservative assumptions about licence renewal.

The World Nuclear Power Reactor table gives a fuller and (for current year) possibly more up to date overview of world reactor status.

Power reactors under construction, or almost so

| Start Operation* | | REACTOR | TYPE | MWe (net) |
|---|---|---|---|---|
| 2010 | India, NPCIL | Kaiga 4 | PHWR | 202 |
| 2010 | Iran, AEOI | Bushehr 1 | PWR | 950 |
| 2010 | India, NPCIL | Kudankulam 1 | PWR | 950 |
| 2010 | Korea, KHNP | Shin Kori 1 | PWR | 1000 |
| 2011 | Argentina, CNEA | Atucha 2 | PHWR | 692 |
| 2011 | India, NPCIL | Kudankulam 2 | PWR | 950 |
| 2011 | Russia, Energoatom | Kalinin 4 | PWR | 950 |
| 2011 | Korea, KHNP | Shin Kori 2 | PWR | 1000 |
| 2011 | China, CGNPC | Lingao II-2 | PWR | 1080 |
| 2011 | Japan, Chugoku | Shimane 3 | ABWR | 1375 |
| 2011 | Taiwan Power | Lungmen 1 | ABWR | 1300 |
| 2011 | Canada, Bruce Pwr | Bruce A1 | PHWR | 769 |
| 2011 | Canada, Bruce Pwr | Bruce A2 | PHWR | 769 |
| 2011 | Pakistan, PAEC | Chashma 2 | PWR | 300 |
| 2011 | India, NPCIL | Kalpakkam | FBR | 470 |
| 2012 | Finland, TVO | Olkilouto 3 | PWR | 1600 |
| 2012 | China, CNNC | Qinshan phase II-4 | PWR | 650 |
| 2012 | Taiwan Power | Lungmen 2 | ABWR | 1300 |
| 2012 | Korea, KHNP | Shin Wolsong 1 | PWR | 1000 |
| 2012 | Canada, NB Power | Point Lepreau 1 | PHWR | 635 |
| 2012 | France, EdF | Flamanville 3 | PWR | 1630 |
| 2012 | Russia, Energoatom | Vilyuchinsk | PWR x 2 | 70 |
| 2012 | Russia, Energoatom | Novovoronezh II-1 | PWR | 1070 |
| 2012 | Slovakia, SE | Mochovce 3 | PWR | 440 |
| 2012 | China, CGNPC | Hongyanhe 1 | PWR | 1080 |
| 2012 | China, CGNPC | Ningde 1 | PWR | 1080 |
| 2013 | Korea, KHNP | Shin Wolsong 2 | PWR | 1000 |
| 2013 | USA, TVA | Watts Bar 2 | PWR | 1180 |
| 2013 | Russia, Energoatom | Leningrad II-1 | PWR | 1070 |
| 2013 | Korea, KHNP | Shin-Kori 3 | PWR | 1350 |
| 2013 | China, CNNC | Sanmen 1 | PWR | 1250 |
| 2013 | China, CGNPC | Ningde 2 | PWR | 1080 |
| 2013 | China, CGNPC | Yangjiang 1 | PWR | 1080 |
| 2013 | China, CGNPC | Taishan 1 | PWR | 1700 |
| 2013 | China, CNNC | Fangjiashan 1 | PWR | 1080 |
| 2013 | China, CNNC | Fuqing 1 | PWR | 1080 |

| | | | | |
|---|---|---|---|---|
| 2013 | China, CGNPC | Hongyanhe 2 | PWR | 1080 |
| 2013 | Slovakia, SE | Mochovce 4 | PWR | 440 |
| 2014 | China, CNNC | Sanmen 2 | PWR | 1250 |
| 2014 | China, CPI | Haiyang 1 | PWR | 1250 |
| 2014 | China, CGNPC | Ningde 3 | PWR | 1080 |
| 2014 | China, CGNPC | Hongyanhe 3 | PWR | 1080 |
| 2014 | China, CGNPC | Hongyanhe 4 | PWR | 1080 |
| 2015 | China, CGNPC | Yangjiang 2 | PWR | 1080 |
| 2014 | China, CNNC | Fangjiashan 2 | PWR | 1080 |
| 2014 | China, CNNC | Fuqing 2 | PWR | 1080 |
| 2014 | China, CNNC | Changiang 1 | PWR | 650 |
| 2014 | China, China Huaneng | Shidaowan | HTR | 200 |
| 2014 | Korea, KHNP | Shin-Kori 4 | PWR | 1350 |
| 2014 | Japan, Tepco | Fukishima I-7 | ABWR | 1380 |
| 2014 | Japan, EPDC/J Power | Ohma | ABWR | 1350 |
| 2014 | Russia, Energoatom | Rostov 3 | PWR | 1070 |
| 2014 | Russia, Energoatom | Beloyarsk 4 | FNR | 750 |
| 2015 | Japan, Tepco | Fukishima I-8 | ABWR | 1380 |
| 2015 | China, CGNPC | Yangjiang 3 | PWR | 1080 |
| 2015 | China, CPI | Haiyang 2 | PWR | 1250 |
| 2015 | China, CGNPC | Taishan 2 | PWR | 1700 |
| 2015 | China, CGNPC | Ningde 4 | PWR | 1080 |
| 2015 | China, CGNPC | Hongyanhe 5 | PWR | 1080 |
| 2015 | China, CGNPC | Fangchenggang 1 | PWR | 1080 |
| 2015 | China, CNNC | Changiang 2 | PWR | 650 |
| 2015 | China, CNNC | Hongshiding 1 | PWR | 1080 |
| 2015 | China, CNNC | Taohuajiang 1 | PWR | 1250 |
| 2015 | China, CNNC | Fuqing 3 | PWR | 1080 |
| 2015 | Korea, KHNP | Shin-Ulchin 1 | PWR | 1350 |
| 2015 | Japan, Tepco | Higashidori 1 | ABWR | 1385 |
| 2015 | Japan, Chugoku | Kaminoseki 1 | ABWR | 1373 |
| 2015 | India, NPCIL | Kakrapar 3 | PHWR | 640 |
| 2015 | Bulgaria, NEK | Belene 1 | PWR | 1000 |
| 2016 | Korea, KHNP | Shin-Ulchin 2 | PWR | 1350 |
| 2016 | Romania, SNN | Cernavoda 3 | PHWR | 655 |
| 2016 | Russia, Energoatom | Novovoronezh II-2 | PWR | 1070 |
| 2016 | Russia, Energoatom | Leningrad II-2 | PWR | 1200 |
| 2016 | Russia, Energoatom | Rostov 4 | PWR | 1200 |
| 2016 | Russia, Energoatom | Baltic 1 | PWR | 1200 |
| 2016 | Russia, Energoatom | Seversk 1 | PWR | 1200 |
| 2016 | Ukraine, Energoatom | Khmelnitsky 3 | PWR | 1000 |
| 2016 | India, NPCIL | Kakrapar 4 | PHWR | 640 |
| 2016 | India, NPCIL | Rajasthan 7 | PHWR | 640 |
| 2016 | China, | several | | |
| 2017 | Russia, Energoatom | Leningrad II-3 | PWR | 1200 |
| 2017 | Ukraine, Energoatom | Khmelnitsky 4 | PWR | 1000 |
| 2017 | India, NPCIL | Rajasthan 8 | PHWR | 640 |
| 2017 | Romania, SNN | Cernavoda 4 | PHWR | 655 |
| 2017 | China, | several | | |

* Latest announced year of proposed commercial operation. Rostov = Volgodonsk

Sources:
WNA information papers