



U.S. DEPARTMENT OF
ENERGY

Nuclear Fuels Storage & Transportation Planning Project
Office of Fuel Cycle Technologies

Nuclear Energy

NWTRB Workshop – Inventory

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Washington, DC

November 18-19, 2013



Standard Contract between utilities and DOE (10 CFR 961)

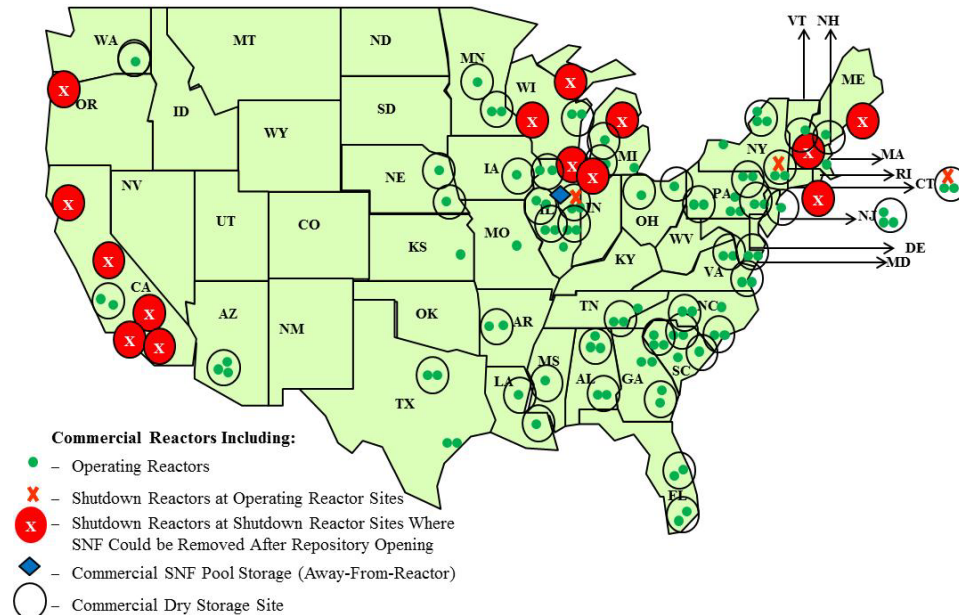
- ***This is a technical presentation that does not take into account the contractual limitations under the Standard Contract***
- ***Under the provisions of the Standard Contract, DOE does not consider spent fuel in canisters to be an acceptable waste form, absent a mutually agreed to contract modification***

Outline

- **Nuclear Power Reactors**
- **Current Inventory**
 - By Reactor Type
 - By Storage Method
 - By Location
- **Projected Inventory**
 - Projected to 2021
 - Projected to 2060
- **Implications**



Commercial Nuclear Power Reactors History and Location



As of August, 2013

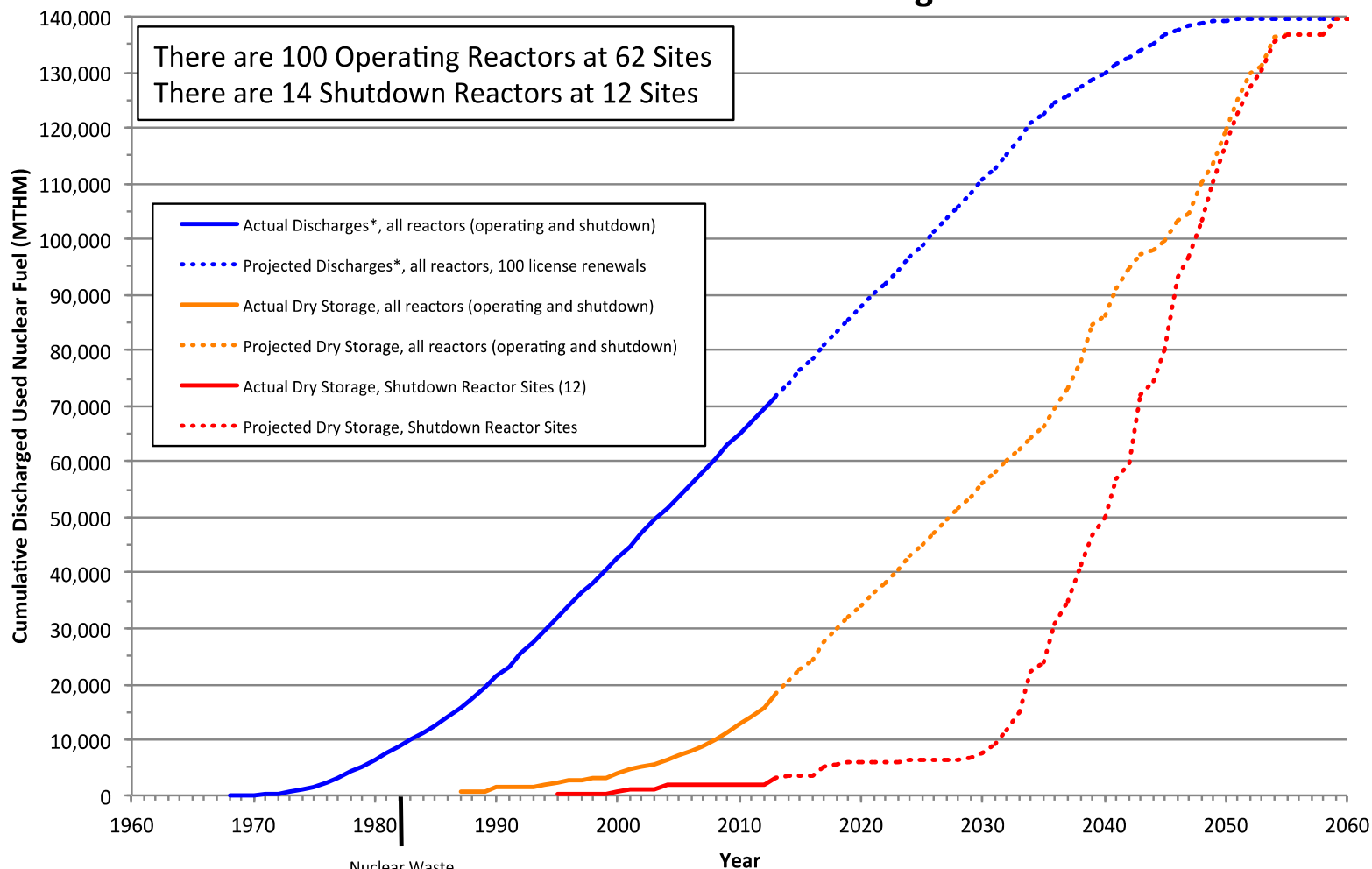
- **119 Nuclear Power Reactors (NPR) Built and Operated**
- **100 in Operation as of November, 2013**
 - 2 Operating NPR have announced “Early Shutdown” dates of 2014 and 2019
- **2 NPR Nearing Completion (not shown)**
- **4 New Build NPR (not shown)**

