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New Program Proposal for Fiscal Year 2011 – Modified Open Cycle

Carter "Buzz" Savage

Nuclear Energy Advisory Committee Meeting

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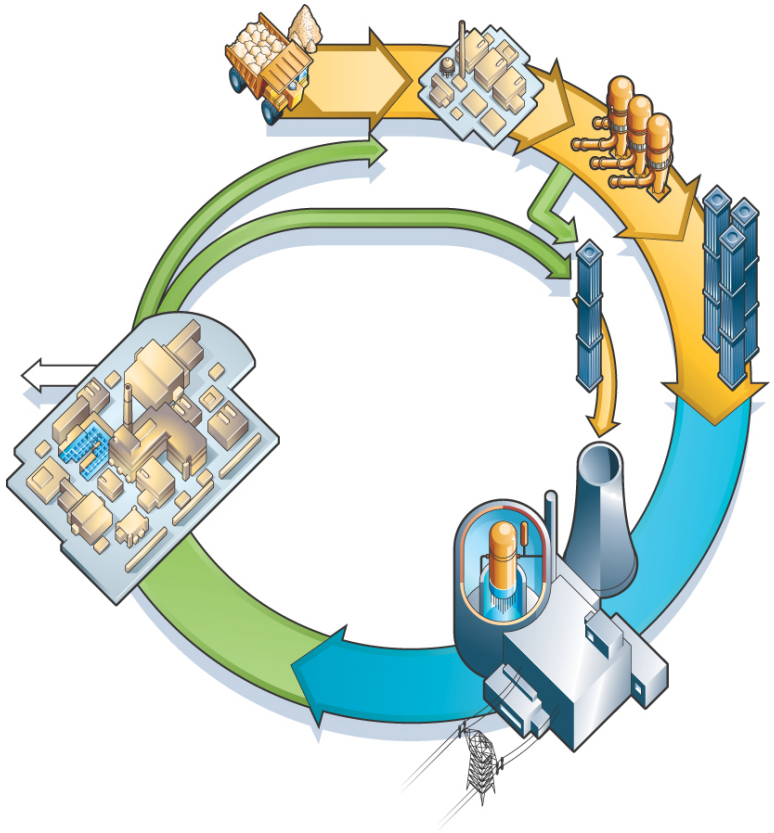
Recycle of Used Fuel

- **Option to recycle used fuel has been the subject of much debate and discussion.**
- **Nonproliferation issues and economics have limited recycle options.**
- **Recycle of used fuel enables increased utilization of uranium resource and potential waste management benefits.**
  - Once through fuel cycle uses less than 1% of energy value of the uranium.



Courtesy AREVA

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Summary of Fuel Cycle Options

- **Once-Through Fuel Cycle – One pass through reactor, used fuel directly disposed in a geologic repository.**
- **Modified Open Cycle – No or limited separations steps and processing applied to used fuel to extract more energy.**
  - ***Spent*** fuel and high-level waste disposed instead of ***used*** fuel.
- **Full Recycle – Only elements considered to be waste are discarded and useful elements are recycled to more fully utilize resources.**
  - High-level waste disposed instead of untreated used fuel.

