An Overview of Spent Fuel Storage in the US

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The past, the present, and the future walked into a bar. It was tense.
UxC – The Ux Consulting Company

- Provides nuclear fuel consulting and market information services to suppliers, utilities, investors, and government agencies internationally
  - Founded in March 1994
  - 16 professionals in company, plus consultant base
  - Offices: Atlanta, GA, Washington, DC, and Vienna, Austria

- Three major lines of business
  - Nuclear fuel cycle consulting
  - Publishing industry market reports
  - Data services
Consulting Services

- **Market Analyses** – Impacts of various market developments on supply, demand, and price
- **Strategic Planning** – Positioning clients to succeed in changing business climate
- **Procurement Strategies** – Informing utilities’ decisions on market timing, pricing, and inventories
- **Utility Procurement Training Seminars** – Basic and advanced seminars for utility fuel managers
- **Policy Issues** – Assessing impact of government policies on clients’ businesses and general market
- **Litigation and Arbitration Support** – Providing expert market and economic advice in legal proceedings
Recent Consulting Projects

► Advising suppliers on marketing strategies and contract terms and conditions
► Supporting major international utilities with reactor and fuel procurement
► Special reports
  ● Uranium Production Cost Study
  ● Nuclear Industry Value Chain
  ● Enrichment Suppliers Assessments
  ● Japan Watch
  ● Kazakhstan's Nuclear Energy Program after Fukushima
  ● China’s Nuclear Energy Market after Fukushima
  ● Impact of Kazakh Production on the Uranium Market
  ● Small Modular Reactor Assessments
  ● Nuclear Reactor Technology Assessments
  ● Nuclear Zirconium Alloy Market report
  ● Hydrofluoric Acid Market Assessment
  ● Beryllium Market Assessment
UxC Covers All Fuel Cycle Segments

Uranium Exploration & Development

Mining of Uranium Ore

Milling of Ore to $\text{U}_3\text{O}_8$ Concentrates

Conversion to UF$_6$

Uranium Enrichment (SWU)

U & Pu Recycle

Reprocessing

Fuel Fabrication

Nuclear Reactor

Spent Fuel Storage

Waste Disposal

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World First: Construction License Issued for Deep Geological Repository in Finland

Less than three years ago, in December 2012, Posiva Oy, the organization responsible for the final disposal of spent nuclear fuel and high-level radioactive waste in Finland, submitted an application for a construction license to build a deep geological repository on the island of Olkiluoto in Barjaski, Finland. On November 12, 2013, the Government of Finland announced it had granted that license. Finland’s Minister of Economic Affairs Olli Rehn said in the press release that “The construction license granted now is the first in the world for a spent nuclear fuel disposal facility. Finland is an international pioneer in nuclear waste management, which also obliges us to take care of matters responsibly and safely in the future. Finnish expertise also provides us with commercial opportunities in developing nuclear waste management in other countries.”

In its press release, Posiva said the favorable decision “is recognition for the extensive R&D work carried out by Posiva for more than 40 years to develop a safe final disposal solution for spent nuclear fuel.”

Posiva’s President and Chief Executive Officer, Mr. Jussi Mikkola, said in a statement, “The construction license that has now been granted for our final disposal facility for spent nuclear fuel is a significant achievement for us, our employees and our shareholders. This pioneering project is important not only for Finland, but also on a global scale. It is the first project entering construction phase in the whole world. I express my thanks and appreciation to all the engineers and partners in Finland and in other countries, who have joined their forces and expertise in this unique and world-class project.”

The government included several conditions on the construction license. When Posiva applies for the expertise operating license, Posiva must submit analyses concerning the environmental impacts of the facility, the security of the spent nuclear fuel, the transport risk involved, and any changes that may have been introduced into the project. Posiva said that construction work may begin towards the end of 2016, and the final disposal of spent fuel generated at the Olkiluoto and Loviisa nuclear power plants is planned to start in 2020. Posiva is also required to submit the operating license application in 2020. The facility will be able to contain 5,000 metric tons of waste. Finland’s disposal facility is made up of two parts: the

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US Policy Status with regard to Spent Fuel

► In 2014, the NRC approved the Continued Storage Rule and its supporting Generic Environmental Impact Statement, which contained the determination that spent fuel can be stored safely for 60 years beyond the licensed life of a reactor.

► The NRC is developing an extended storage and transportation (EST) regulatory program. This program could include a safety and environmental analysis to support very long-term storage (up to 300 years).

