1.1 Background and Context

Beginning in the early 1950s, the nuclear power industry in the United States grew to become second only to coal in its electrical generation capacity. By 1990, there were 111 commercial nuclear power plants with a combined capacity of $99,000\ MW$, representing about 19% of the nation's electric power. Nuclear power production in the US was then $530 \times 10^9\ kWh$, much more than in France and Japan combined though these two countries were among the nations most reliant on nuclear power. France produced 77% of its electricity by nuclear power; in West Germany and Japan the percentages were 33% and 26%. However, in the US no new nuclear plants were ordered after 1978 and the expansion of the US commercial nuclear power industry ceased shortly thereafter. Other countries saw a similar drastic decline in the growth of the nuclear power capacity.

The reasons for this abrupt transition are several. First, the rate of growth of demand for electric power was less than expected. Second, the capital costs associated with new nuclear power plants rose dramatically in the 1970s and 80s, in part because of more stringent regulatory activity. And third, public opposition to nuclear power also rose substantially in the aftermath of the Three Mile Island accident in 1979, a reaction that was further amplified by the Chernobyl accident in 1986. These accidents greatly heightened the public fear of nuclear power plants based on three major concerns, two reasonable and one unreasonable. The unreasonable concern was that a nuclear generating plant might explode like a nuclear weapon, an event that can be dismissed on fundamental physical grounds (see, for example, Nero 1979). However, the other two concerns that continue to have validity are the fear of the release of harmful radioactive material and the concern over the storage of nuclear waste. While Chernobyl rightly increased the concern over radioactive release, the improvements introduced as a result of the lessons learned from the nuclear accidents over the past half-century have greatly reduced the risk of such events. Specifically, it is now recognized that, in the past, a lack of standardization in the design and operation of nuclear power plants significantly impaired their safety margins and that world-wide cooperation, oversight and standardization will radically improve safety margins in the future. Great strides have been made in this regard since the end of the Cold War. Similarly, plans for waste storage and/or recycling continue to be developed both nationally and globally. As von Hippel (2006) has pointed out there is no hurry to recycle nuclear waste for many temporary storage options are possible given how small a volume of waste is produced and temporary storage is advisable when a number of reprocessing options may be found to be advantageous in the years ahead.

Of course, no power generating process is devoid of risks and consequences and, though complex, it is necessary to balance both the long and short-term effects while seeking an appropriate mix of energy resources. In 2011, 63% of the world's electricity generation was produced by coal and gas combustion; 12% was from nuclear power (from the Shift Project Data Portal, 2011). This 12% is significantly smaller than in the year 2006, when nuclear power amounted

to about 20% of the global generation. It is projected that nuclear power generation will remain relatively constant in the decades ahead while the overall demand and generation will continue to grow. This growth is in part caused by population increase and in part by economic development particularly in the developing countries. Efforts to conserve energy in the developed countries have been more than offset by population increases in the less-developed world. Consequently worldwide energy consumption per capita continues to rise and increased by about 20% between 1980 and 2010 (from the Shift Project Data Portal 2011).

However, it is now becoming clear that the increase in the use of combustible fuels, primarily coal and gas, has serious consequences for the earth's atmosphere and climate for the worldwide emissions of CO_2 from electricity production will continue to rise in the decade ahead. Moreover, greenhouse gas emissions are primarily caused by the burning of the combustible fuels coal, natural gas and oil which far exceeds that from the other power sources. The emissions advantage of nuclear power generation has led a number of environmental groups to begin to advocate for nuclear power (see, for example, Duffey *et al.* 2006) as a preferred *green solution* to the energy challenge. Whatever the preferred means of electricity production might be in the future, it seems clear that nuclear power must remain an option. One of the disturbing consequences of the anti-nuclear public sentiment in the past 30 years is that nuclear engineering became quite unpopular in universities (at least in the USA) and hence the nuclear engineering programs and students dwindled to a small number. If nuclear power generation were to become an important national or global objective, there would have to be a radical increase in that component of our engineering educational effort.