Small Modular Reactor Project
in the
United States of America

Debate on Dispersed Nuclear Energy
An Opportunity for Poland?

John E. Kelly
Deputy Assistant Secretary for Nuclear Reactor Technologies
Office of Nuclear Energy
U.S. Department of Energy

25 October 2013
Committed to “All of the Above” Clean Energy Strategy

“By 2035, 80% of America’s electricity will come from clean energy sources. Some folks want wind and solar. Others want nuclear, clean coal and natural gas. To meet this goal we will need them all.”

~2011 State of the Union

“Electricity generation emits more carbon dioxide in the United States than does transportation or industry, and nuclear power is the largest source of carbon-free electricity in the country.”

~ Secretary of Energy, Dr. Ernest Moniz
Meeting Clean Energy Goals will Require a Shift in Electricity Production

<table>
<thead>
<tr>
<th>Source</th>
<th>2010 Elect (TWhr)</th>
<th>2010 CO₂ (Gton)</th>
<th>2035 Elect (TWhr)</th>
<th>2035 CO₂ (Gton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>1000</td>
<td>0.4</td>
<td>1520</td>
<td>0.5</td>
</tr>
<tr>
<td>Coal</td>
<td>1730</td>
<td>1.7</td>
<td>1800</td>
<td>1.8</td>
</tr>
<tr>
<td>Coal (CCS)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nuclear (Large)</td>
<td>790</td>
<td>0</td>
<td>870</td>
<td>0</td>
</tr>
<tr>
<td>Nuclear (SMR)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hydro</td>
<td>325</td>
<td>0</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>Renewable</td>
<td>200</td>
<td>0</td>
<td>440</td>
<td>0</td>
</tr>
<tr>
<td>Petroleum/Other</td>
<td>50</td>
<td>0.04</td>
<td>40</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>4095</strong></td>
<td><strong>2.2</strong></td>
<td><strong>4970</strong></td>
<td><strong>2.3</strong></td>
</tr>
</tbody>
</table>

2010 U.S Electricity Consumption and CO₂ Emissions. *EIA CE=42%*

*EIA Reference Projections 2035*

*CE=43%*

Source: EIA, Annual Energy Outlook 2013
SMRs can be Game Changers

“I believe small modular reactors could represent the next generation of nuclear energy technology, providing a strong opportunity for America to lead this emerging global industry.”

“We are committed to fostering the safe and secure contribution of nuclear power to the global energy mix.”

~ IAEA International Conference on Nuclear Security – July 1, 2013
Well-understood Technology
- Uranium Oxide fuels
- Regulatory and operating experience

Commercial Interest
- At least 4 LWR vendors
- Vendor/Utility coalitions being established

Manufacturing industry involved
- Could revitalize U.S. nuclear infrastructure and create new industries
Design Features that Improve SMR Safety

SMR designs share a common set of design principles to enhance plant safety and robustness

- Incorporation of primary system components into a single vessel
  - Eliminates large pipe break accidents

- Increased ratio of water inventory to decay heat
  - More effective decay heat removal
  - Much longer “coping time”

- Vessel and component layouts that facilitate natural convection cooling by gravity of the core and vessel
  - Eliminates need for electrical power to drive cooling systems

- Below-grade construction of the reactor vessel and spent fuel storage pool
  - Enhanced resistance to seismic events
  - Improved security
SMRs Could Potentially Replace Retiring Coal Plants

Potential SMR Market

\[ \Sigma = 120 \text{ GW(e)} \]
Economic Considerations

**Capital cost comparison**
- New AP1000 reactors in the U.S. are $5B - $7B
- Estimate for SMRs are:
  - $4,700 - $6,000/kWe or
  - $900M - $1200M for 200 MWe plant

**Naval reactor industrial experience shows significant learning**
- Assembly line replication optimizes cost, schedule and quality through greater standardization of components and processes

**Preliminary conclusion is that**
“economy of mass production” can be competitive with “economy of scale”
In 2012, DOE initiated a 6 year/$452 M program

Accelerate commercial SMR development through public/private arrangements
  • Deployment as early as 2022

Provide financial assistance for design engineering, testing, certification, and licensing of promising SMR technologies with high likelihood of being deployed at domestic sites

Funding being provided to industry partners though cost sharing
  • Generation mPower selected on the first funding opportunity
  • Currently reviewing applications for the second funding opportunity

Exploring additional mechanisms for SMR fleet deployment

The U.S. Government wants to support the safest, most robust SMR designs that minimize the probability of any radioactivity release
Commissioned Integrated Systems Test Facility in 2012 to analyze plant performance & response

Established fuel fabrication & testing facility in 2013

Conducting component prototype testing on reactor coolant pumps & control rod drive mechanisms

Site characterization sampling at the Clinch River Site

Significant pre-application interactions with the Nuclear Regulatory Commission

Design Certification Application (Oct 2014) and Construction Permit Application (Jun 2015) on schedule
Our long term goal is to enable deployment of a fleet of SMRs, not just 1 or 2 units.

Envision need for >50 GWe capacity in coming decades based on coal plant replacements alone.

Long term vision is that SMRs would evolve through anticipated deployment phases:
- Regulatory (*where we are today*)
- Early adopters (*first 20 units*)
- Full-scale factory production (*20 – 40 units/year*)
Summary – SMR Technologies are of Great Interest in the U.S.

- Further improve passive safety technology
- Reduce capital cost and project risk
- Regain technical leadership and advance innovative reactor technologies and concepts
- Create high-quality domestic manufacturing, construction, and engineering jobs
- Become global leader in SMR technology based on mature nuclear infrastructure and NRC certified designs

Challenge to SMR fleet deployment:
Prove economy of mass production is competitive with economy of scale