TVA's Consideration of the Use of MOX to Fuel its Nuclear Reactors

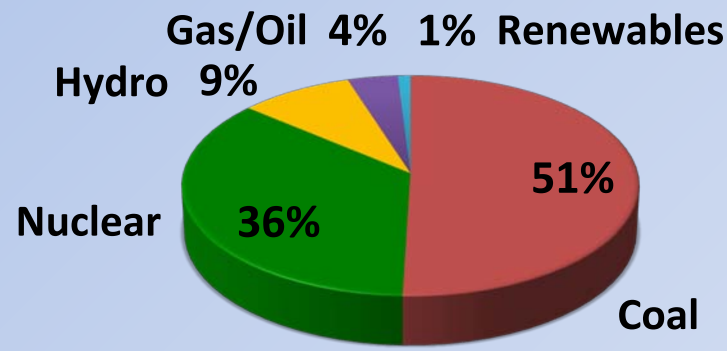
Dan Stout

September 14, 2011

Outline

- Overview of TVA
- Evaluation of MOX
  - Comparison of MOX with UOX
  - DOE's surplus plutonium disposition program
  - Supplemental Environmental Impact Statement
  - Plant modifications
  - Decay heat comparison between MOX and UOX
- Preliminary conclusions
- Summary

Tennessee Valley Authority



FY2010 Generation

Public power provider

- 7-state region
- 80,000 square miles
- 9 million people
- 650,000 businesses
- 155 distributors
- 57 direct-served customers

TVA Vision

One of the Nation's Leading providers of low-cost and cleaner energy by 2020

Low Rates

Cleaner Air

High Reliability

More Nuclear Production

Responsibility

Greater Energy Efficiency

TVA's Unique History

- For more than seven decades, TVA has provided:
  - Affordable electric power
  - Environmental stewardship
  - Economic development opportunities
- Support to national security missions is in TVA's charter:
  - Fertilizer/munitions support
  - Built power plants to provide electricity to the Manhattan Project (Oak Ridge Reservation)
  - Providing irradiation services to DOE to provide tritium which helps ensure the Nation's nuclear deterrence
  - Participating in DOE's non-proliferation efforts through the use of fuel made from blended-down highly-enriched uranium
- TVA can and has performed Department of Energy missions in a manner consistent with other TVA objectives

Nuclear Fuel

- Commercial reactor fuel starts as uranium oxide (UOX)
- Plutonium is a normal byproduct of the uranium fission process in all commercial nuclear reactors
  - ✓ Plutonium builds up in fuel pellets and eventually produces ~40% of the core's heat energy
  - ✓ Fission of plutonium produces more than 50% of the energy at the end of life of the fuel (4-6 years)
- Mixed-oxide (MOX) fuel is a mixture of plutonium and uranium oxides fabricated into fuel and loaded into a reactor in lieu of some UOX fuel
- Fuel form (ceramic pellet) and hardware are the same for both UOX and MOX fuel

Isotopic Differences in UOX and MOX Fuel

Isotope	Fresh UOX Fuel	Spent UOX Fuel	Recycled reactor MOX	Weapons MOX
U-238	96%	93%	91%	95%
U-235	4%	1%	<1%	<1%
Fission products	0%	5%	0%	0%
Avg assembly Pu	0%	1%	9%	4.3%
Pu-238	0%	1%	1%	0%
Pu-239	0%	57%	57%	94%
Pu-240	0%	27%	27%	5%
Pu-241	0%	8%	8%	<1%
Pu-242	0%	7%	7%	<<1%

Recycled reactor fuel MOX is used in 30 reactors world-wide, weapons MOX was tested in Catawba

DOE's Surplus Plutonium Disposition Program

- U.S. and Russia entered into an agreement in 2000 to each dispose of 34 metric tons of surplus plutonium
- U.S. decided to convert the plutonium into MOX fuel and use it in commercial reactors
- DOE is in the process of building a MOX fuel fabrication facility at the Savannah River Site in South Carolina
- Lead Test Assemblies were successfully built and tested in Duke's Catawba reactor