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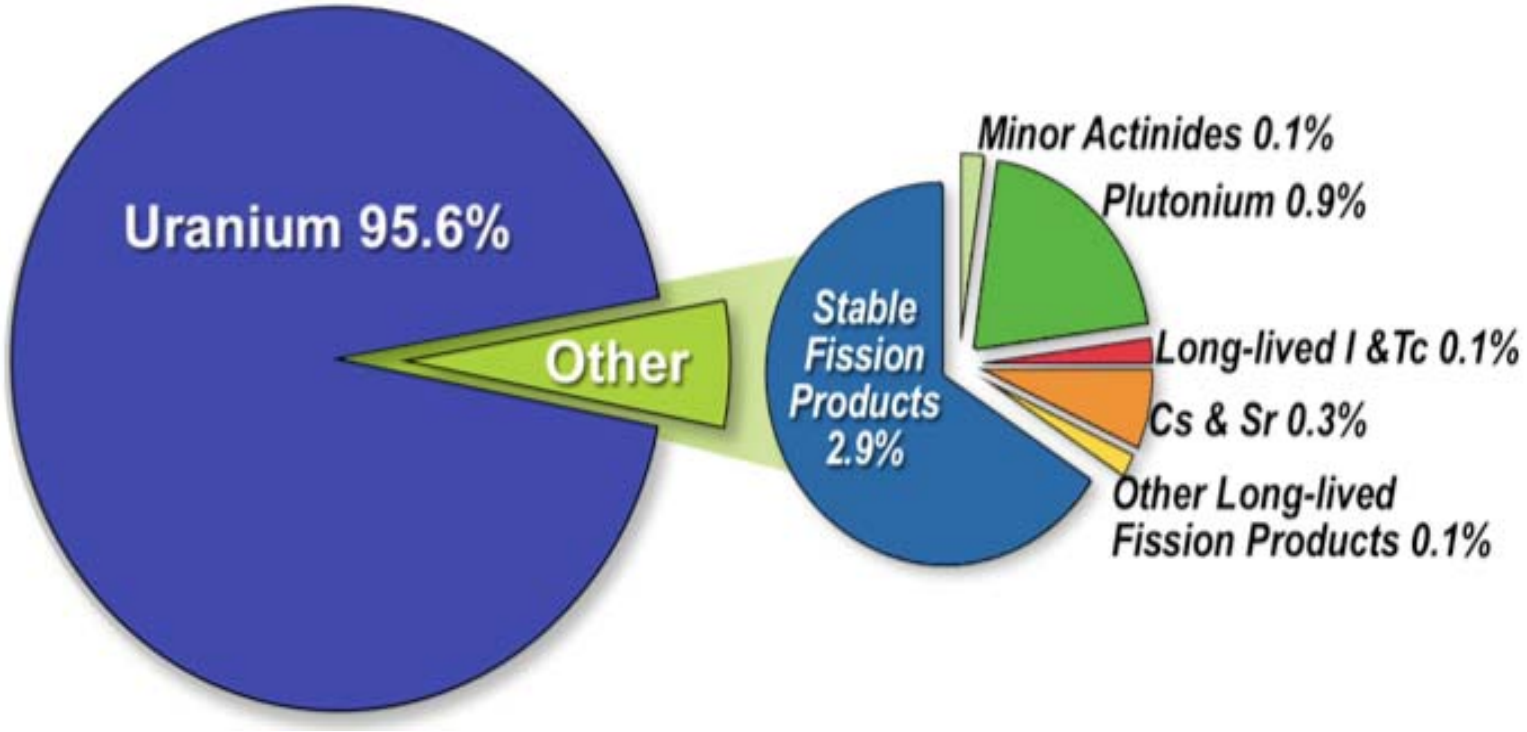
Constituents of Used Light Water Reactor Nuclear Fuel (by mass)



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Descriptions from NE R&D Roadmap to Congress

DOE will conduct R&D to investigate technical challenges involved with three potential strategies for used fuel management:

- **Once-Through** – Develop fuels for use in reactors that would increase the efficient use of uranium resources and reduce the amount of used fuel requiring direct disposal for each megawatt-hour (MWh) of electricity produced. Additionally, evaluate the inclusion of non-uranium materials (e.g., thorium) as reactor fuel options that may reduce the long-lived radiotoxic elements in the used fuel that would go into a repository.
- **Modified Open Cycle** – Investigate fuel forms and reactors that would increase fuel resource utilization and reduce the quantity of long-lived radiotoxic elements in the used fuel to be disposed (per MWh), with limited separations steps using technologies that substantially lower proliferation risk.
- **Full Recycling** – Develop techniques that will enable the long-lived actinide elements to be repeatedly recycled rather than disposed. The ultimate goal is to develop a cost-effective and low proliferation risk approach that would dramatically decrease the long-term danger posed by the waste, reducing uncertainties associated with its disposal.

