—Summary—

GENERATION IV ROADMAP: FUEL CYCLES

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INTRODUCTION

The Generation IV roadmap project (Bennett 2001), which was initiated by the U.S. Department of Energy, January 2000, is developing into an international effort to identify research and development (R&D) pathways for the most promising future nuclear concepts. Four teams are evaluating different reactor concepts: water cooled, gas cooled, metal cooled, and nonclassical. In addition, because of the important fuel cycle issues common to all nuclear reactors, a fuel cycle crosscut group (FCCG) was organized. The FCCG has 13 members, 5 of which are from outside the United States. The group has the responsibility of reviewing energy demand forecasts for the 21st century; developing the characteristics of fuel cycles (such as fuel requirements, waste arisings, necessary R&D, and infrastructure) for comparisons; and identifying common fuel cycle issues.

CONCEPTUAL FUEL CYCLES

A conceptual framework is being developed that can include all potential fuel cycles (Fig. 1). The fuel cycle, from a global perspective, consumes (1) natural resources and (2) labor and capital to produce electricity. Various wastes are generated as a consequence of these actions. The Generation IV goals of sustainability, safety and reliability, and economics require consideration of the entire fuel cycle. A particular fuel cycle may excel in one area but be unacceptable because of deficiencies in other areas.

Natural resources include fuels (uranium and thorium), materials of construction, and renewable resources (such as water for cooling purposes). Wastes may include mill tailings, depleted uranium, spent nuclear fuel (SNF), high-level waste, other radioactive wastes, releases to the environment (air and water), and non-nuclear wastes.

Allowable rates of resource consumption and waste generation depend on multiple factors. Fuel cycles that do not efficiently use natural resources may not be sustainable because of ultimate limits on economically recoverable resources. Similarly, limits may exist on waste. For example, as the number of nuclear power plants increase, it may be necessary to reduce the releases per facility. In addition to the technical health-based limits on allowable releases and waste quantities, social and institutional restrictions may exist as well.

Four generic fuel cycles, that cover the spectrum of feasible technologies for conversion of ore resources to energy have been defined (Fig. 2).

- *Once through*. The fuel is fabricated from uranium and thorium, irradiated, and directly disposed of as a waste.

- *Partial recycle*. Some fraction of the SNF is processed, the fissile material is recycled, and new fuel is fabricated. An example is the French reprocessing system, in which (1) low-enriched-uranium SNF is reprocessed and recycled back to the reactors and (2) the resultant mixed oxide SNF may be directly disposed of.

- *Full recycle*. All SNF is reprocessed for recovery and recycle of plutonium and ^{233}U. An example is the traditional Liquid Metal Fast Breeder Reactor fuel cycle. In this type of system, minor actinides are sent to the waste stream.

- *All-actinide recycle*. All SNF is reprocessed, and all actinides are recycled. One or more fission products (^{99}Tc and ^{129}I) may be recycled as well. Only fission products and trace quantities of actinides become wastes.

The four types of fuel cycles have common facilities—those for mining (uranium and/or thorium), milling (purification of uranium and/or thorium), and fuel fabrication—as well as power reactors and the repository. Some fuel cycles include isotopic separation facilities, reprocessing facilities to recover selected elements from SNF, and special facilities to burn minor actinides.

PATH FORWARD

Based on the approach defined above, an initial report comparing fuel cycles for different Generation IV reactor concepts and identifying common fuel cycle issues (mining, repositories, etc.) will be issued late this year.

REFERENCES

R. Bennett, H. Khalil, R. Versluis, J. Kotek, J. Ryskamp and G. Fiorini, “The Generation IV Roadmap Project,” *American Nuclear Society Annual Meeting, Reno, Nevada* (November 2001).

