Chapter 1

INTRODUCTION

1.1. NUCLEAR ENERGY FOR TOMORROW

The constructive utilization of energy is of paramount importance in the enhancement of society's standard of living. Worldwide, the consumption of primary energy is expected to increase by 2.1%/year[1] due to population increase and rapid economic growth in some regions of the world. Currently, 90% of the energy consumed originates from the burning of fossil fuels, with 30% of the total used as primary energy for electricity production [1-1]. Most of the remaining 70% is used either for transportation or converted into hot water, steam and heat. Nuclear energy is now being used to produce about 17% of the world's electricity.

The burning of fossil fuels to satisfy our ever increasing needs represent significant hazards to society and to the environment. Most of the world's fuel supply is of hydrogen combined with carbon (hydrocarbons). Burning of these hydrocarbons results in the liberation of carbon oxide gases with undesirable side effects: CO is toxic to life, CO_2 is currently labeled as one of the primary causes of the greenhouse effect. Although subsequent global warming has been recognized, there still exists a discrepancy between the worldwide trend of CO_2 emission and the global target of CO_2 reduction. By agreement of 154 countries at the 1992 Rio earth summit, sustainable development in the reduction of greenhouse gases was to be pursued with attainment of the 1990 level by the year 2000 [1-1]. Yet, this reduction has not occurred. The trend has actually been in the opposite direction of ever increasing CO_2 emissions.

World consumption of energy is not going to decrease in the foreseeable future. The ability to supply and utilize energy in a more environmentally friendly manner is a necessity in resolving the global warming issue. This can be addressed through a number of avenues including cleaner, more efficient production and burning of fossil fuels, significantly increasing the use of energy sources such as hydro, wind, solar and biomass and greater utilization of nuclear power in the world's fuel mix. In the majority of scenarios, nuclear power is an essential contributor to successfully addressing environmental issues

The focus of this report is on utilization of the modular high temperature gas cooled reactor (HTGR) to support the goal of meeting the energy demands of the future in an efficient, safe and more economic and environmentally acceptable manner than the present methods of energy production and utilization. The international status and planning associated with development of the HTGR for the production of electricity and utilization in achieving a wide range of process heat applications is examined herein as an advanced source of energy for the twenty-first century.

1.2. THE MODULAR HTGR

The modular HTGR is expected to achieve the goals of being a safe, efficient, environmentally acceptable and economic high temperature energy source for the generation of electricity and for industrial process heat applications such as the production of hydrogen. All HTGRs incorporate graphite moderated, helium cooled cores with ceramic coated fuel

[1] EIA Reference Projection for 1997-2000 = 2%/a

particles capable of handling temperatures of 1,600°C. The most current HTGR designs are capable of continuous operation at average core helium outlet temperatures between 900° and 950°C.

Among the HTGR advances currently under investigation by Member States of the IAEA's International Working Group on Gas Cooled Reactors (IWGGCR) is the closed cycle gas turbine concept which (through the Brayton Cycle configuration) exhibits the capability of achieving net plant efficiencies in the range of 47% at 850°C core outlet/gas turbine inlet temperature. In the area of high temperature process heat, the HTGR is being considered as the energy source for applications including steam and CO_2 reforming of methane for the production of hydrogen as a fuel and/or its subsequent synthesis to other fuels such as methanol. Utilizing the HTGR as the energy source eliminates the need to burn fossil fuels in order to achieve the heat required for these industrial processes to occur.

1.3. THIS REPORT

This report will include an examination of the international activities with regard to the development of the modular HTGR coupled to a gas turbine. The most significant of these gas turbine programmes include the Pebble Bed Modular Reactor (PBMR) being designed by ESKOM of South Africa and British Nuclear Fuels plc. (BNFL) of the United Kingdom, and the Gas Turbine-Modular Helium Reactor (GT-MHR) by a consortium of General Atomics of the United States, MINATOM of Russia, Framatome of France and Fuji Electric of Japan. Details of the design, economics and plans for these plants are provided in Chapters 3 and 4, respectively.

Test reactors to evaluate the safety and general performance of the HTGR and to support research and development activities including electricity generation via the gas turbine and validation of high temperature process heat applications are being commissioned in Japan and China. Construction of the High Temperature Engineering Test Reactor (HTTR) by the Japan Atomic Energy Research Institute (JAERI) at its Oarai Research Establishment has been completed with the plant currently in the low power physics testing phase of commissioning. Construction of the High Temperature Reactor (HTR-10) by Institute of Nuclear Energy Technology (INET) in Beijing, China, is nearly complete with initial criticality expected in 2000. Chapter 5 provides a discussion of purpose, status and testing programmes for these two plants.

In addition to the activities related to the above mentioned plants, Member States of the IWGGCR continue to support research associated with HTGR safety and performance as well as development of alternative designs for commercial applications. These activities are being addressed by national energy institutes and, in some projects, private industry, within China, France, Germany, Indonesia, Japan, the Netherlands, Russia, South Africa, United Kingdom and the United States. Chapter 6 includes details associated with these R&D programmes. Also, support of specific HTGR related research projects is included in the European Union's Fifth Framework Program beginning in 2000. Further opportunities and capabilities of the HTGR in the development of co-generation and non-electric applications are presented in Chapter 7.

Spent fuel disposal and decommissioning are key issues that are significantly influencing the future of nuclear power. Chapter 8 addresses the anticipated manner of handling these areas within the PBMR and GT-MHR. Also addressed are the activities associated with spent fuel disposal and decommissioning of HTGRs previously shutdown.

The development and commissioning of any new nuclear plant concept is subject to risks and challenges to its commercialization. This is also evident in the closed cycle gas turbine, particularly with regard to the design and development of the power conversion system (PCS). The GT-MHR and the PBMR (as well as many other designs under consideration) incorporate state-of-the-art components in their PCS that must operate safely and efficiently for this concept to succeed. These components include magnetic bearings on the rotating machines, large compact plate-fin recuperator modules and seals between PCS components that have size, orientation or environmental operating characteristics yet to be fully demonstrated and proven. These challenges to the commercialization of the GT-MHR and PBMR are discussed in Chapter 9.

The IAEA is advised on its activities in development and application of gas cooled reactors by the IWGGCR which is a committee of leaders in national programmes in this technology. The IWGGCR meets periodically to serve as a global forum for information exchange and progress reports on the national programmes, to identify areas of collaboration and to advise the IAEA on its programme [1-2]. Countries with representation in the IWGGCR include Austria, China, France, Germany, Indonesia, Italy, Japan, the Netherlands, Poland, Russia, South Africa, Switzerland, the United Kingdom and the United States of America. Representation from international organizations includes the European Commission and the OECD-NEA. Activities of the IAEA in support of HTGR technology development are presented in Chapter 10.

REFERENCES TO CHAPTER 1

[1-1] VERFONDERN, K. (Ed), INTERNATIONAL ATOMIC ENERGY AGENCY, Hydrogen as an Energy Carrier and Its Production by Nuclear Power, IAEA-TECDOC-1085, Vienna (1999).

[1-2] CLEVELAND, J., et al., “The Role of the IAEA in Gas-Cooled Reactor Development and Application”, in “Design and Development of Gas Cooled Reactors with Closed Cycle Gas Turbines”, IAEA-TECDOC-899, Vienna, (1997), 257-270.