- **10 NPR on 9 sites shutdown prior to 2000 with only fuel management activities on site and some decommissioning activities ongoing**
- **1 NPR disabled and UNF owned by DOE (Three Mile Island unit 2)**
- **3 NPR permanently shutdown on sites with continued nuclear operations**
- **4 NPR on 3 sites ceased operations or restart activities in 2013**
 - 5 NPR total are shutdown on these sites



Projected Commercial Used Fuel Discharge and Dry Storage Inventory

Historical and Projected Commercial Used Nuclear Fuel Discharges



Assuming Transfer to Dry Storage at Reactor Shutdown

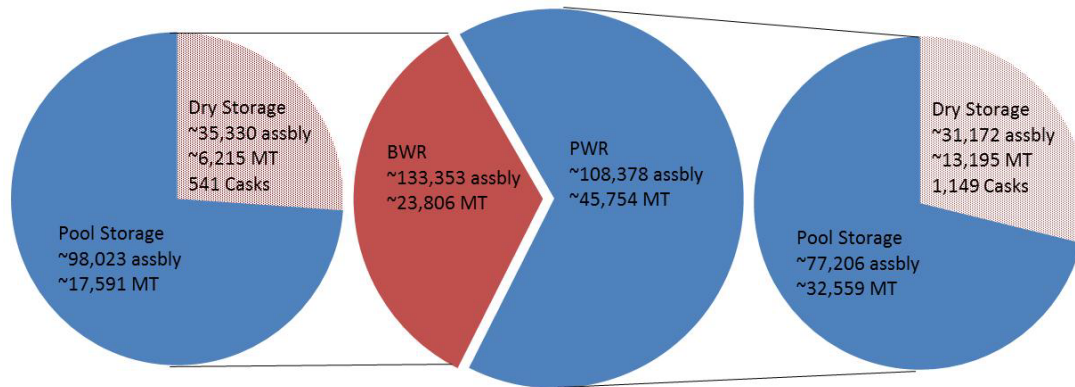
Source: *Based on actual discharge data as reported on RW-859s through 12/31/2002 and projected discharges, in this case for 100 license renewals



Current Projected Commercial Inventory December 31, 2012

Commercial UNF
Thru Dec 2012
241,731 assemblies
69,559 MT

- PWR Discharges ~45% by assemblies and ~66% by mass
- ~27% BWR UNF in Dry Storage
- ~29% PWR UNF in Dry Storage



- UNF discharged and stored at 118 NPR sites, excluding UNF at DOE sites:
 - TMI-unit 2 debris
 - Ft. St. Vrain
 - UNF transferred to INL and SRS
- Data Sources include the 2002 RW-859 database and DOE forecast discharges between 1/1/03 and 12/31/12



Canisters, Storage Cask/Overpacks, and Transportation Cask/Overpacks

- Used nuclear fuel assemblies are placed in canisters in spent fuel pool
- Canisters are removed from pool using transfer cask and placed in storage cask/overpacks for storage at ISFSI
- Canisters are removed from storage cask/overpacks and placed in transportation cask/overpacks for shipping



