Framing the discussion

• Geo-political relevance
  – Carbon and Climate ... or ... Security and Non-proliferation
  – Stakeholders and their timeframes

• Gen III+ LWR designs are “safe enough”
  – The meaning of CDF = 10^{-8}

• Economics in the global energy industry

• Affordability and Competitiveness
  – The role of subsidies

• Risk management
  – Promise versus Proven
  – History of economies of scale and modularization

• Fuel cycle efficiency and nuclear waste
  – Stakeholder versus Customer issues

A nuclear power “product” that Customers want, when they need it
Nuclear Power Development: Search for Competitiveness

Advanced Nuclear Energy may deliver an Affordable and Competitive product

**Gen IV SMR Value Proposition**

- **Size Optimization**
  - Affordability
  - Flexibility

- **Standardization**
  - Fleet O&M economics
  - Rapid shift to NOAK construction

- **Inherent safety**
  - Nuclear island simplicity
  - Limited engineered safety features
  - Mechanistic “Severe Accidents”
Focus on most mature, lowest risk designs can enable Customer relevance.
Advanced Nuclear Energy Development: Real Timeline

Comments

- Innovators not looking “down the road” ... reality of cost and time commitments
- Licensing risk-reduction pushed to back-end ... not aligned with investment timing
- Deregulated and developing markets averse to FOAK costs and risks ... not first movers
- A few Gen IV designs more mature than Gen III+ SMRs ... lower risk, less time

Integrated timeline, cost, and risk underestimated by many stakeholders
Development History: Schedule & Cost Performance

**Domestic:** Most recent U.S. experience is 31 years and counting …
- Westinghouse AP-1000
  - Began life as AP-600 in 1985
  - Attempted to grow out of LCOE problems with shift to AP-1000
  - Final NRC Design Certification amendment issued after 19 revisions to the design
- The uncertain legacy of NP-2010 and the Energy Policy Act of 2005
  - 50/50 cost-sharing program through design certification, with some FOAK risk reduction and PTC
  - GE’s ESBWR was never built
  - Westinghouse sold to BNFL in 1999, then to Toshiba in 2006, then tech transfer deal with SNPTC

**International:** Olkiluoto-3 EPC construction planned for 5 years, now 14 years+
- Variations in licensing requirements, redesign, and component/construction quality issues
- Cost estimate increased by almost a factor of 3 from €3B to €8.5B

Recent nuclear development schedule and cost performance unsustainable
… after all this effort, there is no firm backlog of new orders for these designs
Nuclear Power Development: Timeline “lessons learned”

1. NP-2010 cost-sharing ended after licensing, with 50% of development cost remaining
2. Limited backlog of customer orders drives focus on FOAK cost minimization, short-view
3. Financial pressures drive reactor designers and EPC partners to start construction early
4. Designs not “shovel-ready” when construction begins, causing delays, rework
5. Supply chain not ready due to late engineering and planning
6. Deployment of new GW-class reactors treated as projects, not products
   - Limited standardization
   - Local content and workforce
7. Government involvement in many global procurement processes biases EPC decisions

Root-cause of deployment cost overruns and missed schedules lie in development
Private sector capital can help bring innovation and a sense of urgency, but ...

- Many large fully-public industrial firms not significantly engaged in advanced nuclear
  - GE, Westinghouse, B&W, Siemens, Rolls-Royce, Toshiba, Mitsubishi, Hitachi, etc.
  - Legacy challenges and experiences with GW-class technology development programs
- Most claimed $1.6B in “new” private capital investment is skewed to a few programs
  - Bill Gates’ TerraPower “Black Swan” … 20 year+ planning horizon
  - Gen III+ SMRs … still waiting for the first firm Customer order
- Many venture capital-backed early stage startup companies “plan” early exit
- Private sector investment demands significant change to “business-as-usual”
  - Utility-scale technologies which are economically competitive
  - 10 year development-to-deployment timeline
  - U.S. NRC regulatory reform that enables step-wise licensing with step-wise investment
  - Harmonization of global nuclear regulations to support design certification standardization
  - Exponential increase in market demand or subsidies to offset development costs

Entrepreneurs can unlock Gen IV’s potential ... with a major landscape shift
Nuclear Power Development: Public-Private Partnerships

**Fully or partially nationalized deployment partnerships:**
- China – largest new-build program in the world, full spectrum of technologies
- Russia – robust nuclear industry, in spite of severe domestic economic turmoil
- France – continued slow new-build, development and deployment of EPR

=> *Investments immune to free-market economics, implementing national energy policies*

**Regulated or quasi-regulated utilities**
- TVA, Southern Company and SCANA only new-build programs in U.S.

=> *Regulated return on investment, CWIP*

**Deregulated energy markets**
- UK – No new build construction after more than a decade of policy incentives
- US – No new build projects underway

=> *No comprehensive public-private partnership addressing full market realities*

Global new build only progressing where public financing overcomes challenges
### Partnerships for Gen IV: A Notional Path Forward

#### Modeling and Simulation
- 32 x $100M
  - 50/50 Cost share
  - Analysis platform
  - Technical support

#### Component & Fuel Testing
- 16 x $200M
  - 50/50 Cost share
  - “Test bed”
  - Technical support

#### Demonstration and Prototyping
- 8 x $300M
  - 50/50 Cost share
  - EPC risk
  - Host site
  - Licensing support
  - Technical support

#### FOAK Deployment
- 4 x $500M
  - 50/50 Cost share
  - EPC risk
  - PPA
  - Host site
  - State-of-art enhancements

### Government Role
- 50/50 Cost share
- EPC risk
- Host site
- Licensing support
- State-of-art enhancements

### Private Investor Role
- 50/50 Cost share
- EPC risk
- PPA
- Host site
- State-of-art enhancements

$10.8B ... exactly the same as the U.S. DOE spent on SFS technology alone
Reactor Technology Development Challenges: Conclusions

- Advanced nuclear technology offers promise of products that customers want
- Some Gen IV design ready for deployment by mid-2020’s ... geo-politically relevant
- 20 year+ development timelines and $1B+ investments are a major challenge
- Too much pressure on private sector results in undesirable deployment outcomes
- Significant new private sector investment will require industry landscape shifts
- Public-private partnerships necessary in deregulated, non-nationalized markets
- Full-scale Gen IV program is notionally $10B, and delivers FOAK by mid 2020’s

Nuclear development and deployment challenges are solvable ... by 2020’s