TVA

TVA's Evaluation of MOX Fuel Use Will be Phased and Involve Public Input

- TVA is in the study phase for potential use of MOX fuel
  - ✓ Assessment of public health and safety
  - ✓ Assessment of required physical changes to reactors
  - ✓ Assessment of operational impacts
  - ✓ Assessment of fuel cost savings relative to uranium fuel
- In order to proceed to the engineering and licensing phase, TVA must conclude:
  - ✓ MOX fuel use in TVA reactors is safe for workers, public and environment
  - ✓ MOX fuel use is beneficial to TVA customers
- **Public input will be sought and factored into decision-making along the way by DOE, TVA and NRC**

Topics/Activities Under Evaluation Include:

- Receiving the MOX fuel
  - ✓ Security
  - ✓ Shipping canister handling
  - ✓ Radiation dose

- Using MOX in the reactor
  - ✓ Physics differences
  - ✓ Behavior during postulated severe accidents
  - ✓ Physical plant modifications
  - ✓ Operating differences

- Storing used MOX fuel in pools and dry casks
  - ✓ Decay heat
  - ✓ Radiation dose

Likely Plant Modifications for MOX Fuel Use

- Security Modifications for Receipt of MOX fuel
  - Security checkpoint changes for receiving MOX fuel shipments
  - Designated holding area for MOX transport vehicles
  - Potential on-site roadway improvements
  - Fuel pool/overhead crane lockout
  - Closed circuit TV surveillance of refuel floor

- Conversion to enriched boric acid in Pressurized Water Reactors
  - Provides improved reactivity control without creating a precipitation problem which could occur in certain accident scenarios if boron concentration is high
  - Physical modifications
    - Enriched Boric Acid (EBA) mixing and batching system
    - EBA feed tanks, transfer pumps and piping and recovery system
    - Installation of a mass spectrometer for isotopic analysis
    - Improved reactor makeup controls
    - Potential post accident sampling system modifications for EBA samples
  - This mod is not necessary, but enables increased core fraction to be MOX