Empty canister showing baskets for UNF assemblies



Empty canisters staged at Zion



Loading canister into storage overpack at Trojan using transfer cask



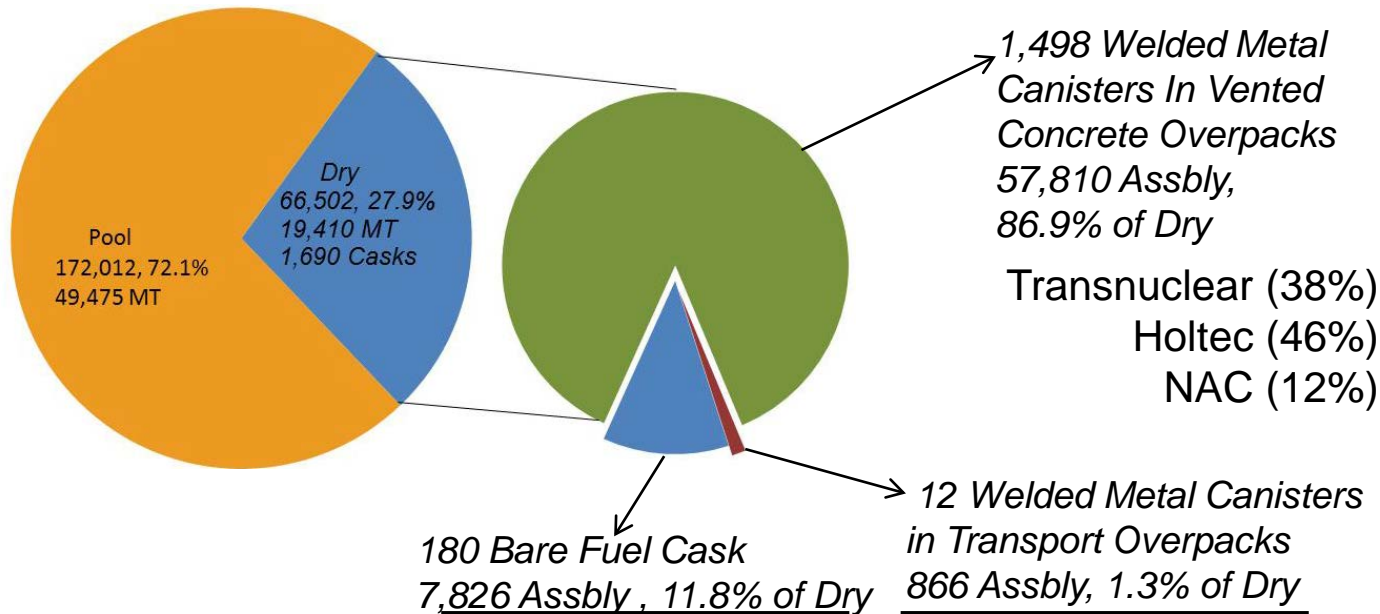
NAC-STC transportation overpack showing impact limiters and personnel barrier

Loaded storage overpacks at Trojan ISFSI





Current At Reactor Commercial Inventory Dry Storage Systems



1,498 Welded Metal Canisters In Vented Concrete Overpacks

Transnuclear (38%)
Holtec (46%)
NAC (12%)

12 Welded Metal Canisters in Transport Overpacks



Transnuclear TN-32

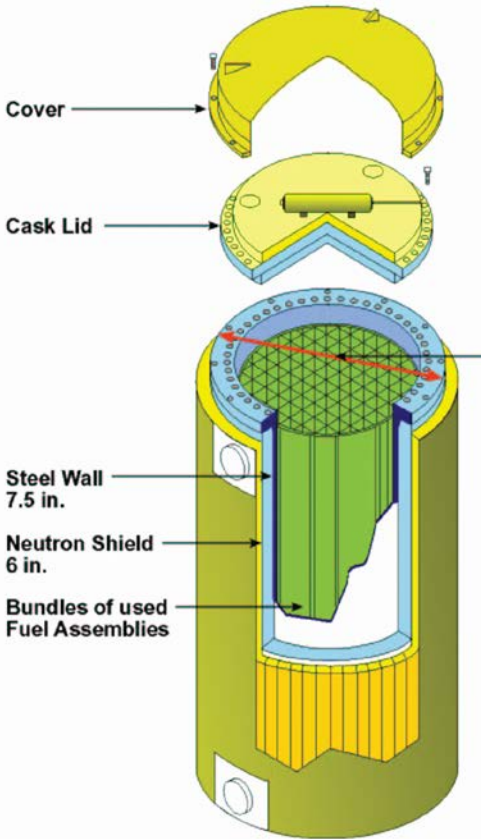


Holtec HiStar 100





Bare Fuel in Bolted Casks



TN-68 Configuration

■ 4 Vendors have provided bare fuel casks

- Westinghouse MC-10
- GNB Castor V21/V33 (cast iron body)
- NAC I-128
- Transnuclear TN-32, TN-40, TN-40HT and TN-68

