A Decommissioning Renaissance

Florida Chapter
Health Physics Society
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Eric W. Abelquist, Executive Vice President
Next Generation HP - Solomon
Decommissioning over the past 20 years

- U.S. built decommissioning leadership in environmental cleanup and nuclear power plant D&D
- NRC decommissioning rulemaking (1997) and related guidance (MARSSIM) in late 1990s supported 1st decommissioning wave
  - Trojan, CY, MY, Yankee Rowe, Big Rock Point, Rancho Seco
- 20-year plant extensions swept through the industry, shifting the decommissioning timeline
- Decommissioning industry is mature—and on the precipice of sustained worldwide growth
Operational worldwide reactors by age
(source: IAEA Power Reactor Information System)

More than 50% of operational reactors worldwide are > 30 y
Projected surge in retiring nuclear plants
(source: International Energy Agency)
Decommissioning is a growth industry

- Decommissioning is on the cusp of an impressive surge both in the U.S. and internationally

- Lucrative niche for years to come

- Fukushima Daiichi has led to an uptick in international decommissioning

Market factors driving premature nuclear power plant decommissioning

- Uptick in uranium prices due to increasing global demand
- Slack demand for electricity
- Cheap natural gas (shale gas developments)
What’s driving nuclear power plant decommissioning?

Aggressive competition:

- Competitive markets undervalue major attributes of nuclear power plants—nuclear power’s clean, reliable, base-load electricity cannot compete with spot market prices for natural gas and subsidized renewables

Shutdown due to market factors:

- Kewaunee Nuclear Power Plant in WI
- Vermont Yankee Nuclear Power Plant
- Exelon considering closing some of its nuclear stations due to market conditions—reportedly losing $1 B over the past 5 years

Shutdown due to equipment issues:

- Crystal River Nuclear Plant in FL
- San Onofre Nuclear Generating Station Units 2 and 3
Timing matters—DECON vs. SAFSTOR

Not all decommissioning is market-driven...planned DECON continues at Humboldt Bay Power Plant and Zion Nuclear Facility.

SAFSTOR is an attractive option when decommissioning funds insufficient.

Vermont Yankee may sit for decades while its radioactive components cool and its decommissioning fund grows.
Internationally, nuclear decommissioning is picking up steam... not from fission

- 10 Magnox reactors in the UK
- Germany plans to shutter all 20 of its nuclear power plants (NPPs) by 2022
- Belgium and Switzerland planning phase out of their nuclear plants (2025 and 2034, respectively)
- France has 13 experimental and power reactors slated for decommissioning—9 reactors currently undergoing DECON
- Fukushima Daiichi Nuclear Power Station—and many of Japan’s nuclear fleet may be prematurely decommissioned
Cavendish Fluor partnership to decommission Magnox nuclear sites

- Planned expenditure for Magnox Ltd 2015/16 ~$900 M

- 10 Magnox nuclear power stations and 2 nuclear research sites:
  - Berkeley, Bradwell, Chapelcross, Dungeness A, Hinkley Point A, Hunterston A, Oldbury, Sizewell A, Trawsfynydd and Wylfa
  - Winfrith and Harwell research sites
Germany’s nuclear decommissioning

- Four nuclear operators—E.ON, RWE, EnBW, and Sweden’s Vattenfall—estimate nuclear reactor decommissioning will cost $1 billion per plant....a recent estimate is $24.2 billion total.

- Prefer immediate dismantling route (as opposed to SAFSTOR) and re-use of site (green field).

- Seeks a fleet-wide approach to decommissioning for economies of scale.

- Re-started search for high-level waste repository.
Belgium, Bulgaria and France

- 7 Belgium nuclear reactors will be shuttered at 40 y—decommissioning commencing 2014 to 2025
- Bulgaria: EU funds to support decommission Units 1 to 4 of the Kozloduy nuclear power plant; decommissioning will soon commence for Units 1 and 2
- French decommissioning proceeding, need intermediate-level radioactive waste disposal site:
  - 1 pressurized water reactor (PWR); 300MW
  - 1 heavy-water reactor (HWR); 70 MW
  - 6 natural uranium/gas-cooled reactors; 70 to 540 MW
  - 1 fast-breeder reactor (FBR); 1240 MW
Will Japan abandon nuclear power?