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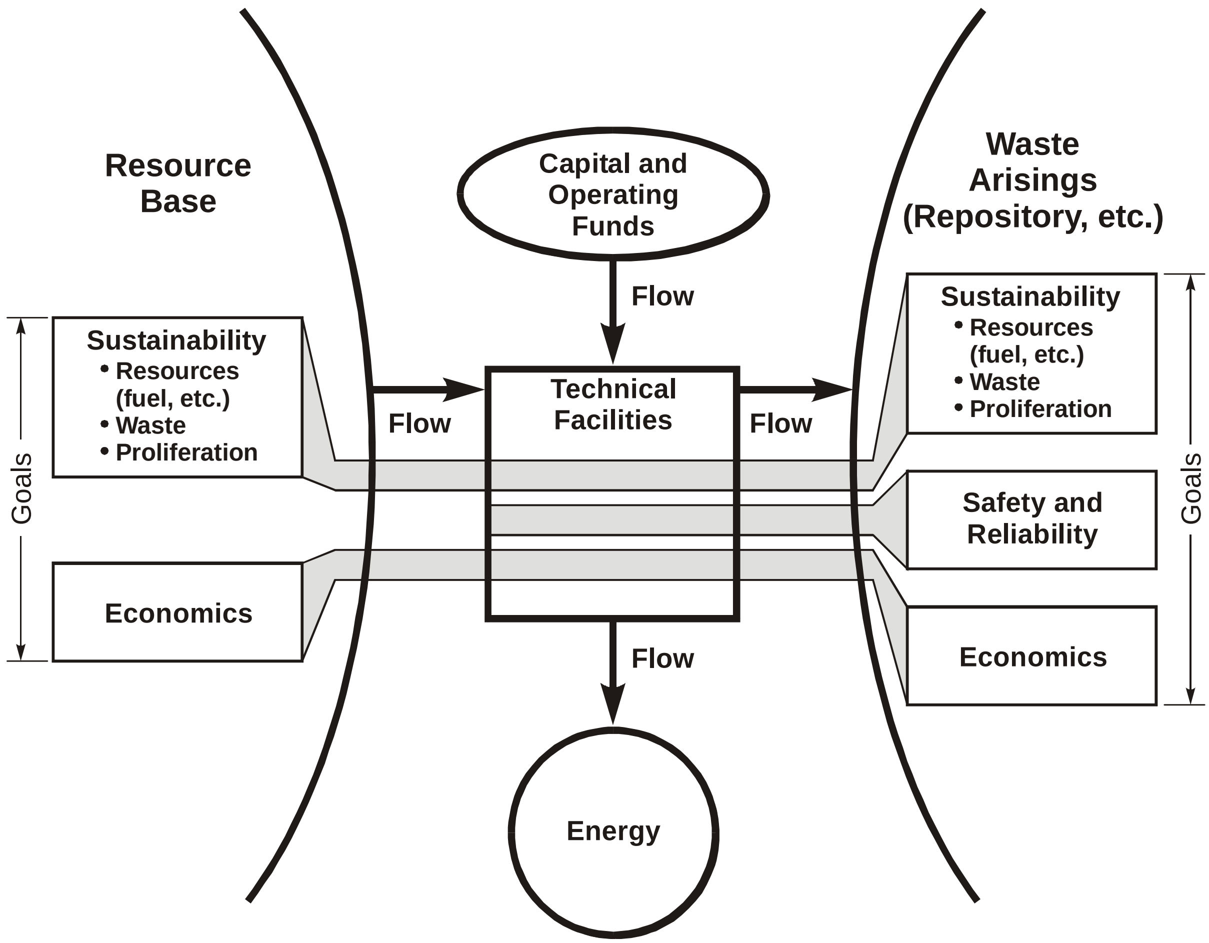

Fig. 1. The Fuel Cycle in the Abstract.

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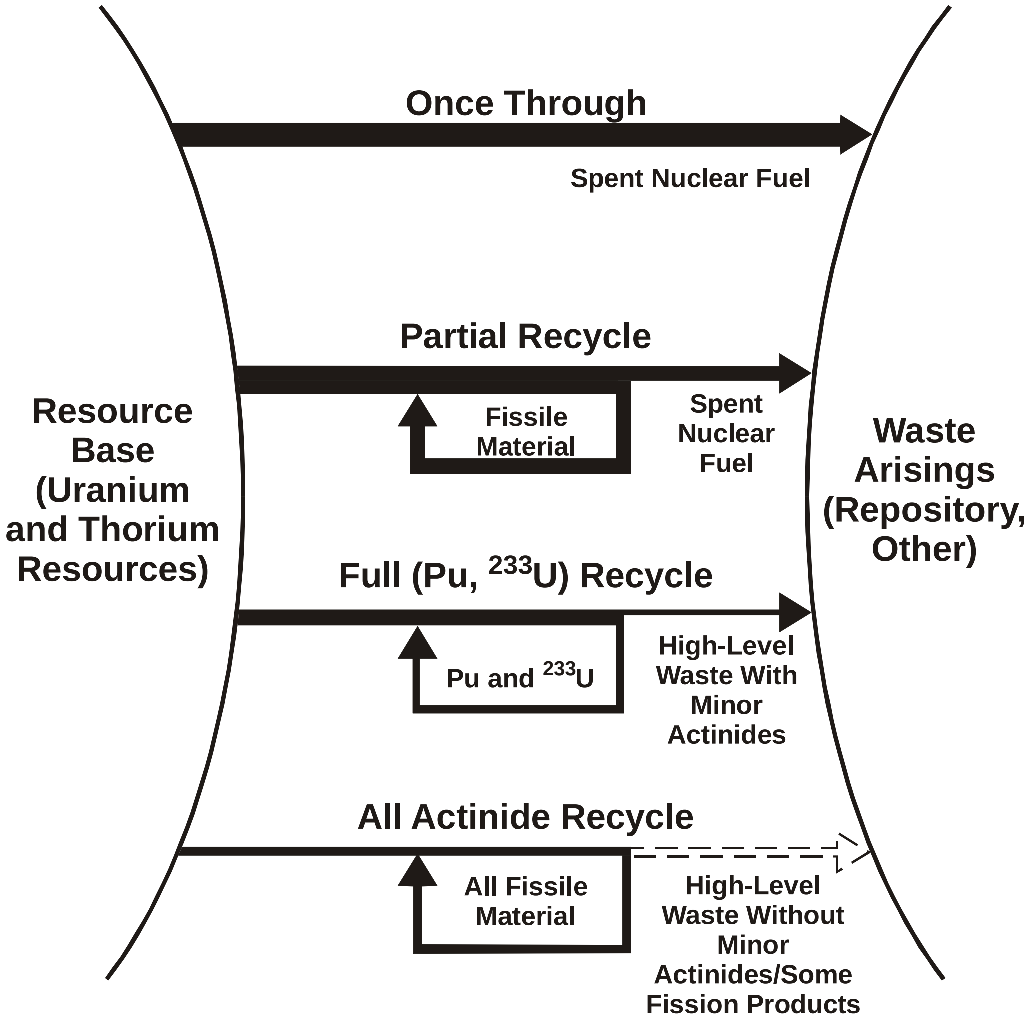

Fig. 2. Alternative Fuel Cycles.