Transportation of Legacy Casks is Challenging

■ TN-40 and TN-68 have a current transportation certificate of compliance (CoC)

- Prairie Island and Peach Bottom continue to load

■ Physical configuration varies

- Length from 175 to 215 inches
- OD from 94.8 to 110.25 inches
- Weight from 230,000 to 250,000 lbs



Metal Canisters Already in Transportation Overpacks

■ Holtec Hi-Star 100 – generic overpack

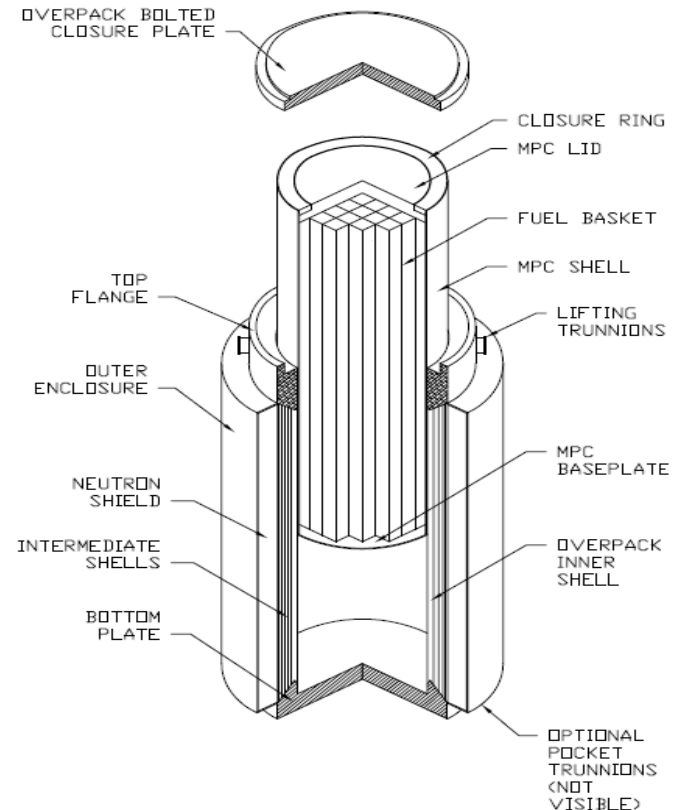
- Length: 203 in., 305 in. with impact limiters
- OD: 96 in., 128 in. with impact limiters
- Weight: 282,000 lbs. for heaviest configuration

■ Specific design for Humboldt Bay

- Approximately 78 in. shorter than generic

■ Transportation-“ready” packages

- Requires only impact limiters for transportation
- 12 casks at Humboldt Bay, Dresden, and Hatch
- Contents are licensed for transport