TVA

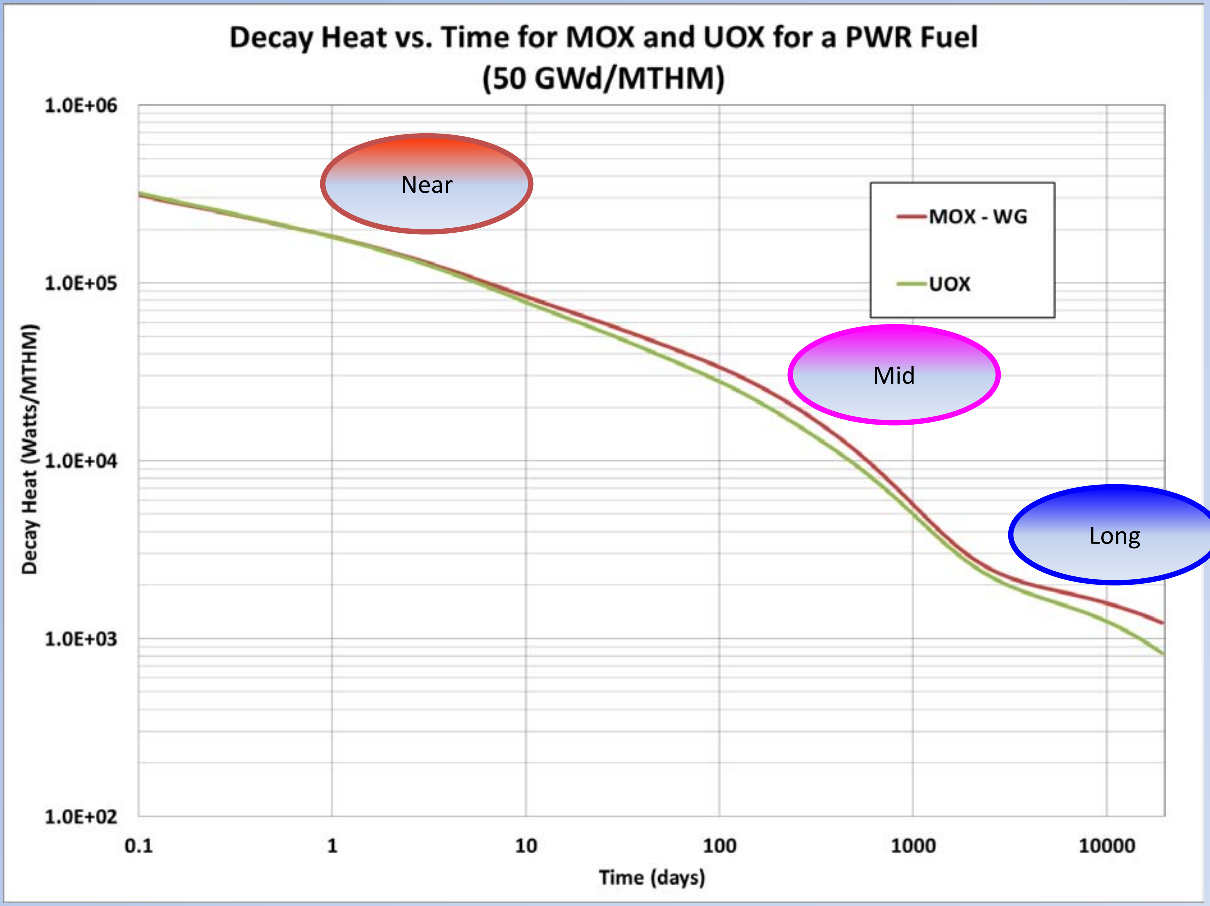
Decay Heat Loads

Time After Discharge (Days)	PWR WMOX at 50 GWD/t (KW/MTHM)	PWR UOX at 50 GWD/t (KW/MTHM)	WMOX/UOX Decay Heat Ratio
0.01	597	615	0.97
1	182	182	1.00
10	83.8	78.0	1.07
100	33.7	27.9	1.20
1,000 (2.74 yr)	5.7	5.1	1.13
10,000 (27.4 yr)	1.6	1.3	1.27

Source: ORNL/TM-2011/290, Decay Heat Calculations for PWR and BWR Assemblies Fueled with Uranium and Plutonium Mixed Oxide Fuel Using SCALE, Brian J. Ade and Ian Gauld

TVA

How does Decay Heat of Used MOX Compare to UOX and Why Does it Matter?



