Book Review

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Nuclear Renaissance: Technologies and Policies for the Future of Nuclear Power
by William J. Nuttall, with a foreword by Rt. Hon. Brian Wilson MP
Published 2005
by Taylor & Francis Group,
270 Madison Avenue, New York, NY10016, USA, 322pp
ISBN: 10:0-70503-0936-9

1 Introduction

Is the global need for clean, secured and reliable energy pushing the world towards seeing the atom for peace again? Figures from the IAEA suggest that the world is witnessing a nuclear-power growth. Does this reawakened interest in nuclear energy serve as an indicator for a future nuclear renaissance? Few developing countries are now nursing the idea of having their pioneer nuclear power plant. Some energy experts believe that nuclear energy is one of the few solutions to the problems of high greenhouse gas emissions associated with fossil fuel plants and a substitute for the intermittent renewables. Nuclear renaissance is rather a Western view, because countries in Asia have continued nuclear plant constructions at the time when Europe and North America have stopped (Yoshimura, 2011). Figures from the IAEA indicate that, as of March 2009, there were 438 nuclear plants in operation in 30 countries and as of January 2011, 44 nuclear power plants were under construction in 13 countries. Furthermore, over 50 countries have approached the IAEA for assistance over their plans to have their pioneer nuclear power plant. It was estimated that the global nuclear-power capacity will grow to between 473 and 738 GWe by 2030 (yLeóns, 2011). It is important to mention that nuclear growth has implications for health, safety and the environment (Aliyu et al., 2013, 2014).

The WNA report (WNA, 2011) on the comparison of life-cycle emissions of greenhouse gases by various electricity generation methods concludes that the greenhouse gas emissions of nuclear power plants are among the lowest of any electricity generation method and are on a life-cycle basis comparable with those of the renewables.

This paper presents a review of the book on Nuclear Renaissance by William Nuttall. The fact that the book was published before notable events like the Fukushima tsunami inundation may lead critics to denigrate the current review. It is believed that the future edition of this book will address issues such as the Fukushima tsunami inundation, the Stuxnet virus attack at the Busher plant, and the Kashiwazaki–Kariwa 2007 earthquake, which have been discussed in current literature (Petrangeli, 2013). However, the Fukushima Daiichi nuclear accident is discussed by this review.

1.1 Main features of the Fukushima accident

On 11 March 2011, a 9.0 Richter scale earthquake and subsequent tsunami occurred in Tohoku Japan. A 14 m high tsunami overran the FNPP (Fukushima Nuclear Power Plant) in the northeast of Japan, causing the release of radioactive materials into the environment. This was as a result of the reactor rod meltdown and multiple explosions of hydrogen gas in the reactors after the backup cooling system failed. The accident led to the atmospheric and oceanic dispersion of fission products around Japan and other parts of the world.

The FNPP is located on the Japanese east coast, about 250 km to the north of Tokyo. The station houses six BWRs (Boiling Water Reactors), which were all commissioned in the 1970s. The power output of Unit 1 was rated at 1.38 GW. The other units (2–5) were rated at 2380 MW each, and Unit 6 at 3290 MW (Högberg, 2013).

At the time of the earthquake, Units 1–3 were under normal operation, whereas Units 4–6 were shut down for routine inspections and refuelling. The power production in Units 1–3 was immediately stopped as designed as the first vibrations were detected. The subsequent peak accelerations reached 0.56 g in the horizontal direction in some of the units, somewhat higher than the 0.46 g the reactors were designed for.

The tsunami generated by the earthquake hit the plant with wave heights that temporarily inundated the station up to about 14 m above sea level (Figure 1), whereas the reactors were designed to withstand wave heights of 5.7 m. As a result of this, the turbine building was flooded with salty seawater (Figure 2), damaging the diesel-powered back-up generator as well as other emergency accessories of the reactors (Högberg, 2013).

Hydrogen leakage in the reactor containment caused violent explosions destroying the upper parts of the reactor buildings in Units 1, 3, and 4 (Figure 3) (Högberg, 2013).