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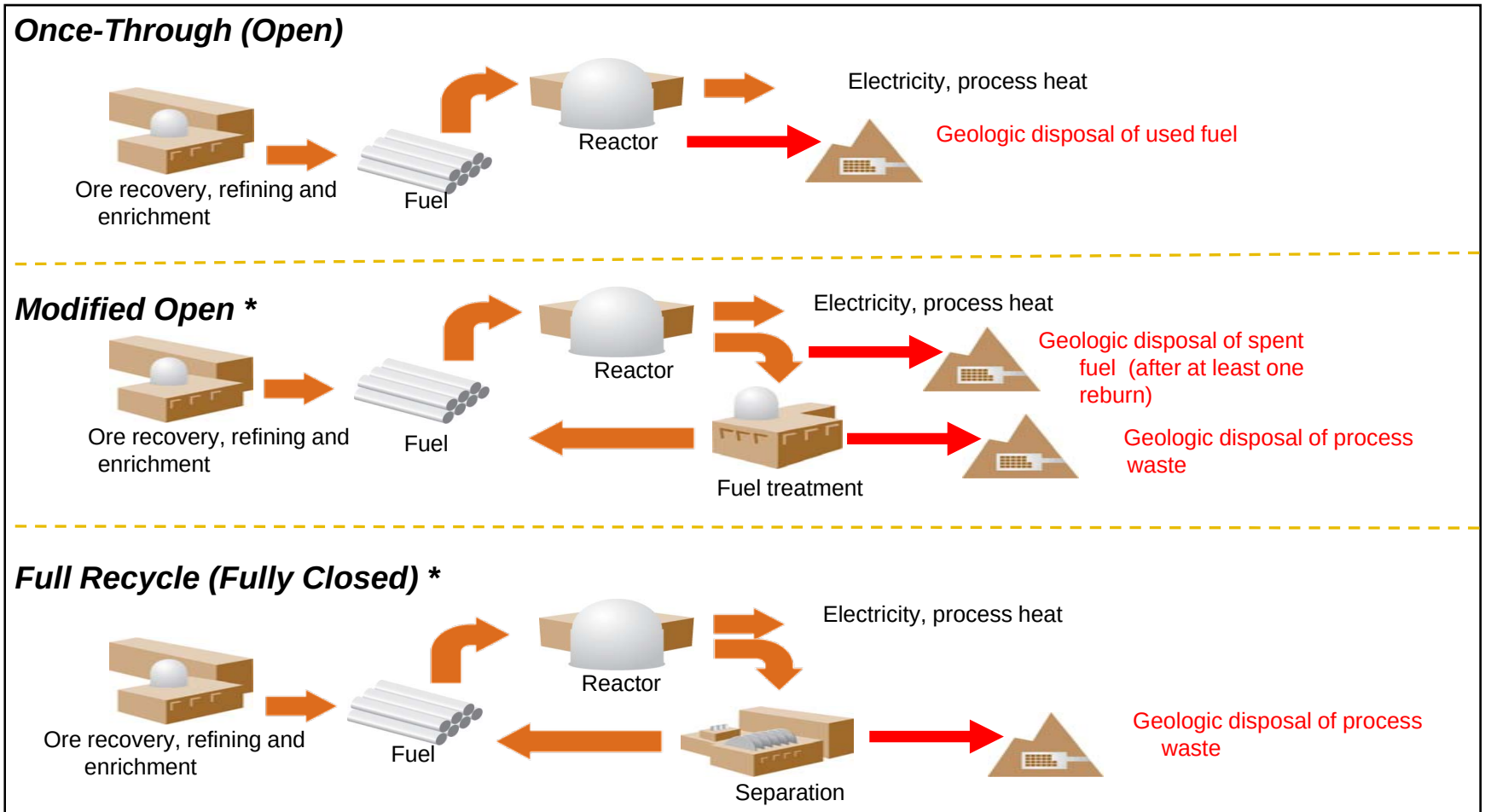
Three Potential Fuel Cycle Options



*A specific fuel cycle strategy may include more than one fuel design, reactor design, or fuel treatment process.

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Fuel Cycle Options Details

- **Once-Through**
  - No recycling or conditioning of used fuel
  - Low uranium utilization
  - Appropriate for a low price uranium future
  - Appropriate when repository capacity and/or actinide loadings are not show stoppers
- **Modified Open Cycle**
  - Limited used fuel conditioning or reprocessing (e.g., recladding) steps
  - Higher uranium utilization and burnup (i.e., used fuel is spent fuel)
  - Appropriate for a high price uranium future
  - Appropriate when major constraint is on repository capacity (e.g., heat loading, geologic media)
  - Appropriate when actinide loading is not a show stopper
- **Full Recycle**
  - Multiple reprocessing and recycle steps resulting in transmutation of most actinides
  - “Complete” uranium utilization (with breeder)
  - Appropriate for a high price uranium future
  - Appropriate when repository capacity and/or actinide loadings are show stoppers

