2.4 NUCLEAR FISSION

2.4.1 EXISTING PLANT RESEARCH AND DEVELOPMENT

Technology Description

Currently, 103 commercial nuclear power plants generate 20% of U.S. electricity – with about 100 GWe installed capacity – emitting no greenhouse gases (GHGs). Through the Nuclear Energy Plant Optimization (NEPO), DOE is working with the nuclear industry to apply new technology to nuclear and nonnuclear equipment in existing plants, enabling them to produce more electricity by optimizing their operating lifetimes. If not renewed, most current nuclear power plant licenses will expire between 2005 and 2030. If these plants are shut down and replaced with fossil-based generation, CO_2 emissions will *increase* by more than 160 million metric tons carbon per year (MMTC/yr) by 2030 (assuming 208 gC/kWh). Extending the lifetimes and optimizing the generation of these plants for 20 more years will avoid more than 3,200 MMTC through several years beyond 2050.

The goal of this area of R&D is to increase the efficiency, reliability, and power generation of existing nuclear power plants; and to help make the economic and clean air benefits of the plants available through current and renewed license terms. In 2003, 16 nuclear units have received approval to extend their operating licenses to 60 years; 34 others have filed or announced their intent to file for license extensions; and most, or all, of the remaining plants are expected to follow suit.

System Concepts

- Improve availability and maintainability of nuclear plants.
- Provide technology to predict and measure the extent of materials damage from plant aging.
- Operate plants at higher power levels, based on more accurate measurement and knowledge of safety margins, reduced consumption of onsite electrical power, and power uprates.

Representative Technologies

- Prediction and monitoring of stress-corrosion cracking of reactor internals and steam generators, materials-cladding processes.
- Advanced technologies for online condition monitoring of conventional equipment (pumps, motors, valves, etc.) to minimize production losses from unplanned outages.
- Replacement of aging, hard-to-maintain safety system instrumentation with easy-to-maintain advanced, digital electronics.
- Materials measurement and diagnostic technologies to determine the condition and fitness of aged materials.
- Advanced core loading strategies; nuclear fuel and cladding research.
- Advanced power generation technologies to increase electrical output.

Technology Status/Applications

- Current technology does not adequately determine residual life; overly conservative margins may result in premature shutdown or refurbishment.
- Replacing major components (e.g., steam generators) may be prohibitively expensive; better techniques are needed.
- Some in-service valve testing technology is in place, but current technology fails to efficiently detect a significant number of failures.
- Technology development for condition monitoring is required for application to nuclear plants.
- Technology advances are needed to achieve future extended power uprates.

Current Research, Development, and Demonstration

RD&D Goals

- Increase electrical generation capability from existing plants by achieving continued improvement in average industry capacity factors and developing break-through technologies for long-term operation.
- Address the long-term effects of component aging; optimize efficiency; and improve plant reliability, availability, and productivity while maintaining high levels of safety.

RD&D Challenges

- Development and demonstration of new technologies to allow future extended power uprates.
- Complete the DOE/nuclear industry R&D program for research on existing nuclear plant life extension and generation optimization technologies.

RD&D Activities

- The department and the electric utility industry's Electric Power Research Institute (EPRI) developed the *Joint DOE-EPRI Strategic Research and Development Plan to Optimize U.S. Nuclear Power Plants* to help the Federal government and private sector jointly identify, prioritize, and execute R&D. The plan, first issuec in March 1998 and later updated in October 2000, is based on input from utilities, DOE national laboratories, the Nuclear Regulatory Commission (NRC), and other key stakeholders. Research funded under the NEPO program is consistent with this joint strategic plan.
- A previous cooperative research and development agreement between DOE's Office of Nuclear Energy, Science, and Technology; and the Electric Power Research Institute started development of advanced electronics to replace Westinghouse safety-system components.
- Activities to improve monitoring of the condition of nuclear power plants are supported by DOE's Offices of Nuclear Energy, Science, and Technology; and the Nuclear Regulatory Commission.
- Advanced technologies are being applied to existing light water reactors and aging research, funded by DOE.

Recent Progress

- An initial industry decision was made to commercialize DOE electronics technology for replacing Westinghouse safety system components.
- Nonintrusive evaluation of pressurized water reactor accumulator discharge check valves has reduced testing time and improved reliability.
- Hydrogen water chemistry is used in boiling water reactors to control stress-corrosion cracking.
- Electrical cable condition monitoring and aging management techniques.

Commercialization and Deployment Activities

- The NEPO program has made significant progress toward addressing many of the material aging and generation optimization issues that have been identified as the key long-term issues facing current operating plants. Examples of recent results from the NEPO program include the development of new electrical cable monitoring techniques for improved prediction of cable lifetimes; and the development of techniques to qualify smart transmitters to replace existing analog transmitters, which are less accurate and are difficult to maintain.
- Advanced diagnostic techniques are gaining wider acceptance for evaluating the status of safety-related equipment.
- Successful technology may not be sufficient to extend the life of all plants if adverse regulatory or economic factors dominate.
- DOE/industry Sustainable Electric Partnership Agreement provides a basis for DOE/industry cooperation and ensures commercial deployment.
- DOE/industry NEPO program partnership provides another basis to ensure commercial deployment of R&D successes.

Market Context

- Technologies to support improved operations and life extension have enhanced the economics of existing nuclear power plants and thus increased their market value.