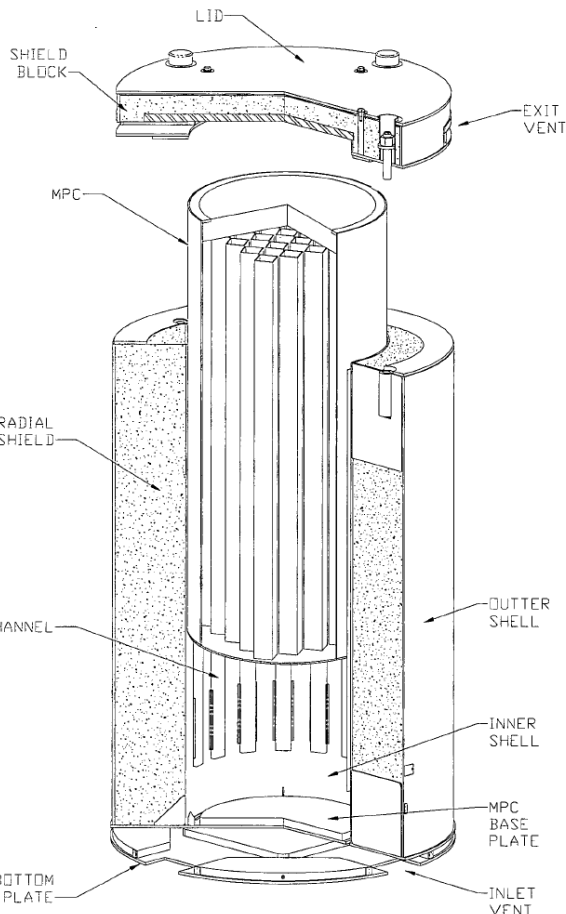


Holtec HiStar 100

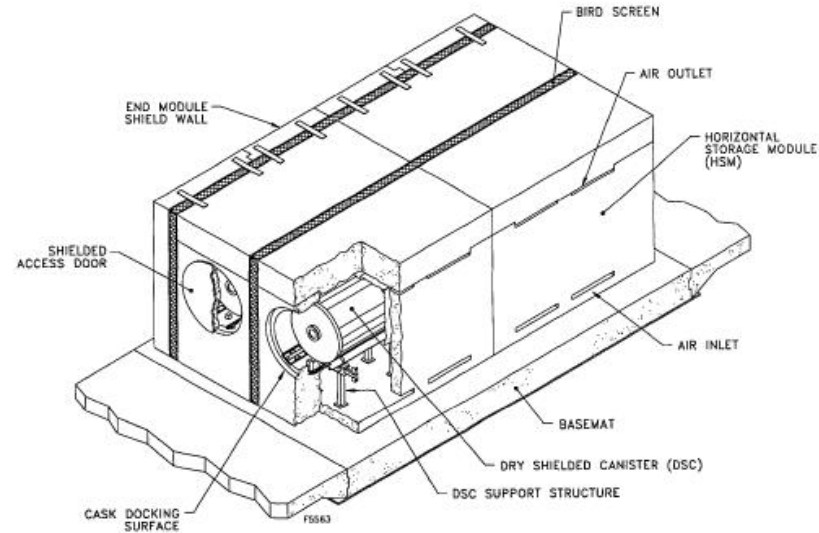


Above grade vented storage overpacks and modules are most widely deployed

Typical vertical cask at grade Holtec and NAC



Holtec HI-STORM



Transnuclear Horizontal Storage Module

Vendor specific transfer casks support fuel movement

- Pool to dry storage
- Storage to transportation cask
- Transportation to storage at ISF





26 Different Welded Metal Canister Designs Have Been Licensed

Typical Configurations

Right Circular Cylinder

- Length 122.5 to 196 in.
- Inner Diameter 60.5 to 68.75 in.
- Weight 55,000 to 105,000 lbs.
- Lifting configurations differ

Interior Cell Dividers

- 7, 12, 24, 32, 37 PWR assemblies
- 52, 61, 68, 80, 87, 89 BWR assemblies
- Differing materials of construction, especially neutron absorber materials

Shield Plug

Welded Cover Plate

NRC Licenses

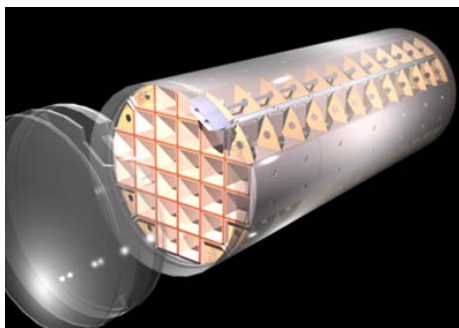
- 5 designs (308 canisters) designated for "Storage Only"
- 21 designs are "Storage and Transportation"
- Vendor's terminology varies
- None are licensed for disposal
- Allowable decay heat and fuel burnup varies by design
- Allowable failed fuel canisters varies by design from 4 upwards

- Transportable Storage Canister (TSC)
- Multi-purpose Canister (MPC)
- Dry Shielded Canister (DSC)

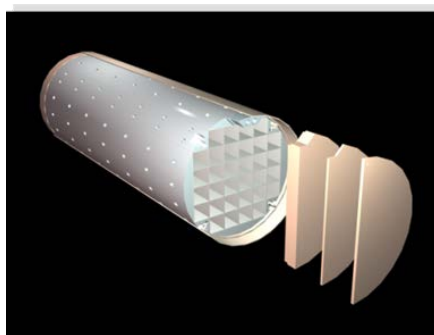


Evolution of Dry Shielded Canisters for Pressurized Water Reactors (PWRs)

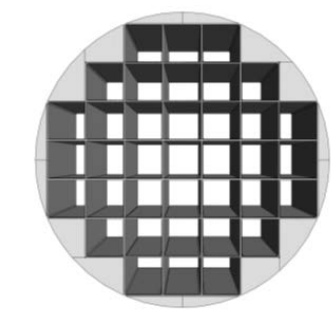
YEAR	NUHOMS® Canister	Assemblies Capacity	Loaded Weight
1985	7 P	7	10 tons
2000	24 PTH	24	40 tons
2003	32 PTH	32	55 Tons
2012	37 PTH	32	55 Tons



NUHOMS® 24PTH



NUHOMS® 32PTH



NUHOMS® 37PTH

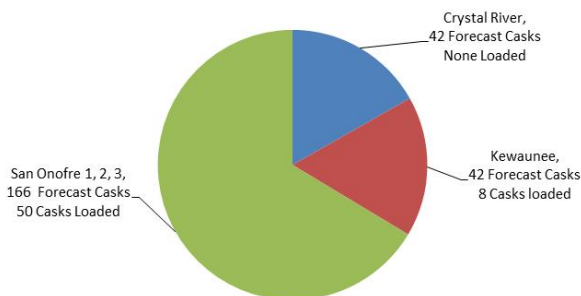
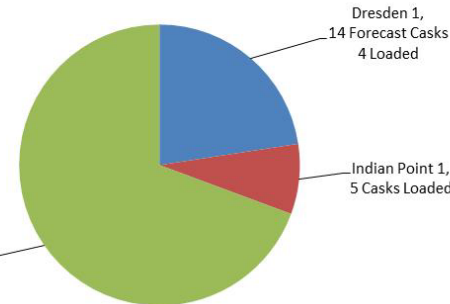
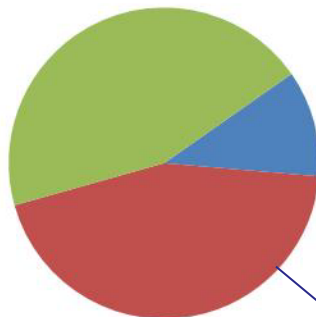