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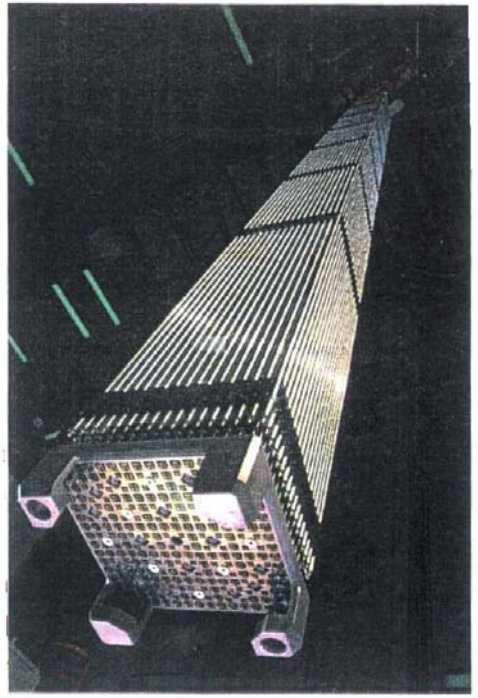
Once Through Fuel Cycle

- **With once-through, used nuclear fuel from commercial reactors is disposed in a repository.**
- **Uranium utilization is less than 1%.**
- **Fuel burnups have increased through the years.**
- **Higher burnups would result in less used fuel disposed but would not increase uranium utilization.**
- **LWR and Fuel Cycle R&D Programs pursuing advanced fuel designs that may double fuel burnups (100 GW/MTHM).**
  - Fuels may required enrichments higher than 5%.
- **Higher burnups result in less used fuel disposed but similar amounts of actual waste (transuranics and fission products).**



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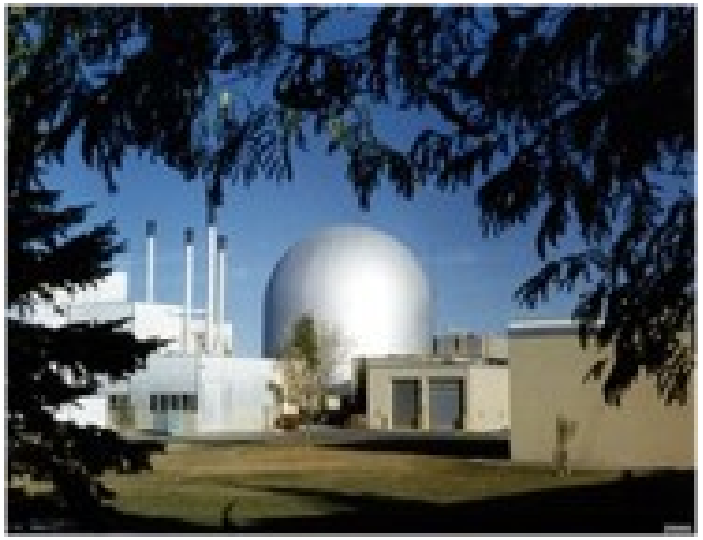
Full Recycle

- **With completely closed fuel cycles, only high-level waste forms are disposed in a repository.**
- **Recycle of plutonium to LWRs as MOX increases uranium utilization, but only slightly**
- **Recycling fissile in fast reactors combined with breeding in depleted and recycled uranium can enable uranium utilization to approach 99%.**



EBR-II Fast Reactor - Idaho

- **Aqueous, dry and new, innovative separations technologies are being considered for used fuel separations.**
  - Ex: Alkaline dissolution and separation, ionic liquid extraction, super critical fluid extraction, uranium crystallization, volatility approaches (airox, deox, fluoride volatility), zone refining
- **Metal, oxide and other fuels are being considered for fast reactors**.

