UxC Actively Tracks Reactor Developments and Market Demand

► Nuclear Power Outlook (NPO)
  • Quarterly reviews of country developments & bottom-up reactor forecasts to 2040

► Nuclear Reactor Technology Assessments
  • Analysis of all major LWR/PHWR designs

► Small Modular Reactor Market Outlook
  • Analysis of all available SMR designs

► Supporting Utilities on New Reactors
  • Creating cost models & analysis for new plants
  • Advising utilities on vendor negotiations, etc.

► UxC Requirements Model (URM)
  • Used for UxC fuel forecasts since Q1 2009
Where Have We Been?

- 61-Year Annual Average: 10 Units / 7,500 MWe
- Average Since 2000: 4 Units / 3,500 MWe
- 73% of All Operating Units Built Before 1990

Total New Builds Since 1954:
- 588 Units
- 455 GWe
Where Are We Now?

- 437 reactors / 376 GWe operating in 31 countries today
  - Provide roughly 13% of total global electricity as baseload power
- 67 reactors under construction in 15 countries
- Traditional ~20 countries with nuclear power in steady state, but a few in slow decline (e.g., Germany, Japan, Belgium)
- 10 faster growth/new build expansion countries
- Up to 20 “newcomer states” → no more than 10 possible by 2030
- Post-Fukushima, safety is paramount (trumps economics)
- Relative low costs of competing energy sources makes new nuclear a hard sell in many places (including the U.S.)
- Same logic for nuclear power applies as before:
  - Increased world demand for electricity due to economic & population growth
  - Climate change and environmental issues impacting fossil fuels
  - Many countries desire enhanced energy security and diversification
- However, fallout from Fukushima, shale gas boom, and renewables has created significant headwinds for global nuclear power…
Current Major Questions

► What will be the pace of China’s new reactor construction?
► Will any more U.S. reactors retire early? Who will build new ones?
► When will Japan’s reactors restart? Will any new units be built?
► Are phase-outs in Germany, Belgium & Taiwan a done deal?
► What are the costs for post-Fukushima safety requirements?
► Which reactor suppliers will stay? Which might get out?
► Will Ukraine turmoil impact Russian exports?
► Are China’s reactor export ambitions to be taken seriously?
► Can climate change policies be fashioned to help nuclear?
► Can potential new countries make progress & achieve goals?
► What is the future of SMRs?
Nuclear power remains a critical part of the global energy system, and all independent forecasts indicate continued expansion.
How Will We Get There?

- **Average Age of Operating Units:** 28 Years Old
- **Assuming Global Average 55-Year Lifespan:**
  - By 2030, Loss of 72 Units & 48 GWe
  - By 2040, Loss of 243 Units & 206 GWe
  - By 2050, Loss of 362 Units & 329 GWe

Future growth requires new build plus replacement capacity!

~1,040 GWe new build
~720 GWe new build
~490 GWe new build
Current & Potential Nuclear Countries

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Status</th>
<th>Color</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>One or more operating nuclear power plants</td>
<td>Grey</td>
<td>31</td>
</tr>
<tr>
<td>High Potential</td>
<td>Active construction or significant preparatory activities</td>
<td>Red</td>
<td>14</td>
</tr>
<tr>
<td>Medium Potential</td>
<td>Some preparatory activities, but more long-term prospects</td>
<td>Orange</td>
<td>17</td>
</tr>
<tr>
<td>Low Potential</td>
<td>Interest, but no serious preparations or competencies</td>
<td>Yellow</td>
<td>13</td>
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Source: UxC *Nuclear Power Outlook*, Q1 2015
Critical Countries

Nuclear power’s future depends greatly on 7 key countries:
- Additional Capacity in: China, Russia, India and South Korea (CRIS)
- Maintaining Capacity in: U.S., France and Japan

- **China**: 26 construction / 100+ in planning
- **Russia**: 9 construction / ~20 in planning
- **India**: 6 construction / 30+ in planning
- **South Korea**: 5 construction / ~10 in planning
- **U.S.**: 5 construction / new build vs. shutdowns?
- **France**: 1 construction / dropping to 50%?
- **Japan**: 2 construction / how many will restart?

CRIS represent ~66% of all new build in UxC forecasts thru 2030

Totals:
- 54 under construction
- 170 additional possible by 2030

Other important countries to watch:
- UAE, UK, Turkey, Poland, Finland, Saudi Arabia, South Africa, Brazil
UxC Nuclear Power Forecasts

Base Case: 57% net growth by 2030

Source: UxC *Nuclear Power Outlook*, Q1 2015
Asia = 44% of world in 2030 (vs. 23% in 2014)

Source: UxC Nuclear Power Outlook, Q1 2015
Reactor Technology Selections

New Reactor Types, 2009-2020

- PWR: 82%
- PHWR: 11%
- BWR: 4%
- FBR/HTR: 3%

New Reactor Vendors, 2009-2020

- China: 33%
- Russia: 20%
- KEPCO: 13%
- Westinghouse: 10%
- India: 8%
- AREVA: 6%
- CANDU Energy: 3%
- GE-Hitachi: 4%
- MHI: 1%
- Undecided/Other: 2%

