Nuclear Energy for Remote Applications

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Objectives

► Consider GenIII+/GenIV nuclear power plants for remote applications

► ACEP – INL/CSNR collaboration:

**POLAR** design team
- Taylor Duffin (*University of Utah*)
- Michael Kuca (*University of Alaska*)
- Haley McIntyre (*University of Alaska*)
- Christopher Morrison (*Rensselaer Polytechnic Institute*)
- Vishal Patel (*Texas A&M*)
- Alana Vilagi (*University of Alaska*)

► Opportunities and Obstacles to deployment
Fuel Supply Chain; Consumer Costs

- AK utilities: $0.20 to $1.30 per kWh
- Remote fuel price: $5 to $10 per gallon

Technology: Big Picture

INL (2013)
Technology: Small and Mini

Gen III+ iPWR
- Integrates steam generator into pressure vessel
- Passive designs remove decay heat
- US Modular design compliments macro-grid

Examples (MWe)
- NuScale - 45
- CAREM – 25

Gen IV reactors
- Alternative cooling designs
- Factory sealed, no refueling
- Individual units compliment micro-grid

Examples (MWe)
- Toshiba 4S – 10
- G4M – 25
- SSTAR - 20
CSNR ACEP Collaboration

- CSNR: mini reactors for space exploration
  - Some aspects apply to northern deployment
- Design a mini Gen IV mobile reactor
  - Parameters
    - Safe
    - Transportable
    - Passive cooling, Non-pressurized vessel
    - Less than 10 MWe
    - Long life
POLAR
Passively Operated Lead Arctic Reactor

- 15MWth/5MWe
- PbBi cooled, natural circulation
- Core Outlet Temp 550 °C
- Open air Brayton Cycle 500 °C
- Ship weight 100 ton
# POLAR Lifetimes at 5 MWe

<table>
<thead>
<tr>
<th>Case</th>
<th>Approximate Lifetime (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W-Cermet Fuel Loading 1</td>
<td>6</td>
</tr>
<tr>
<td>W-Cermet Fuel Loading 2</td>
<td>10</td>
</tr>
<tr>
<td>SiC Fuel</td>
<td>15</td>
</tr>
<tr>
<td>UZr Fuel</td>
<td>20</td>
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</tbody>
</table>
## Process Heat Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Temperature Range (Celsius)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Processing</td>
<td>30-50</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>45-50</td>
</tr>
<tr>
<td>District Heating</td>
<td>30-80</td>
</tr>
<tr>
<td>Desalination</td>
<td>30-130</td>
</tr>
<tr>
<td>Biomass to Biofuels</td>
<td>200-500</td>
</tr>
<tr>
<td>Oil Production</td>
<td>500-600</td>
</tr>
<tr>
<td>Coal to liquid fuels</td>
<td>800-900</td>
</tr>
<tr>
<td>Hydrogen Production</td>
<td>800-1000</td>
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</tbody>
</table>
Process Heat Applications
Licensing Issues for SMRs

► Deterministic focus on Light Water Reactors
  • Staffing: 4 operators per shift for total 40-80
  • Core Damage Frequency

► Possible Strategies for Gen IV
  • New Regulations – time consuming
  • Exemptions – complex
  • Risk-Informed Performance-Based Licensing
Risk-Informed Performance-Based Licensing

- Preferred licensing strategy for the Next Generation Nuclear Plant project
- Review process that emphasizes outcomes rather than prescriptive methods for achieving them, providing more flexibility in design
NRC Licensing Timeline

- **Generation III+ Evolutionary Designs**
  - LWRs
  - iPWRs
  - NuScale
  - mPower
  - HI-SMUR
  - W-SMR
  - HTGR

- **Generation IV Revolutionary Designs**
  - NGNP
  - PRISM
  - 4S
  - GIF
  - Gen4

- **Fast Reactors – Closed Fuel Cycle**
- **GIF – DOE Supplied**
- **LMRs**
- **iPWRs**
- **LWRs Gen III+**

- **Time (Y)**
  - 2012
  - 2022
  - 2032
  - 2042

- **Beyond the Horizon**
Alaska Sustainable Energy Act 2010

- Gave Legislature authority to designate land in state for nuclear facility based on economics
  - Health and public safety NRC jurisdiction

- The Department of Environmental Conservation shall adopt regulations governing the issuance of nuclear facility siting permits
  - Authorization program has not been created

- Require municipal approval
Conclusions

• Remote nuclear power plants may be viable in 2020s
  • Continue UA R&D Partnerships

• Lack of super utility; promote stakeholder alliance
  – Military, Civilian, Industry
  – Communicate with state and federal legislators

• Licensing challenges are not insurmountable
  – Early site permitting
  – Siting facilitated through legislature

• Initial capital investments
  – First of a kind funding
  – Master Limited Partnership
References


Ingersoll, et. al. (2004). *Status of Preconceptual Design of the Advanced High-Temperature Reactor (AHTR)*. ORNL.


References


Sabharawall, et. al. (2011). Feasibility study of secondary heat exchanger concepts of the advanced high temperature reactor. INL/EXT-11-23076


Venneri, et. al. (2014). Design of a Tungsten CERMET LEU-NTR. ANS-NETS.

Questions?