- Japan's nuclear reactors were taken offline for routine maintenance and testing after the Fukushima accident.
- Utilities retiring older reactors; nuclear plants ~40 years old will undergo decommissioning.
- 43 reactors are operable and potentially able to restart (down from 54 reactors before March 2011 Fukushima accident).
- Two-thirds may never return to operation because of 1) high costs, 2) local opposition or 3) seismic risks.
Fukushima Daiichi cleanup: Expensive and time-consuming

Cleanup estimates vary widely
- $58B decontamination in Fukushima prefecture
- $100B for radiation cleanup and compensation to residents
  - $23B for radiation cleanup of the territories
  - $20B to scrap the nuclear plant
  - $10B for temporary storage of radioactive soil
  - $47B for compensation to residents in the affected area
- $100B clean-up over 30 to 40 years
- $250B total economic loss
Defense projects:
Cleaning up our Cold War legacy

- Defense cleanup projects in the U.S. and U.K. and Canada are ramping up
  - Department of Energy’s cleanup program has an annual budget nearly $6 billion
  - Army Corps of Engineers has a $100 million budget for the Formerly Utilized Sites Remedial Action Program (FUSRAP)
  - U.K.’s Nuclear Decommissioning Authority (NDA) cleanup at Sellafield, Dounreay and Magnox reactors has planned expenditure for 2015/16 of $5 billion
  - Canada established the Nuclear Legacy Liabilities Program (NLLP)
DOE EM FY 2015 Budget Request

Funding by Field Site

Total Requested: $5.622 B
ORO EM Longer-Term Cleanup Plans

- Complete transuranic debris processing (~ 2018)
- Complete construction of Mercury Treatment Facility (~ 2020)
- Complete Cleanup of ETTP (~2022)
- Begin demolition of mercury buildings at Y-12 (~ 2023)
- Complete U-233 disposition (~ 2024)
- Begin operation of new disposal facility (~ 2024)
- Complete transuranic sludge processing (~ 2026)
- Begin demolition of central campus buildings at ORNL (~ 2027)
U.S. Army Corps of Engineers FUSRAP

- Major FUSRAP sites being remediated in FY15:
  - Iowa Army Ammunition Plant, IA
  - St. Louis Airport Site, Vicinity Property and Downtown Site, MO
  - Maywood Site, NJ
  - Niagara Falls Storage Site, NY
  - Shallow Land Disposal Area, PA

- Since the Corps began administering FUSRAP, annual program funding has ranged between $100M to $140 M
Management challenges face UK’s Nuclear Decommissioning Authority

• Sellafield Complex
  – Planned expenditure for 2015/16 ~ $3 B
  – Commence sludge retrievals from First Generation Magnox Storage Pond
  – Demolition of Magnox reprocessing stack
• Dounreay
  – Planned expenditure for 2015/16 ~ $320 M
  – Decontamination of Prototype Fast Reactor pond
  – Low-level waste vaults now operational

• NDA’s latest estimate of the authority’s estate is $107 B...$81B due to Sellafield
Canadian Nuclear Legacy Liabilities Program

- Annual program spend ~$100 M
- Chalk River Laboratories (70%)
  - 2018 shutdown of medical isotope production research reactor
- Whiteshell Laboratories and nearby Underground Research Laboratory (20%)
- 3 shutdown prototype reactors (10%)
  - Nuclear Power Demonstration (NPD) reactor
  - Douglas Point reactor
  - Gentilly-1 reactor
NRC-regulated complex materials sites
(Total of ~50 complex materials sites in U.S.)