The accident had a negative impact on the Japanese economy as most of the country's operating nuclear power plants were shut down. Politically, the government was forced to have a rethink over the future of nuclear energy in its economy. Prior to Fukushima, the government had plans to increase its nuclear capacity to 50% of its energy mix (BBC, 2012). The accident had a strong impact on the public opinion and led to political debate about fission energy. The event induced enormous media coverage in the first few weeks after the accident but attention declined with time and the post-Fukushima public opinion towards nuclear energy has been found to be negative (Perko et al., 2012).

Figure 1 The tsunami that hit the Fukushima Daiichi Nuclear Power Station on 11 March 2011 (photo: TEPCO)

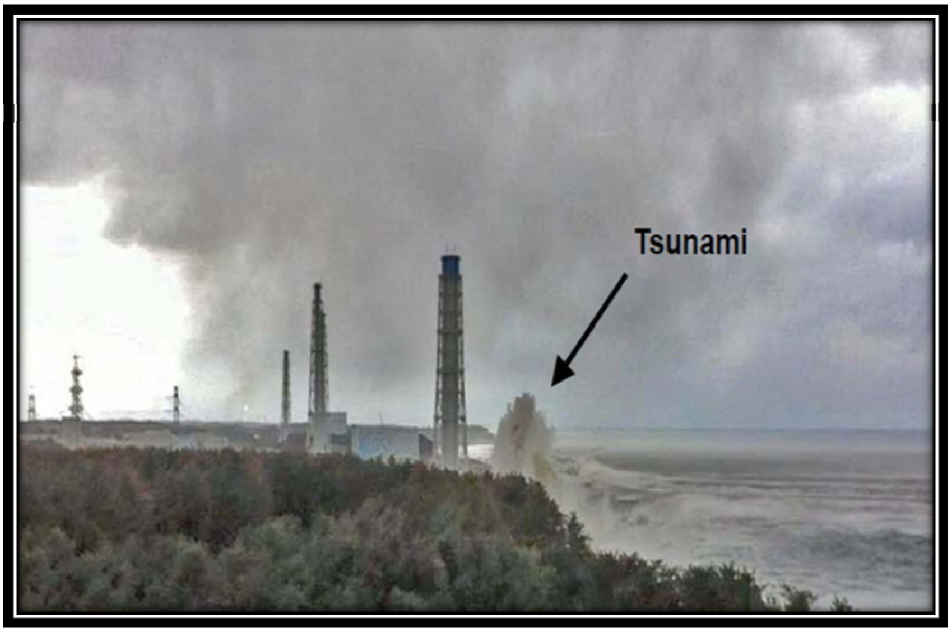
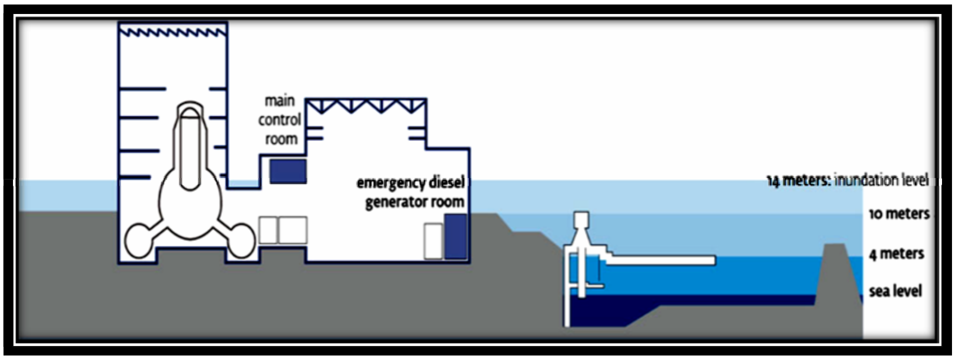


Figure 2 Cross-section showing the inundation level at Fukushima Daiichi Units 1–4 (NAIIC, 2012) (see online version for colours)



Overall, the Fukushima nuclear facility has done very well for withstanding the earthquake and tsunami forces that are well beyond the designed provision of the plant. As depicted in Figure 3, the greater part of the facility is still standing after being hit by the tsunami. Moreover, the plant design is an old one (probably generation II), and the generation III+ reactors have better safety systems.

Since the anti-seismic design of nuclear power plants become popular in the 1960s and 1970s, it has been noted that future plant design will give increasing attention to tsunamis, which was the major cause of accident at Fukushima nuclear power plant (Petrangeli, 2013).