UNF at Shutdown Nuclear Power Reactors

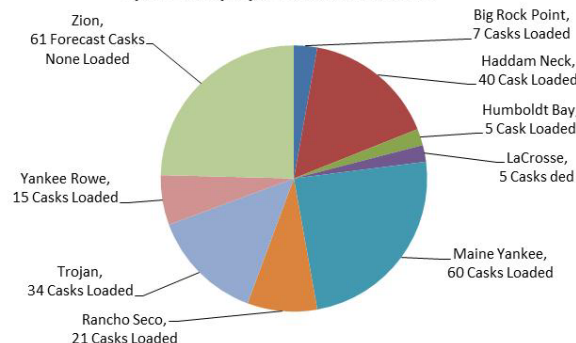
Permanently Shutdown Reactor Fuel
560 Fuel Casks, ~31 GTCC Casks
6,208 MT, 18,199 Assemblies

Shutdown Reactor Fuel Casks
62 Fuel Casks, ~6 GTCC Casks
647MT, 3,933Assemblies

Early Shutdown Reactor Fuel Cask
250 Fuel Casks, ~10 GTCC Casks,
2,747MT, 6,617 Assemblies



Stranded Reactor Fuel Casks
248 Fuel Cask, 15 GTCC Casks,
2,813MT, 7,649 Assemblies



Stranded UNF and Shutdown Reactor UNF based on RW-859 Database
Early Shutdown UNF based on DOE projections
Projected number of casks based on continued use of currently deployed systems



Deployed Storage Systems at Shut-down Reactor Sites

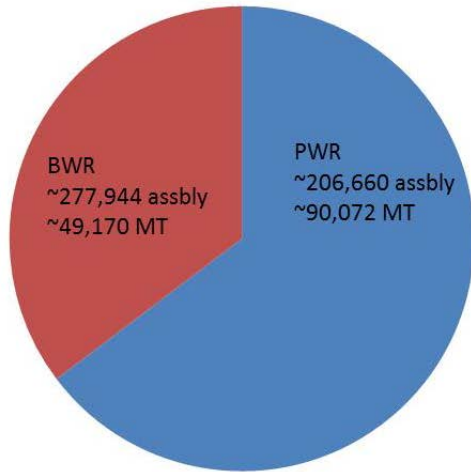
12 shutdown plant sites use 17 different canister designs, 8 different storage overpack designs, and requires 8 different transport overpack designs

Reactor	Shutdown Date	Assbly	Initial Uranium (MT)	Storage System/Canisters	Transport Cask Status	Number of Canisters Fuel/GTCC
Big Rock Point	8/29/1997	441	58.05	Fuel Solutions W150 Storage Overpack / W74 Canister	TS-125 (Docket No. 71-9276); Certificate expires 10/31/2017. None fabricated	7/1
Haddam Neck	12/5/1996	1,019	412.29	NAC-MPC / MPC-26 and MPC-24 canisters	NAC-STC (Docket No. 71-9235); Certificate expires 5/31/2014. Foreign use versions fabricated.	40/3
Humboldt Bay 3	7/2/1976	390	28.94	Holtec HI-STAR HB / MPC-HB canister	HI-STAR HB (Docket No. 71-9261); Certificate expires 3/31/2014. Fuel in canisters in fabricated casks. No impact limiters.	5/1
LaCrosse	4/30/1987	333	38.09	NAC MPC-LACBWR/MPC-LACBWR canister	NAC-STC (Docket No. 71-9235); Certificate expires 5/31/2014. Foreign use versions fabricated.	5
Maine Yankee	12/6/1996	1,434	542.26	NAC-UMS/UMS-24 canister	NAC-UMS (Docket No. 71-9270); Certificate expires 10/31/2017. None fabricated	60/4
Rancho Seco	6/7/1989	493	228.38	TN NUHOMS / FO-DSC, FC-DSC, and FF DSC	NUHOMS MP187 (Docket No. 71-9255); Certificate expires 11/30/2013. One cask fabricated. No impact limiters.	21/1
Trojan	11/9/1992	780	358.85	TranStor Storage Overpack / Holtec MPC-24E and MPC-24EF canisters	HI-STAR 100 (Docket No. 71-9261) Certificate expires 3/31/2014. Units fabricated but dedicated to storage at other sites. No impact limiters	34/0
Yankee Rowe	10/1/1991	533	127.13	NAC-MPC / MPC-36 canister	NAC-STC (Docket No. 71-9235); Certificate expires 05/31/2014. Foreign use versions fabricated	15/1
Zion 2	2/21/1997	1,143	523.95	NAC MAGNASTOR / TSC 37 canister	NAC MAGNATRAN (Docket No. 71-9356); License under review.	61/4
Zion 1	9/16/1996	1,083	495.49			
Stranded		7,649	2,813			248/15
Crystal River	2009	1,319	611.98	Does not have a licensed ISFSI, early selection TransNuclear, NUHOMS 32PTH1 storage canister, in a Horizontal Concrete Overpack	TN MP197HB (Docket No. 71-9302); This cask is not currently licensed for the 32PTH1 payload; One in fabrication	41/2 None loaded
Kewaunee	2013	1,335	513.33	TransNuclear, NUHOMS 32PT storage canister, in a Horizontal Concrete Overpack	TN MP197HB (Docket No. 71-9302); This cask is not currently licensed for the 32PT payload; One in fabrication	42/2 8 loaded
Songs 1,2,3	2012	3,963	1,622.17	TransNuclear, NUHOMS 24PT and 24 PT1 storage canister, in a Horizontal Concrete Overpack	TN MP197HB (Docket No. 71-9302); This cask is not currently licensed for the 24PT or 24 PT1 payloads; One in fabrication	166/6 51 loaded
Recent Shutdown Reactor Plants Total		6,617	2,747			250/10