► In mid-2013, DOE announced it would invest $15.8 million to study high burnup fuel that has been in storage for long periods of time. EPRI leads the project team, which also includes AREVA Federal Services, AREVA TN, Dominion, AREVA Fuels, and Westinghouse Fuels. Westinghouse, NAC International, NEI, and several national laboratories are also providing support.
Blue Ribbon Commission recommendations in 2012 had 8 key elements, one of which was “prompt efforts to develop one or more consolidated storage facilities.” Legislation was introduced in 2015 that would create a process to allow interim storage facilities.
Two applications for private consolidated storage facilities will be submitted to the NRC in 2016

Waste Control Specialists (WCS) announced plans to build a CISF at the site of its LLW disposal facility in Andrews County, Texas. WCS has partnered with AREVA TN and NAC International in the effort, and its application for a site-specific Part 72 license will reference AREVA TN and NAC storage technology. Has broad local and state consent.

- EnergySolutions recently announced it will acquire WCS.
Holtec International also announced plans to build a CISF near Carlsbad, New Mexico. Holtec has partnered with the Eddy-Lea Energy Alliance (ELEA) for this facility, which will use Holtec’s HI-STORM UMAX (underground, maximum capacity) storage system. Has strong local consent, and consent of the New Mexico Governor, but the Congressional delegation initially was somewhat ambivalent.

DOE announced in December it is launching a consent-based process to site federal spent fuel storage and disposal facilities, and a separate repository for defense waste, which was announced in March.
In December, EIA released results of its Nuclear Fuel Data Survey (data as of June 30, 2013)

- 241,468 total fuel assemblies stored at commercial sites
  - 136,821 BWR fuel assemblies stored at commercial sites
  - 102,647 PWR fuel assemblies stored at commercial sites
  - These assemblies contain nearly 69,700 metric tons of uranium
  - Approximately 25% is in dry storage
  - Approximately 2,000 to 2,400 MTU is discharged each year from US reactors
Dry Storage of Spent Fuel

► ISFSIs are Licensed under 10 CFR Part 72

● General or site-specific license
  ▪ Most ISFSIs operate under a general Part 72 license.
  ▪ Currently, 13 ISFSIs in the US operate under a site-specific license, including a wet storage ISFSI at the GE-Morris facility in Illinois. To date 7 site-specific ISFSI licenses have been renewed, most recently Prairie Island’s. ISFSI licenses can now be renewed for a 40-year period.
## ISFSIs with Site-Specific Licenses

<table>
<thead>
<tr>
<th>Licensee</th>
<th>Site</th>
<th>License</th>
<th>Initial License Expiration Date</th>
<th>Renewed License Expiration Date</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominion</td>
<td>Surry</td>
<td>SNM-2501</td>
<td>2006</td>
<td>2046</td>
<td>License renewed in 2005 with exemption for an additional 20 years</td>
</tr>
<tr>
<td>Progress Energy</td>
<td>H.B. Robinson</td>
<td>SNM-2502</td>
<td>2006</td>
<td>2046</td>
<td>License renewed in 2005 with exemption for additional 20 years</td>
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<tr>
<td>Duke</td>
<td>Oconee</td>
<td>SNM-2503</td>
<td>2010</td>
<td>2050</td>
<td>License renewed in 2009 with exemption for an additional 20 years</td>
</tr>
<tr>
<td>DOE</td>
<td>Ft. St. Vrain</td>
<td>SNM-2504</td>
<td>2011</td>
<td>2031</td>
<td>License renewed in 2011 for an additional 20 years</td>
</tr>
<tr>
<td>Constellation</td>
<td>Calvert Cliffs</td>
<td>SNM-2505</td>
<td>2012</td>
<td>2052</td>
<td>Renewed October 23, 2014 for a 40-year period</td>
</tr>
<tr>
<td>Xcel Energy</td>
<td>Prairie Island</td>
<td>SNM-2506</td>
<td>2013</td>
<td>2053</td>
<td>Renewed December 9, 2015 for a 40-year period</td>
</tr>
<tr>
<td>Dominion</td>
<td>North Anna</td>
<td>SNM-2507</td>
<td>2018</td>
<td>N/A</td>
<td>Renewal not yet submitted</td>
</tr>
<tr>
<td>Portland GE</td>
<td>Trojan</td>
<td>SNM-2509</td>
<td>2019</td>
<td>N/A</td>
<td>Renewal not yet submitted</td>
</tr>
<tr>
<td>SMUD</td>
<td>Rancho Seco</td>
<td>SNM-2510</td>
<td>2020</td>
<td>N/A</td>
<td>Renewal not yet submitted</td>
</tr>
<tr>
<td>GE</td>
<td>GE-Morris (wet storage)</td>
<td>SNM-2500</td>
<td>2022</td>
<td>2022</td>
<td>License renewed in 2004 for 20 years; was the first ISFSI license renewed</td>
</tr>
<tr>
<td>PG&amp;E</td>
<td>Diablo Canyon</td>
<td>SNM-2511</td>
<td>2024</td>
<td>N/A</td>
<td>Renewal not yet submitted</td>
</tr>
<tr>
<td>DOE</td>
<td>Idaho Spent Fuel Facility</td>
<td>SNM-2512</td>
<td>2024</td>
<td>N/A</td>
<td>Renewal not yet submitted</td>
</tr>
<tr>
<td>PG&amp;E</td>
<td>Humboldt Bay</td>
<td>SNM-2514</td>
<td>2025</td>
<td>N/A</td>
<td>Renewal not yet submitted</td>
</tr>
</tbody>
</table>
Every US nuclear reactor site except for TMI-1, Shearon Harris, and Wolf Creek, either has dry storage implemented or has near-term plans to implement dry storage.