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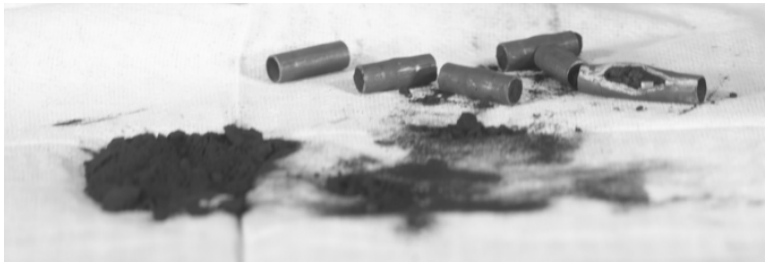
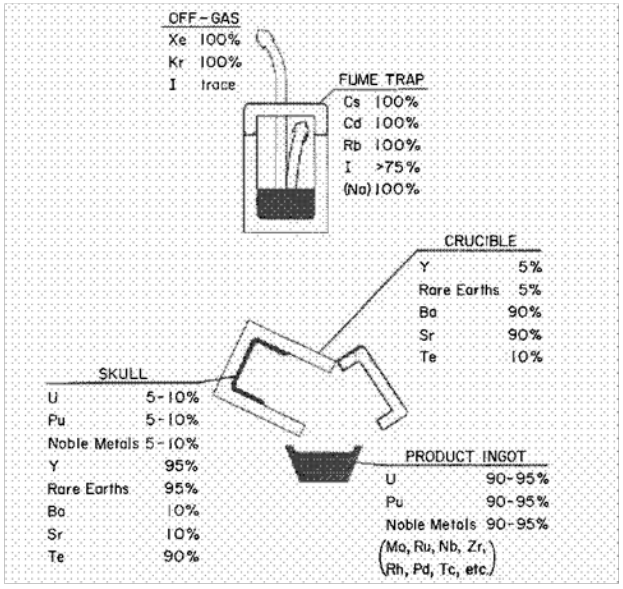
Modified Open Cycle

- Modified open cycles can provide benefits of both Open and Full Recycle fuel cycles.
- Modified open cycles involve reuse of fuel which may require some form of treatment.
- Treatment means modification of the used fuel.
- This could be as simple as heat treating the used fuel cladding or as complex as chemical processing and recladding the fuel.
- Some separations processes employed for full recycle may be used for the modified open cycle.





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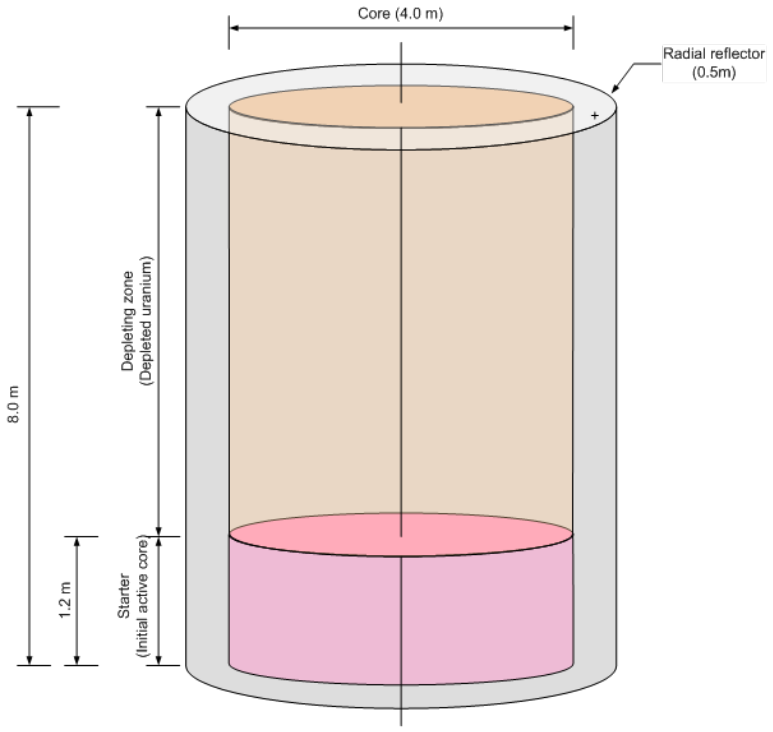
Modified Open Cycle Example Concepts

- Breed and burn recycle reactor concepts (including the traveling wave designs)
- Deep burn of recycled transuranics in high-temperature gas reactors (requires fuel processing)
- Deep burn of recycled transuranics in inert matrix fuels
- DUPIC process for recycle of LWR fuel into CANDU reactors with thermal treatment of used fuel
- Fission-fusion systems
- Accelerator driven systems