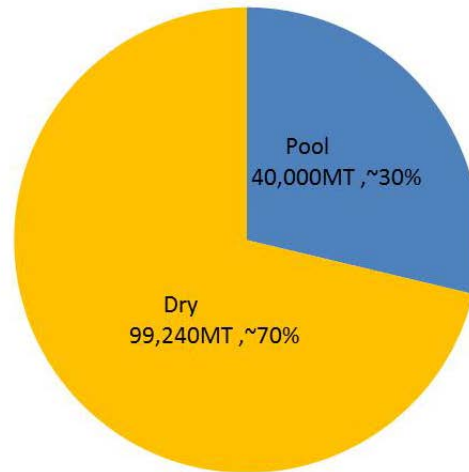


Potential Inventory Estimated at 2060, No Replacement Scenario

Potential Inventory at 2060
No NPR Replacement Scenario



Potential Inventory at 2060
Storage Method



- Current pool storage is ~50,000MT
- Early reactor shutdowns assumed to reduce the combined pool capacity to ~40,000MT
- Balance of fuel moved to dry storage
 - Assumes no incentive to reduce the pool inventory

- No Replacement NPR Scenario Potential Inventory Includes:
 - Shutdown reactor UNF
 - Announced “early shutdown” reactor UNF for NPR not planning to operate 60 years
 - Remaining NPR assumed to get a single license extension and operate for 60 years
 - New builds are not included



Potential New Build NPR Inventory

Reactor Type	Forecast Discharges 1/1/13 to 12/31/60		Total Projected Discharged Fuel	
	Assemblies	Initial Uranium (MT)	Assemblies	Initial Uranium (MT)
Watts Bar 2	2,242	1,031.32	2,242	1,031.32
Bellefonte 1	2,614	1,202.44	2,614	1,202.44
Vogtle 3	2,506	1,060.04	2,506	1,060.04
Vogtle 4	2,504	1,059.19	2,504	1,059.19
Summer 2	2,351	980.37	2,351	980.37
Summer 3	2,326	969.94	2,326	969.94
Total	14,543	6,303	14,543	6,303



Storage vs. Transportation Approvals

- **NRC 10 CRF Part 72 storage licenses and CoCs have been amended to meet plant needs, including storage of high burnup, high heat load fuel**
- **NRC 10 CFR Part 71 transportation CoCs have not kept pace**
 - With one small exception, no HBU fuel is licensed for transportation
 - Even canisters limited to 45 GWd per assembly require extended cool time to transport
- **Storage:**
 - Burnups up to 65 GWd
 - Heat loads up to 40 kW
- **Transport**
 - Burnups to 45 GWd
 - Heat loads in mid-20s kW
- **Plants continue to load dozens of HBU fuel and high heat load canisters each year that will require licensing actions, and or CoC amendments to transport**



Effect of Thermal Constraints on Large DPCs

■ Thermal constraints are more stringent on transportation overpacks than on dry storage canisters/overpacks

- Utilities loading recently discharged higher burn-up UNF
- Approaching storage canister/overpack limits
- Vendors developing canisters with higher thermal limits
 - Holtec Hi-Storm FW: ~47 Kw/canister

Canister	Storage Heat Limit	Transport Heat Limit
Holtec MPC-68	34kW	18.5kW
Holtec MPC-32	34kW	20kW
NUHOMS 32P	40.8kW	24kW
NUHOMS 61B	31.2kW	24kW
NAC UMS 24	23kW	20kW

■ Large dry storage canisters loaded to storage thermal limit would have to stay on-site for an extended period of time

- Perhaps decades between loading and when canister could be transported off-site