96 total units
(70 units in 2015-2020)

Source: UxC Nuclear Power Outlook, Q1 2015
Reactor Technology Options

► Large LWRs
  ● Vast majority of current and projected future reactors are large PWRs
  ● Leading designs include Westinghouse AP1000, AREVA EPR, KEPCO APR1400, Rosatom VVER-1200, and China Hualong-1

► PHWRs (CANDU)
  ● Only few countries interested: India, Canada, Argentina, Romania

► SMRs
  ● LWR designs have the market edge (SMART, NuScale, mPower, Holtec, W-SMR, CAREM)
  ● Other designs are farther out (Gen4Energy, EM², 4S)
  ● SMRs need economies of scale to be achievable (chicken & egg)

► Advanced Reactors
  ● Few FBRs in world: Russia, India, China
  ● Liquid metal designs show promise: Transatomic, Terrestrial, PRISM
  ● Bill Gates’ support of TerraPower makes people pay attention
NSSS Market Developments

► Post-Fukushima, reactor designs that can best handle extended Station Blackout events will likely have an advantage.
► Due to a smaller “nuclear market pie,” expect fierce competition and consolidation as well as certain vendors exiting the market.
► Russia (Rosatom), France (AREVA), South Korea (KEPCO), and Japanese vendors (Toshiba, Hitachi, MHI) have advantage in bidding reactor projects given strong government support.
► China’s “going out strategy” means companies are looking to exports as well as investments in international nuclear projects.
► Technology transfer and localizing content remains important for many newcomers.
► SMRs are getting much more attention due to perceived pluses in terms of cost and safety factors.
Nuclear Project Business Models

► Traditional: NPP built & operated by electricity utility
  ● Turn-Key Project
  ● EPC Contract Only
  ● Complete Utility Control

► Multiple Owners (Group Financing)

► NSSS Provides Financing

► Build-Own-Operate (BOO)

► Build-Own-Operate-Transfer (BOOT)

► Government Financing or Support (e.g., gov’t sites)

► Finding ways to overcome the high capital burden is critical to opening new markets
Global Successes & Challenges

► **Successes:**
  ● China has mastered large-scale construction and reactor supply chain
  ● Vendors are working better at collaborating and teaming arrangements
  ● Russia has proven that providing financing with NPPs works
  ● Public can be convinced of nuclear power advantages (e.g., UK)
  ● Passive safety features can be added to designs without huge cost impacts

► **Challenges:**
  ● Continuing political uncertainty in various countries
  ● Regulatory reviews take too much time and cost too much money
  ● Plethora of reactor designs makes it hard for customers to choose
  ● Over-reliance on government support; lack of financing options
  ● Newcomers often underestimate the time horizon to get to new nuclear
Nuclear Fuel Cycle
Front-End Nuclear Fuel Markets

► Major Trends
  ● Post-Fukushima all sectors are oversupplied
  ● Utilities are holding large inventories and future demand growth is lower
  ● Producers have reduced output, but overcapacity remains
    ▪ Uranium: Mined supply plus secondary supplies are well above annual req’ts
    ▪ Conversion: Capacity is sufficient through 2025, but new plants will be needed
    ▪ Enrichment: Large overcapacity all in centrifuges / Future projects on hold
    ▪ Fabrication: Capacities suffice, but technical limits given design variations

► Impact of Global Nuclear Expansion
  ● Most new reactor sales include fuel supplies
  ● Expanding nuclear countries are increasing fuel cycle activities
    ▪ Examples: China, India, Russia, South Korea
  ● Some newcomer countries are considering domestic fuel cycle development
    ▪ Examples: Saudi Arabia, Jordan, Vietnam
  ● Traditional markets losing importance as emphasis shifts to Asia
Back-End Fuel Cycle Issues

► Major Trends
● Only Finland and Sweden are well-advanced in repository development
● Reprocessing limited to handful of countries (France, Russia, Japan, etc.)
● Default preferred option is long-term storage in pools & dry casks
● Large decommissioning programs mean huge increase in RadWaste

► Impact of Global Nuclear Expansion
● Despite talk, no new vendors are offering spent fuel take-back
● Some growing countries pursuing reprocessing (China, South Korea, India)
● Newcomer countries are focused on reactor construction and fuel supply
● Low level waste disposal capacity remains insufficient
● As typical, back-end issues are being pushed to the back-burner
Conclusions

► Reactor growth is global, but heaviest in Asia. Near term story is less optimistic, but long-term fundamentals remain strong
► Key factors impacting future new build rate include: natural gas prices, carbon policies and political will
► In order to maintain steady growth, additional plus replacement capacity will be needed on a large scale
► Post-Fukushima market shake-out will likely continue for several more years
► SMRs showing promise, but won’t see success until post-2025
► Fuel cycle markets will follow the reactor demand developments
► Challenges/Risks for global nuclear power remain:
  ● Another major accident
  ● Continued high capital costs for new reactors
  ● Negative public opinion and policymaker sentiment
  ● Shifts in economic growth or relative economics of other energy options
Questions?

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