Three Periods of Interest

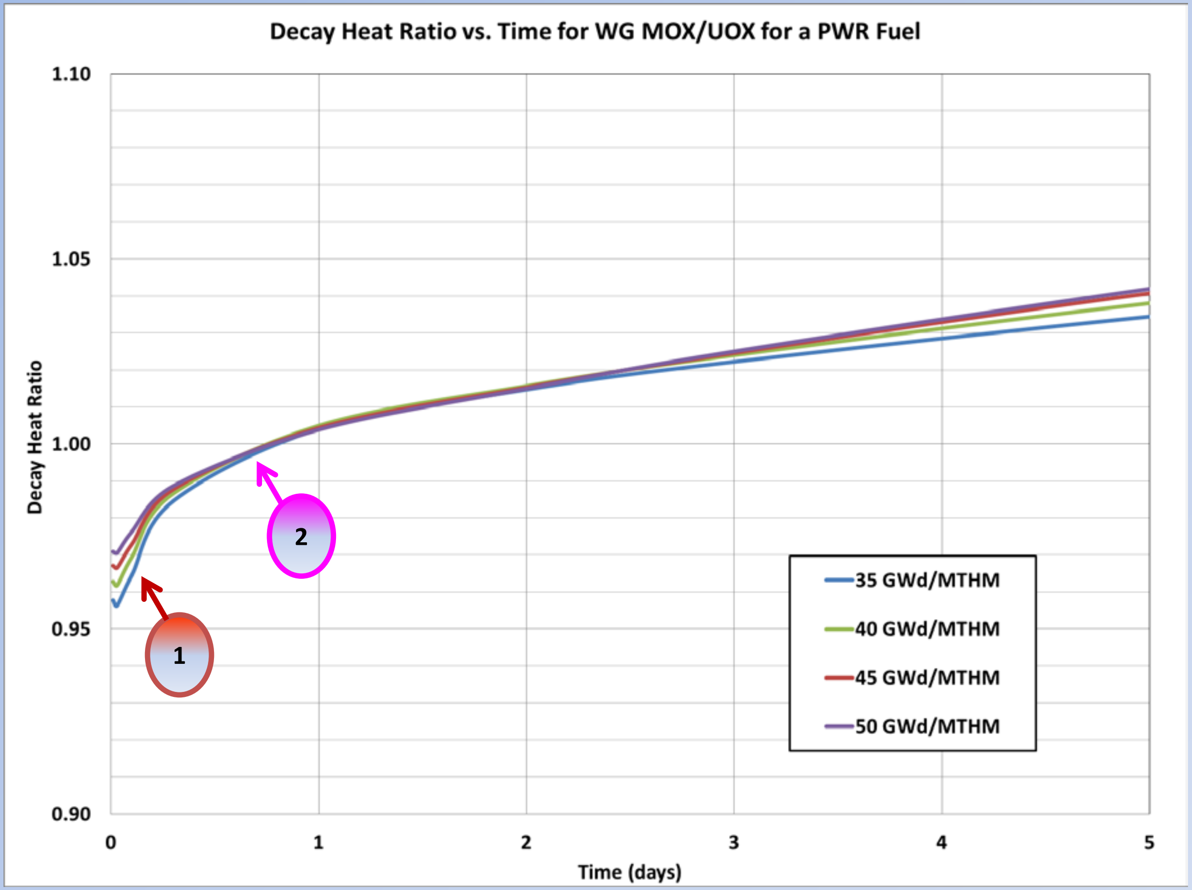
Near term (first few days):
Determines performance in accidents

Mid term (Near 5-year point):
Determines spent fuel pool or dry cask thermal requirements

Long term (30 – 50 years):
Determines geologic repository or dry cask storage thermal requirements

Source: ORNL/TM-2011/290, Decay Heat Calculations for PWR and BWR Assemblies Fueled with Uranium and Plutonium Mixed Oxide Fuel Using SCALE, Brian J. Ade and Ian Gauld