Effect of Thermal Constraints on Potential UNF Acceptance Strategies

Evaluated acceptance of UNF from reactors for two different strategies

1. All UNF shipped in large DPCs
2. UNF from pools shipped in re-useable bare fuel transportation casks

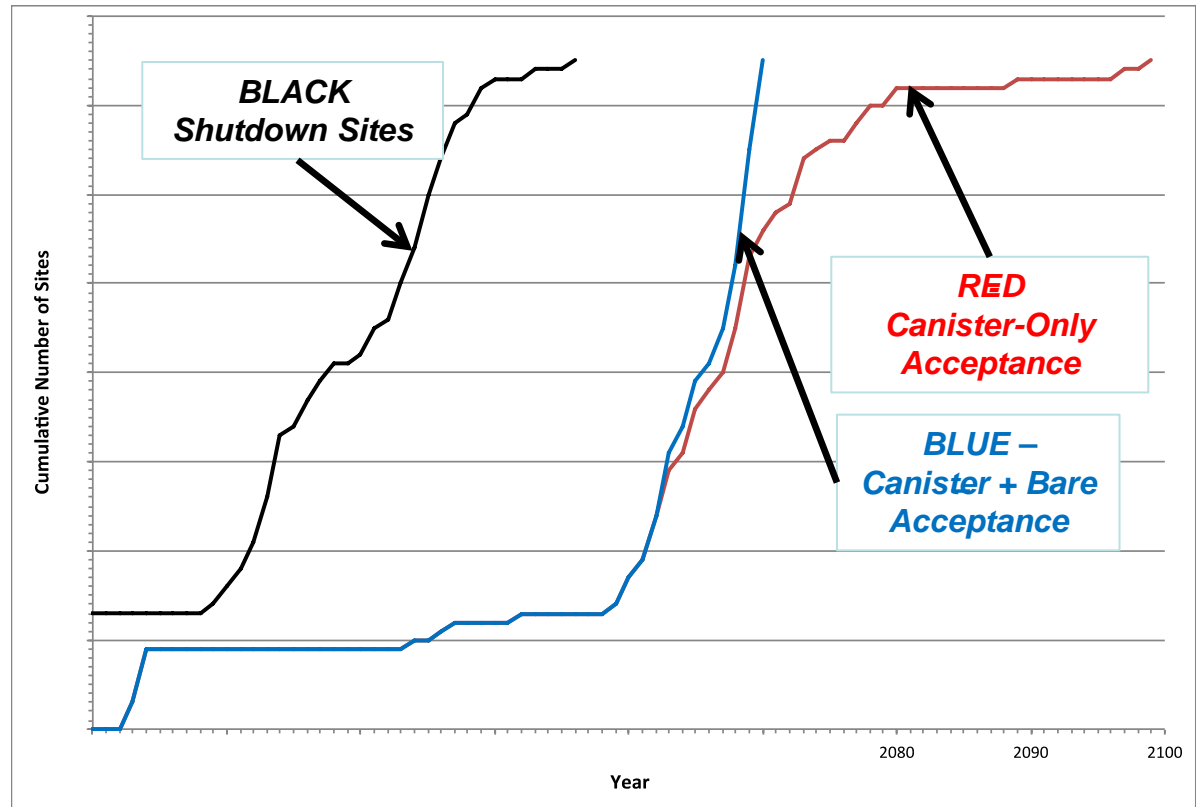
Canister-Only acceptance strategies have an irreducible "tail"

- Due to need to decay-store DPCs to meet thermal limits

Acceptance of bare fuel in re-useable transportation casks that could accommodate higher heat loads could allow for earlier and faster UNF transport

- Bare fuel rail transportation casks have not been certified for most fuel types

Number of Shutdown Sites Cleared of UNF (3,000 MTHM/yr Oldest-Fuel-First Allocation)





Repackaging Requires a Substantial Effort

- Potentially package or re-package ~206,000 BWR and ~277,000 PWR fuel assemblies
- Canisters that would have to be opened depends on UNF management strategy, acceptance rates, and start dates

	Acceptance Rate	Acceptance Start Data	Management Strategy	Dry Storage Canisters at Reactors
Dry Storage Only	3,000 MT/yr	2021	Oldest Fuel First	~11,000
Dry and Bare Fuel Transport	3,000 MT/yr	2021	Oldest Fuel First	~3,800
Dry and Bare Fuel Transport	4,500 MT/yr	2021	Oldest Fuel First	~3,600
Dry and Bare Fuel Transport	~4,300 MT/yr	2021	Eliminate Additional Dry Storage Canister Production	~3,300

- Waste Disposal Canisters to be produced depends upon geologic repository considerations

	4-PWR/9-BWR	12-PWR/24-BWR	21-PWR/44-BWR
PWR Waste Packages	52,250	17,417	9,952
BWR Waste Packages	<u>30,333</u>	<u>11,375</u>	<u>6,205</u>
Total Waste Packages	82,583	28,792	16,157



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Discussion

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■ Discussion