Figure 3 Damaged reactor buildings of Units 3 and 4 caused by hydrogen explosions on 14–15 March (NAIIC, 2012) (photo: Air Photo Services, Japan)

2 The book review

This book covers a full range of topics surrounding nuclear power and public policy in 11 chapters divided into three parts: The Policy Landscape; Nuclear Fission Technologies; and Nuclear Fusion Technologies.

Chapter 1 highlights the fundamental factors that serve as drivers to the reawakened interest in nuclear power. The chapter also discusses the difficulties faced by the nuclear industry, which include stories of cost over-runs, construction delays, safety fears and occasional accidents. Accidents such as Three-Mile Island in Pennsylvania USA in March 1986 and the Chernobyl disaster of April 1979 are terrible events that give nuclear power a very low score in public assessment. The author believes that the true opposition to nuclear power came in the early 1990s, with the Shoreham boiling water reactor, which is the world's most expensive nuclear plant, being decommissioned without having sold any electricity, representing a true nadir of nuclear power. The fundamental issue driving the coming back of nuclear power is the concern for the global climate and the need to reduce the emission of greenhouse gases from fossil fuels. Another issue that drives the interest in nuclear power is the fact that most fossil fuels, on which today's technologies depend, are from a politically unstable region of the world (Middle East), and this causes instability in the price of the fuels.

Chapter 2 explores issues in energy policy. Within the context of this chapter, the particular aspect of policy discussed in the book is electricity. Using the UK as a case study, this chapter highlights some key areas related to energy policy in the following order: economics, security of supply, and environment. The author notes some important issues not captured in the UK's bare energy policy triangle. The new energy policy considers economics, reliability of supply, fuel poverty, industry, and technology.

Chapter 3 explores how nuclear power works and how electricity is generated using nuclear fission technology. Taking the reader back through the basics of nuclear fission (and fusion), this chapter briefly explains the technicalities of reactor science. In addition, basic terminologies of reactor science are defined in a less technical manner. The chapter discusses the economy of nuclear power and compares the cost of various methods of electricity generation, showing how competent nuclear power is in a deregulated electricity market. The electricity production costs for nuclear power have reduced in the USA by improvements in plant availability and operation efficiency, and the improvements have been matched only by improvements in the performance of the coal-fired plants, which account for a high percentage of the emission of greenhouse gases.

Other issues considered in Chapter 3 are nuclear power and the atmosphere, nuclear power security of supply and reliability, nuclear accidents and nuclear bombs, and nuclear industry skills. Three serious Western accidents are discussed: the NRX nuclear accident in Chalk River, Canada; the Windscale fire of 1957 in the UK; and the SL-1 reactor incident of 1961 in the USA. These accidents illustrate respectively the danger associated with equipment failure, unforeseen science and operator error in reactor safety. A brief account of the Chernobyl disaster is given. Readers are referred to Hewitt and Collier book *Introduction to Nuclear Power* for further details on the accidents.

Another issue that is vital to safety is the possibility of a terrorist attack on nuclear facilities and the risk of diversion of nuclear materials by skilful well-connected terrorist networks for weapon making. A terrorist weapon made from materials from a civil nuclear fuel cycle (i.e. based on plutonium not enriched uranium) would be unlikely to resemble a nuclear weapon. It is important that plans for nuclear renaissance must recognise the increased need to protect nuclear facilities from terrorist attack and the diversion of radioactive materials for proliferation of nuclear weapons by terrorist networks and rogue states.

Chapter 4 explores the issue of nuclear waste management. Different countries have distinct views as to what is a *waste*. Settling this question will be slow and difficult. In the UK, there has been debate over the grouping of some radioactive materials, such as separated civil plutonium, as waste or asset. The delay in the disposal programme of high-level radioactive waste continues to have a negative impact on the image of nuclear-power industries (Yoshimura, 2011). Different methods of radioactive waste disposal and policy issues in radioactive waste disposal are considered. The generic options for the radioactive waste management that involve deep geological disposal of the waste are safer. Although there is an international consensus that the geological disposal of high-level waste is practically feasible (Yoshimura, 2011), environmentalists have opposed this method of disposal on the grounds that once a radioactive material is out of sight it is out of mind.