Near-Term: Little Difference



Three Points

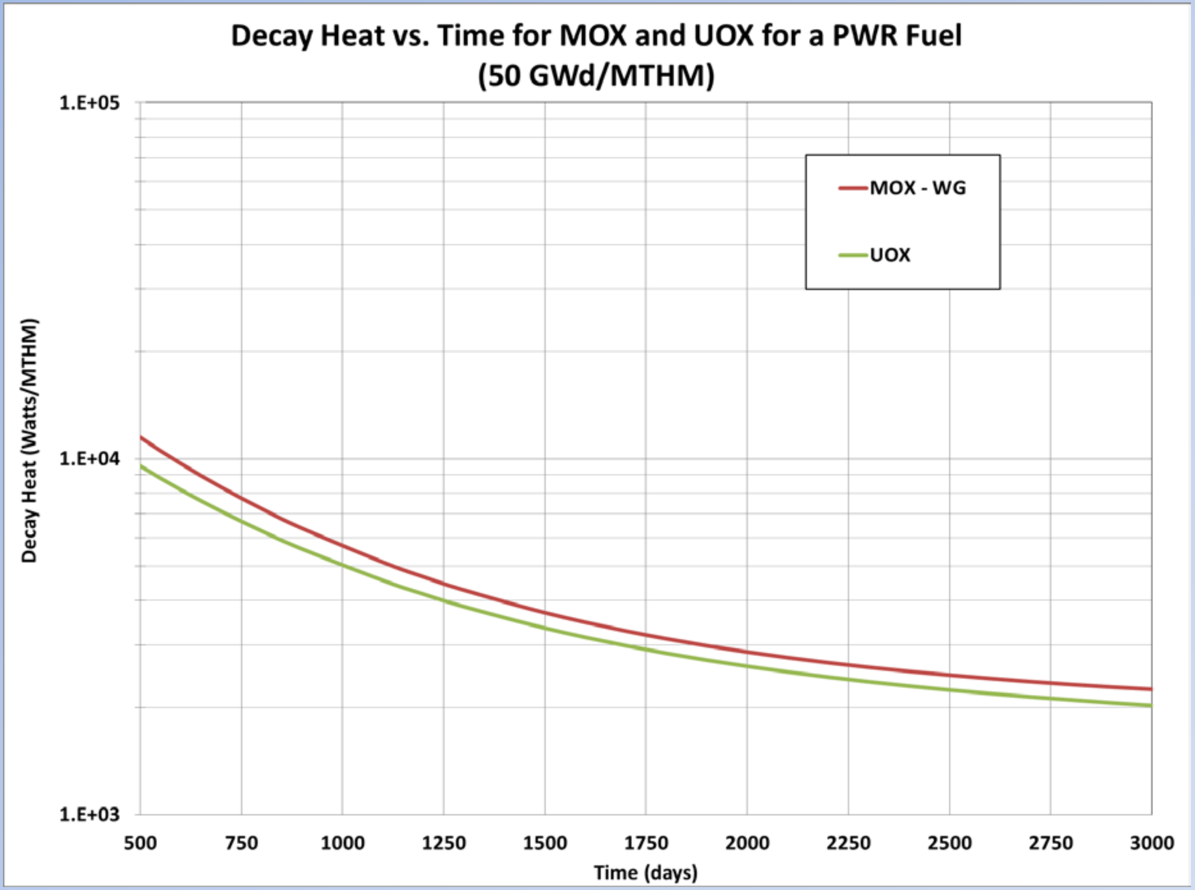
1 – Initially, MOX has less decay heat than UOX.

2 – The crossover point (where MOX has higher decay heat) occurs within several hours to a day, depending on fuel type (PWR vs. BWR) and burnup

3 – From an accident management and accident consequence stand point, the differences are insignificant

Source: ORNL/TM-2011/290, Decay Heat Calculations for PWR and BWR Assemblies Fueled with Uranium and Plutonium Mixed Oxide Fuel Using SCALE, Brian J. Ade and Ian Gauld

Mid-Term: Slightly More Time in Fuel Pool and No Change to Dry Cask Thermal Design



Four Points:

1 – At year 5 (1825 days), UOX thermal load is 2800 Watts/MTHM

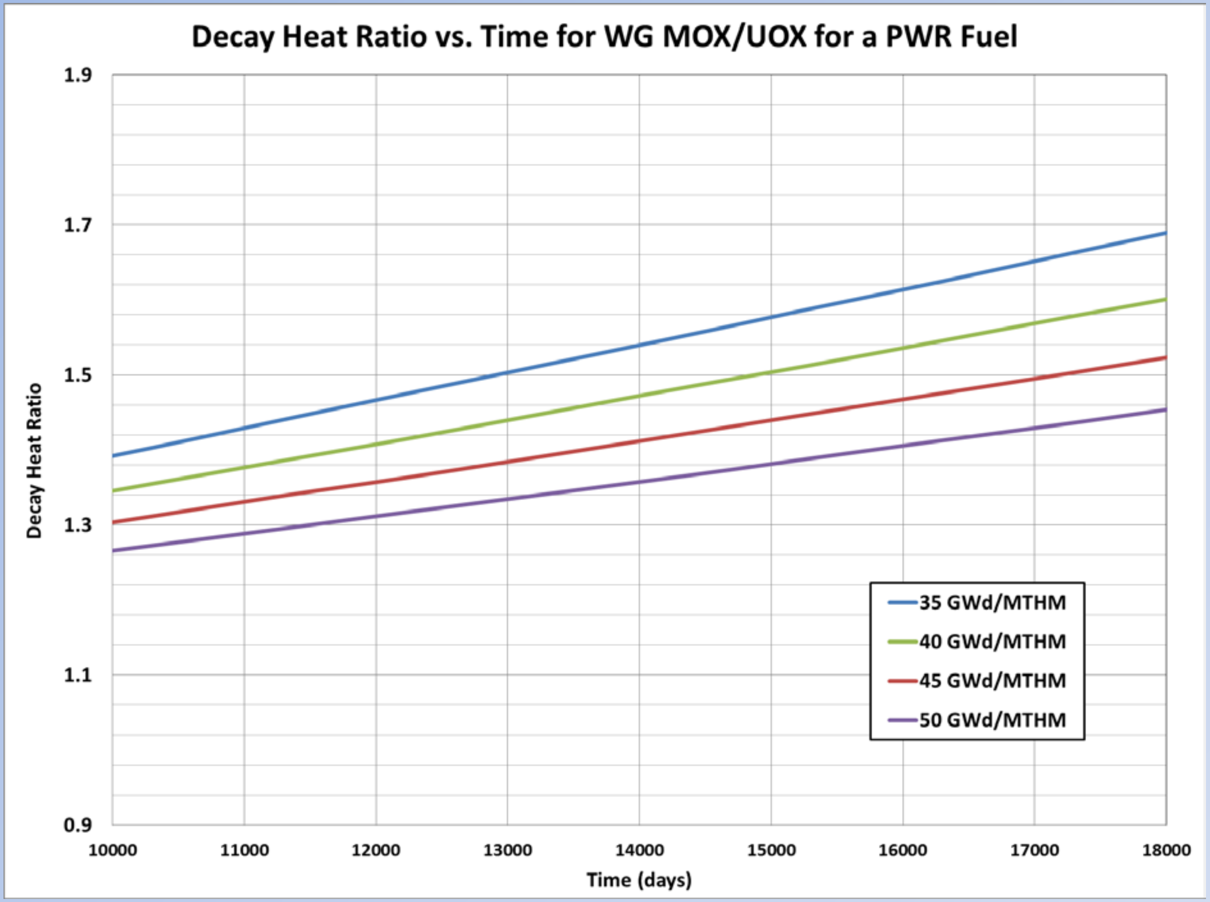
2 – MOX reaches that same thermal load at day 2065, only 240 days longer than UOX.

3 – Difference in heat load between used MOX and used UOX is not a driver on spent fuel pool cooling or space requirements. It is also not a driver on dry cask thermal design.

4 – Heat management is very geology/repository specific.

Source: ORNL/TM-2011/290, Decay Heat Calculations for PWR and BWR Assemblies Fueled with Uranium and Plutonium Mixed Oxide Fuel Using SCALE, Brian J. Ade and Ian Gauld

Long-term: MOX Decay Heat Must be Considered in Repository Design



Three Points:

1 – The ratio of MOX to UOX is between 1.3-1.7 times higher for PWRs

2 – At 30 years, the heat load in MOX is ~55% of UOX at 5 years. Used MOX thermal load can be safely managed in dry casks.

3 – Used MOX would need to be kept in dry cask storage an additional 56 years longer than UOX to have the same thermal impact on a repository at the time of emplacement.

Source: ORNL/TM-2011/290, Decay Heat Calculations for PWR and BWR Assemblies Fueled with Uranium and Plutonium Mixed Oxide Fuel Using SCALE, Brian J. Ade and Ian Gauld

TVA

Preliminary Conclusions

- Relative to UOX fuel, the thermal load of MOX fuel is:
  - ✓ Expected to have no discernable effect following a severe accident
  - ✓ Manageable in pools and dry casks
  - ✓ To be addressed in repository design
- Core design flexibility enables varying the MOX burnup relative to UOX burnup

Summary

- SEIS process will assess safety to workers, public and environment
- MOX Program will proceed in phases with multiple opportunities for public input
- Physical modifications for MOX fuel use are manageable
- TVA expects DOE's MOX to cost TVA less than UOX
- TVA will proceed only if MOX is safe and beneficial to TVA's customers
  - ✓ Decision to proceed with engineering & licensing: late 2012 / early 2013
  - ✓ Earliest MOX use in TVA reactors: 2018