2.11 Fuel cycle variations

To conclude the discussion of nuclear fuel cycles, it is appropriate to reprise the variations in the fuel cycle represented by the present family of nuclear power generating reactors. The basic fuel cycle for a light water reactor (LWR) (see section 4.3.1) is depicted in figure 1 but without the dashed line indicating plutonium recycling. As described above, the basic cycle begins with enriched uranium ($3.5 - 5\%$ ^{235}U as compared to the 0.71% in natural uranium). The depleted uranium from the fuel preparation process contains about 0.2% ^{235}U. Spent fuel removed from the reactor contains about 0.8% ^{235}U and the fission products described previously, as well as plutonium. As indicated by the dashed line in figure 1, the plutonium can be recycled and used again in a fuel in which it is mixed with uranium that might typically only need to be enriched to about 2.0% ^{235}U. Such a *mixed oxide fuel* (MOX) consisting of UO_2 and PuO_2 needs to be carefully adjusted to have the desired neutronic activity.

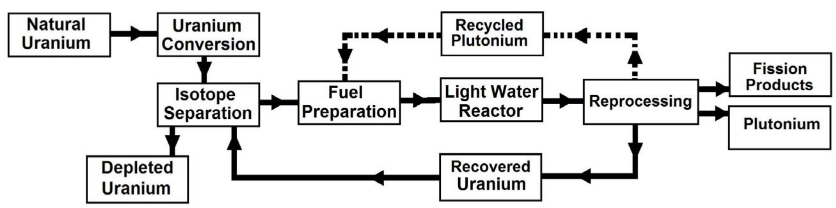

Figure 1: The conventional light water reactor (LWR) fuel cycle (solid line) with plutonium recycling (dashed line) and without (no dashed line).

As a second example, note the very different fuel cycle for the high temperature gas reactor, HTGR (see section 4.6), depicted in figure 2 that utilizes thorium as the primary fertile material. This is mixed with highly enriched uranium (93% ^{235}U) to provide the necessary neutron activity. In the reactor the thorium produces ^{233}U that can then be recycled in mixed fuel, MOX.

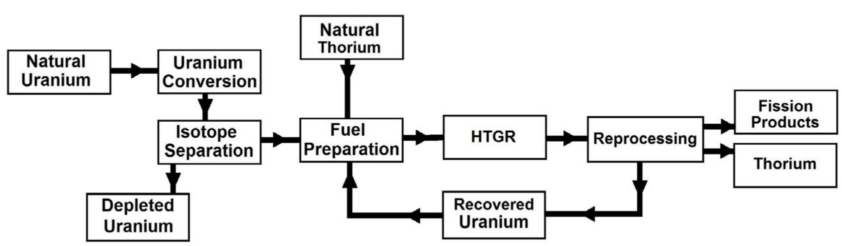

Figure 2: The Thorium fuel cycle for the high temperature gas reactor (HGTR).

As a third example, the fuel cycle for a typical liquid metal fast breeder reactor, LMFBR, (see section 4.8) is shown in figure 3. This may be fueled with

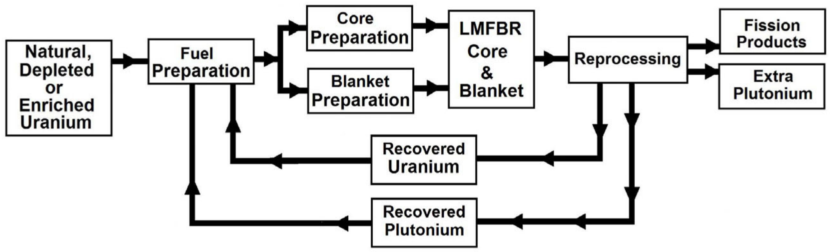

Figure 3: The liquid metal fast breeder reactor (LMFBR) fuel cycle.

a mix of natural, depleted (recycled) or enriched uranium as well as recycled plutonium. As described in sections 4.7 and 4.8, the driver core of an LMFBR is surrounded by a blanket in which natural uranium produces plutonium that can later be recycled in new fuel. This recycling of plutonium (as well as uranium) makes much more thorough and efficient use of the basic uranium fuel and therefore not only extends the potential use of the natural uranium resource but also reduces the cost of the power produced.

Finally it should be noted that there is significant potential for interactions between the various fuel cycles. These interactions allow for increased efficiency in the utilization of the limited natural resources and also allow improved cost effectiveness. Moreover, the potential for the development of improved fuel cycles in the future means that temporary or retrievable storage of nuclear waste may be the optimum strategy.