In the UK, radioactive waste has been categorised into very low-level waste (VLLW), low-level waste (LLW), intermediate level waste (ILW) and high-level waste (HLW). The classification of the UK's radioactive waste is done based on the specific activity, the type of radioactivity, and the thermal properties of the material. As of 2001, the inventory of the UK's radioactive wastes stock shows the relative volumes of the LLW, ILW and HLW as follows: 1,510,000 m^3, 237,000 m^3 and 1510 m^3 respectively. Study of the UK's waste inventory shows that the radioactivity contained within the waste is in inverse proportion to the volumes of the waste involved, and that HLW is the most problematic type of nuclear waste. In addition, other topics such as spent fuel, naturally occurring radioactive materials, depleted uranium, the need for dialogue on waste in any nuclear renaissance, the use of plutonium in reactors (fast and thermal), and the US and the Finnish experiences in nuclear waste management are discussed.

Chapter 5 explores the technologies, safety, criticisms and economics of different types of water-cooled reactor. Some of the rectors discussed are the Advanced Passive series (AP 600 and AP 100), the CANDU series, and the European Pressurised Water Reactor (EPR), which is a product of the Franco-German collaboration Framatome ANP. Boiling water reactors such as BORAX–III and the GE-Toshibah-Hitachi ABWR are also considered.

The AP6 600 and AP 1000 are designed by Westinghouse Electric company LLC based on experience in pressurised light water reactors, which dates back to the 1950s. As the name implies, the AP series of nuclear reactors makes use of passive safety features; and safety-critical pumps, fans, diesel generators and other rotating machineries are all avoided. The design depends on the natural attributes of gravity, convection and the properties of compressed gas to ensure safety in terms of any reactor disruption. The capital cost and economic risk of the AP series reactor are lower than those of other forms of light water reactors because of the combined attributes of passive safety, simplified design and accelerated construction. The estimated final electricity cost of AP 1000 is 3.0–3.5 $/kWh, which is more competitive in the liberalised US electricity market than the AP 600 with electricity cost of 4.1-4.6 $/kWh. The most stinging criticism of the AP 1000 design is on the manufacturers and not on the design. The criticism runs that it is more than 20 years since Westinghouse Electric constructed any civil power reactor anywhere. The implication of such comments is that the company has lost the capabilities in area of civil nuclear-power reactor design and construction (Nuttall, 2004).

Chapter 6 discusses high-temperature gas-cooled reactors (HTGR). The chapter examines the engineering challenges faced in the past by the HTGR concept and how developments in both engineering and material science have improved our confidence in the HTGR concept. One key characteristic of the HTGR concept is its fuel design, known as the Triso. The economics and criticisms of the pebble bed HTGR reactors are also discussed in this chapter.

Chapter 7 considers the various technologies of nuclear fuel reprocessing. The chapter discusses the details of the partitioning and transmutation of nuclear waste. Some of the methods of nuclear fuel partitioning considered are aqueous separation, magnetic separation and the electrochemical separation technique, which is the most expensive method of partitioning. Details of the nuclear waste transmutation (the conversion of radioactive materials into stable nuclides by neutron capture) are presented.

The book also considers other topics, such as the Generation IV reactor technologies and nuclear fusion technologies. The future of nuclear fission will be bright with the latest designs and considerations of the Generation IV reactors, which are economic, safe, low waste and proliferation-resistant power plants, and they are the core of any nuclear renaissance that will be deployed by 2030.

Reading this book will not turn one into an expert in nuclear power technology and electricity policy. However, the manner in which the author presents his arguments without the use of ambiguous equations, and the way in which basic technical terminologies are explained, make the book recommendable for all English readers with little or no science background.

In the author’s personal conclusion, nuclear power is a beneficial but not an essential technology. Nuclear energy has its advantages and disadvantages, and it should be assessed fairly, but not technocratically.

Acknowledgements

Our sincere appreciation goes to the Malaysian Ministry of Higher education and the Universiti Teknologi Malaysia (UTM) for providing a research grant (Q.J130000.2526.03H67) from which part of this work was supported. We also acknowledge the support of the Research Management Center of UTM.

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