Currently, there are 73 ISFSIs in the US – counting the 5 sites that have both a general and a site-specific ISFSI license as two ISFSIs, and not counting the PFS facility. TMI-2 spent fuel stored in Idaho is counted.
- One new ISFSI started operating in 2015 at Callaway

In 2016, three new ISFSIs are scheduled to become operational: Clinton, VC Summer, and Watts Bar. South Texas Project is scheduled to start in 2016/2017, and Crystal River could become operational in 2017/2018.
Growth of Commercial Dry Storage

► StoreFUEL started tracking cask loadings in 2004

- As of August 2004, we reported 602 casks loaded with 20,564 assemblies in the US.
- At the end of 2010, we reported 1,387 casks loaded with 54,046 assemblies.
- At the end of 2015, we reported 2,277 casks loaded with 93,426 assemblies. 190 casks were loaded in 2015.
- 1,657 casks have been safely loaded just since mid-2004.
Three active cask vendors in the US

- **AREVA TN** is AREVA’s dry storage and spent fuel transport company. Currently markets the modular NUHOMS dry cask system, which is in use at 27 US sites storing over 29,000 assemblies in more than 800 systems. AREVA TN also has its bare fuel metal cask system in use at 5 sites with 175 systems. AREVA TN thus has a total of over 37,700 assemblies stored in 979 systems. AREVA TN has partnered with WCS for the CISF in Texas.

- **Holtec International** is best known for its HI-STORM cask technology, which is in use at 29 US sites, storing more than 41,000 assemblies in over 800 casks. Two new cask designs were deployed at US sites in 2015 – the HI-STORM UMAX at Callaway and the HI-STORM FW at Browns Ferry. Holtec plans to build a CISF with ELEA in New Mexico.
Key Players in Spent Fuel Storage

- **NAC International** specializes in nuclear materials transport, spent fuel storage and transport technologies, nuclear fuel cycle consulting, and fuel cycle information services. It is the only active cask vendor that has shipped and continues to ship commercial spent fuel in the US. NAC systems are in use at 11 US sites, storing 10,622 assemblies in 395 systems. NAC has partnered with WCS for the CISF in Texas, and is in the process of loading 40+ casks of HLW at West Valley for DOE.

- **EnergySolutions** no longer actively markets cask systems, but renewal of its VSC-24 system is being finalized. ES has 66 cask systems storing 1,833 assemblies in use at 4 US plants. ES operates a LLW facility in Utah, and recently announced it intends to buy Waste Control Specialists. ES also manages customized projects for utility customers, such as the Zion decommissioning project and most recently ES entered into a similar agreement with Dairyland Power Cooperative.
Current Status of Dry Storage

Number of Assemblies in dry storage at the end of 2015

Dual-Purpose concrete casks in use

Total casks in use
Market Share – BWR Fuel

Dual-purpose concrete systems deployed

- BWR
- Other 1%
- TN 39%
- NAC 1%

BWR assemblies in dual-purpose concrete systems

- BWR
- Holtec 64%
- Other 1%
- TN 34%
- NAC 1%

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Market Share – PWR Fuel

Dual-purpose concrete systems deployed

- PWR: 26%
- Holtec: 26%
- TN: 44%
- Other: 5%

PWR assemblies in dual-purpose concrete systems

- PWR: 33%
- Holtec: 33%
- TN: 29%
- Other: 0%
Market Share at Shutdown Sites

- Holtec: 16%
- NAC: 57%
- TN: 25%
- BFS/ES: 2%

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Summary of Projected SNF Discharges

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Thousand MT

Africa & Middle East
Asia & Oceania
Eastern Europe
North America
South America

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Final Thoughts

► The dry storage market in the US will continue to see steady growth for the next several decades.

► Another ~200 casks are expected to be deployed in 2016 in the US at commercial reactor sites. In addition, DOE is loading NAC casks at West Valley.

► The global dry storage market also will continue to grow as a result of:
  ● Decommissioning plants (Germany)
  ● Delays in repository programs
  ● Delays in reprocessing plans in countries that are pursuing reprocessing