Nuclear Power

Highlights

■ **Process and Technology Status –** In nuclear reactors, the energy released by the uranium (U) fission reactions provides heat to a coolant fluid. The fluid may either directly drive a turbine-powered electricity generator or heat a secondary coolant, which drives the turbine. This process produces no greenhouse gas emissions. Some 440 nuclear power plants (about 372 GW) are currently (2009) in operation worldwide, providing 15% of the global electricity (25% in OECD countries). Nuclear capacity grew by 17% per year from 1970 to 1990, (some 218 plants were built in the 1980s) and slowed to 2% from then onward as a consequence of the 1986 Chernobyl accident. Existing plants are equipped with ***Generation II*** (***Gen II***) reactors that first appeared in the 1970s. ***Gen III and Gen III+*** reactors are evolutionary designs that were developed in the 1990s. To various extents, they include passive safety features and have a longer lifetime, reduced costs, and shorter licensing and construction time. Gen III and III+ reactors were built mostly in East Asia. More than 40 GW are presently under construction mostly in China, India, Russia, Ukraine, South Korea, Japan, Taipei, Bulgaria, Finland, France, and the United States. A further 23 GW have been approved for construction and some 40 GW are currently under consideration.

■ **Costs –** Recently, the cost of nuclear electricity has been reassessed by several studies. Volatile prices of materials and technologies, i.e. the 2008 price peak and the economic crisis that followed, make the economic assessments particularly arduous as the final cost of nuclear electricity is dominated by the investment cost. An analysis by the UK Department of Trade and Industry (2007), based on the French EPR reactor, suggested *overnight* investment costs between $1700 and $3200/kW (central value of $2500/kW) and levelized electricity costs between $62 and $88/MWh (central estimate of $76/MWh), assuming a 6-year construction, 80% load-factor, 40-year lifetime; 10% interest rate, and including waste and decommissioning costs. The then current private-sector estimates suggested an average electricity cost between $58 and $68/MWh. The most recent study called *Projected Costs of Generating Electricity* (IEA-NEA, March 2010), based on data from more than 25 Countries and international organisations for nuclear, coal and gas-fired power plants to be commissioned by 2015, suggests nuclear overnight investment costs between $1600 and $5900/kW ($4100/kW central value) and electricity costs between $42 and $137/MWh, assuming a 10% interest rate, 5-6 years construction, 85% load-factor, 60-year lifetime; and including waste and decommissioning costs. If the interest rate is 5%, the nuclear electricity cost drops to $29-82/MWh and, in most countries, it turns out to be the most convenient option for electricity generation. With a 10% interest rate, coal- and gas-fired power are slightly more convenient (even assuming a price of $30/tCO_2$ for CO2 capture and storage in coal-fired power plants), but results of the comparison depend much more on local conditions (labour, materials, fuels, technology prices, and energy policies). Quoted nuclear power costs are also available from vendors. The overnight investment cost of the AREVA EPR reactor under construction in Flamanville (France) was €2060/kW in 2007 and rose to €2500/kW in 2008 (1€~1.3US$); the cost of the Finnish EPR in Olkiluoto was €1875/kW in 2003, but current estimates are more than double because of construction problems and delays; the Westinghouse AP1000 and the GE-Hitachi ABWR reactors are both in the range of $3000/KW (2008); at the end of 2009, the South Korean (KEPCO) APR reactor won an international bid to build four 1400-MW units in the United Arab Emirates at an estimated price of $2300/kW against the AREVA EPR at $2900/kW and the GE-Hitachi at $3600/kW. In terms of electricity cost, the APR's $30/MWh was lower than the EPR's $40/MWh and the GE's $69/MWh. Increasing prices of fossil fuels and pricing of CO_2 emissions make nuclear power an attractive option for base-load electricity generation. However, it is perceived as *financially* risky if compared to coal or gas power because of the high investment cost and long licensing, construction and return time.

■ **Potential & Barriers –** Nuclear power is practically a carbon-free source of energy. If it is used to replace super-critical coal-fired power plants, a 1-GW_e nuclear reactor can save some 6 million tonnes of CO_2 emissions per year and related airborne pollutants. Several countries are currently reconsidering the role of nuclear energy to reduce CO_2 emissions and the use of fossil fuels. To encourage private investments in nuclear power and to lower the *financial* risk compared to coal or gas power, policy measures and streamlined licensing procedures are being implemented in several countries. Globally, some 115 GW are under construction, approved and/or planned by 2020. In the long term, assuming the construction of an average 30-GW nuclear capacity per year between now and 2050 and a carbon price of $50/tCO_2$, the International Energy Agency (IEA-ETP, 2008) predicts that the nuclear share of global electricity will increase from the current 15% to 19-23% by 2050 and nuclear energy will contribute some 6% to the global 2050 CO_2 reduction versus the business-as-usual scenario. Today's technical and economic capacity could enable the construction of 35 to 55 GW per year, but estimates do not take into account the need for nuclear industry reorganisation and the ongoing lack of industrial facilities and human skills. Major international initiatives such as the ***Gen IV*** International Forum (GIF) and the Global Nuclear Energy Partnership (GNEP) aim to promote the renaissance of the nuclear industry and the development of new-generation reactors with improved safety and economic performance, reduced waste and nuclear proliferation issues. A new generation of nuclear reactors with improved performance (***Gen IV***) is under development and could be commercialised beyond 2030. As for uranium availability, at the current demand level, proven reserves are sufficient for about 85-100 years. Geologically estimated resources could extend reserves by a factor of 3 and the use of *fast breeder reactors* could in principle extend reserves by a factor of 60, thus making nuclear energy unlimited. In some countries, nuclear fuel enrichment and handling are still considered to be military operations submitted to strict domestic and international rules, and monitored by the International Atomic Energy Agency (IAEA). Waste management, health and proliferation risks raise public concern about the civil use of nuclear energy.

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