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Location</th>
<th>State</th>
<th>Criteria</th>
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<tr>
<td>AAR Manufacturing, Inc.</td>
<td>Livonia</td>
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<td>Alameda Naval Air Station</td>
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<td>Cimarron (Kerr-McGee)</td>
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<td>FMRI (Fansteel), Inc.</td>
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<td>Hunter's Point Naval Shipyard</td>
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<td>Jefferson Proving Ground</td>
<td>Madison</td>
<td>IN</td>
<td>LTR-RES</td>
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<td>St. Louis</td>
<td>MO</td>
<td>LTR-UNRES</td>
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<td>McClellan (former Air Force base)</td>
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<td>Shallow Land Disposal Area</td>
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<td>Maywood</td>
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<tr>
<td>Westinghouse Electric (Hematite Facility)</td>
<td>Festus</td>
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Some of the complex materials sites regulated by agreement states

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<tr>
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<tr>
<td>Superbolt (formerly Superior Steel)</td>
<td>Carnegie</td>
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<td>Weston Solutions (Kerr-McGee)</td>
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<td>The Boeing Company</td>
<td>Simi Valley</td>
<td>CA</td>
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<tr>
<td>Beta Chem Laboratory</td>
<td>Lenexa</td>
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<td>Pearland-Manvel Landfill</td>
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Research/test reactors, uranium recovery sites and fuel cycle facilities

- 8 research and test reactors undergoing decommissioning, including Ford Nuclear Reactor (Univ. of Michigan), State University of New York at Buffalo, and WPI

- 22 Title II uranium recovery sites currently decommissioning, 11 are regulated by the NRC, and 11 by Agreement States

- Two fuel cycle facilities undergoing partial decommissioning – NFS in Erwin, TN and Honeywell in Metropolis, IL
EPA and State-regulated Decommissioning Projects

• NORM/TENORM Affected Industries/Projects
  – Minerals and mining
  – Thorium industry (gas mantles, welding rods)
  – Oil and gas production (pipe scale)
  – Inappropriate/accidental landfill disposals (containing Ra-226)

• Department of Defense (DoD) cleanup projects
  – EPA oversight under CERCLA, working with State regulatory agencies (NRC has limited involvement, stays informed)
  – FY15 $315 M to clean up legacy BRAC sites (e.g., McClellan AFB, Alameda NAS, Hunter's Point)
  – FY15 $1.1 B for Environmental Restoration at active installations ($896 M) and Formerly Used Defense Sites (FUDS) ($208 M)
Decommissioning challenges

• Waste management/disposal

• Clean-up criteria and public acceptance

• Promulgate risk-informed rulemaking for nuclear power plant decommissioning
  – Risks related to emergency or security events is reduced for permanently shutdown plants
Putting it all together...
Decommissioning market size

- Global nuclear decommissioning market for nuclear reactors expected to grow at **14.1%** to 2018
- European nuclear decommissioning market forecast growth of **43.1%** to 2018
- “Global nuclear decommissioning cost seen underestimated, may spiral”; Reuters, Jan. 19, 2015:
  - IEA predicts **200 reactors** will retire by 2040 at estimated cost of **$100 billion**
  - Experts believe this figure could easily double due to underestimates of nuclear plant decommissioning and cost of nuclear waste disposal

U.S. Remediation and Environmental Cleanup Services estimated $18.1B in 2014 (IBISWorld)
Decommissioning workforce

Where are the jobs?

- Federal regulators – principally NRC, EPA, States
- Federal agencies with cleanup missions – DOE EM, DoD, USACE
- Internationally – IAEA, decommissioning authorities and companies
- Decommissioning Industry – top-tier providers CH2M Hill, CB&I, Bechtel, Fluor, URS, Westinghouse and many 2nd and 3rd tier companies

Academic institutions considering curriculum concentrations that address decommissioning disciplines, including skilled trades and crafts.
Connect the dots
Decommissioning is part of the nuclear life cycle...and that’s good for business

- 450 nuclear power plants in the world
- Hundreds to be retired in the next 35 to 40 years
- 100s new nuclear build coming online 10 to 15 y
- Another wave of construction to replace those 450 nuclear plants that are in the marketplace now
- ALL will have to be decommissioned
- Nothing is certain but death and taxes...and DECOMMISSIONING