produced by coal. The quantity of radioactive material liberated by the burning of coal is considerable, since on average it contains a few parts per million of uranium and thorium. Modern coal-fired electric plants are designed and operated to reduce the emission of particulates from the stack, and also to decrease the emission of sulfur oxide and nitrogen oxide. Older plants, such as the majority of those in China, are far from meeting these standards for fly ash and gaseous emissions. When coal is burned, all the uranium daughters accumulated by disintegration—radium, radon, polonium—are also released. The United Nations Scientific Committee on the Effects of Atomic Radiation evaluates the radiation exposure to the population from this source.[2] Per gigawatt-year (GWe-yr) of electrical energy produced by coal, using the current mix of technology throughout the world, the population exposure is estimated to be about 0.8 lethal cancers per plant-year distributed over the affected population. Table 7.2 summarizes these data. With 400 GWe of coal-fired power plants in the world, this amounts to some 320 deaths per year; in the world at large, some plants have better filters and cause less harm, while others have little stack-gas cleanup and cause far more.

In addition, there is a major exposure to the radioactivity of coal that arises from the use of ash to make concrete. With about 5% of power-plant ash being incorporated into housing, the population dose for the 400 GWe of coal plant leads to an estimated 2000 cancer deaths per year. But if most of the ash went into concrete for dwellings, the annual death toll from radiation from this source would rise to about 40,000.

Some see in accidents a reason to abandon nuclear power in favor of alternate ways—so-called soft-energy paths—that they propose to help arrive at a harmonious development of industrial societies. There is much merit in both the more efficient use of energy and in its supply from renewable sources. The world used 375 quads of energy in 1996; the United States used 75. We have noted in Table 8.4 that solar electric power conceivably could amount to about 1500 quads per year worldwide; fuel from biomass, 600 quads; and 270 quads from exploiting the temperature difference between the warm surface water of the oceans and the colder water at depth. Biomass, in particular, may develop beyond the 3% of U.S. energy needs that it now meets, as the revolution in biotechnology enables the production of alcohol from cellulose rather than from sugars. It is highly desirable to have small-scale energy sources if they can be achieved at affordable cost and with acceptable environmental impact. It will be necessary, however, to carefully compare these alternatives—including their harmful side effects—to the more traditional ways of producing energy—e.g., fossil-fueled plants burning coal, gas, or oil; hydropower; and nuclear power stations.