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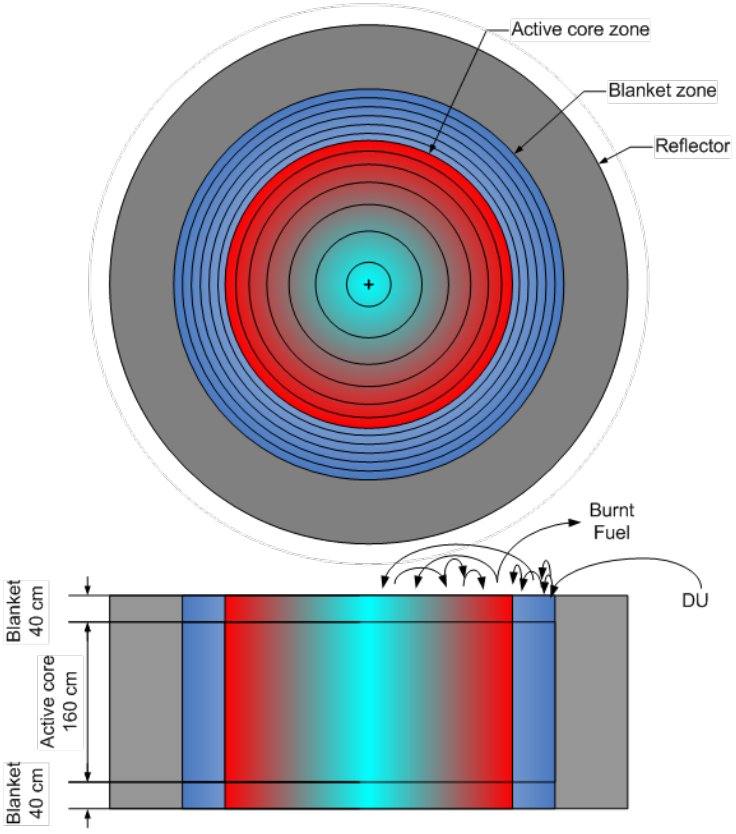
Modified Open Cycle Research Needs

- **Modified open cycles can be made possible by**
  - Design of systems that utilize novel physics concepts
  - Development of fuel forms that accommodate much higher exposure
  - Development of fuel conditioning processes that avoid complex chemical operations.
- **To support deployment of preferred fuel cycle option by 2050, research and development discovery phase for modified open cycles must be completed in approximately 10 years.**
- **A focused effort will be needed to meet this time frame.**



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Fiscal Year 2011 Budget Request for Modified Open Cycle Research

- **FY 2011 DOE Budget Request included $40M for research into Modified Open Cycles as part of DOE's Fuel Cycle R&D Program.**
  - The modified open cycle has not been studied as thoroughly as the other two fuel cycle strategy options and that is why it is being singled out as a new technical area for FY 2011

- **Tentative allocation of FY11 funding to specific Modified Open Cycle R&D areas:**
  - ***55% to Fuels***
  - ***30% to Separations and Waste Forms***
  - ***20% to System Studies (Concept Definition and Analyses)***

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Examples of Modified Open Cycle R&D Proposed for FY11

- ***Fuels Research:*** Identify novel fuel forms, ultra-high burnup fuels, thorium-based fuels, deep burn of transuranic-bearing TRISO fuels

- ***Separations and Waste Forms Research*:** Initiate the exploration of limited treatment of used fuel to add more fuel material to the used fuel, remove wastes from the fuel that inhibit the nuclear reactions, and repair or replace the cladding that contains the fuel.

- ***System Studies:***
  - Initiate systems engineering approach to define, establish requirements for, and evaluate modified open fuel cycle options.
  - Initiate systems analyses to provide needed information on such topics as transuranic management, separations and partitioning efficiency, fission product behavior, materials reuse, transmutation approaches of modified open fuel cycle systems and cost-benefit analyses.

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Summary

- ***Once-Through, Modified Open, and Full Recycle*** **fuel cycle options are proposed to be examined in FY2011.**
- **Special emphasis is being placed on Modified Open Cycle concepts, since they have not received as much attention.**
- **Modified Open Cycles provide an alternative approach for increased resource utilization, reduced waste hazard, and low proliferation risk.**
- **FY2011 DOE Budget Request includes $40M for fuels, separations and waste forms, and system concept studies related to modified open cycles.**