# Challenges and Lessons Learned for New Nuclear Build Projects

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Technical & Regulatory Issues Facing Nuclear Power Plants

Leveraging Global Experience

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# Presentation Overview

- Brief Excel Services Corporation (EXCEL) History and New Nuclear Build Experience & Capabilities
- New Nuclear Build Challenges and Strategies for Success
- Summary & Conclusions

# Brief EXCEL History

- For over 33 years, EXCEL has been delivering innovative and value-added solutions to the most complex issues facing the global energy industry.
- EXCEL is ideally positioned to assist its clients address the challenges faced in the rapidly evolving energy industry.
- With deep expertise and broad reach into solutions for operating safely, efficiently, and cost-effectively, EXCEL can create sustained value for energy producers, and any client responsible for protecting critical infrastructure, managing and mitigating risks, and strengthening all aspects of operational excellence.

# New Nuclear Build (NNB) Services

## *Service Offerings*

New Nuclear Build Services

- Technology Selection
- Site Selection
- Early Site Permit (ESP)
- Nuclear Infrastructure Establishment
- Design Certification Document (DCD)
- Combined License Application (COLA)
- Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)
- Small and Advanced Reactors
- 10 CFR 50 and 52 Training



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# New Nuclear Build Services

## *Selected Key Projects*

New Nuclear Build Services

- Technology Selection
  - Switzerland
  - Finland
  - UAE
- Site Selection
  - Switzerland
  - Finland
  - UAE
- Early Site Permit (ESP)
  - Exelon Clinton Power Station
  - TVA Clinch River SMR Project

# New Nuclear Build Services

## *Selected Key Projects*

New Nuclear Build Services

- Nuclear Infrastructure Establishment
  - UAE
  - Ongoing: Kenya and others
- Design Certification Document (DCD)
  - AP1000 Design Certification Application
  - GEH ESBWR Design Certification Application
  - AREVA EPR Design Certification Application
  - MHI US-APWR Design Certification Application
  - KHNP APR1400 Design Certification Application
  - Toshiba ABWR Design Certification Rule Renewal Application

# New Nuclear Build Services

## *Selected Key Projects*

New Nuclear Build Services

- Combined License Application (COLA)
  - SNC Stewart County Project COLA
  - NuStart AP1000 Reference COLA (R-COLA) and Subsequent COLAs (S-COLAs)
  - NuStart ESBWR R-COLA
  - UniStar  Four COLAs
  - Entergy, DTE Energy, and Dominion Power COLAs (GEH ESBWR)
  - NRG South Texas Project (STP) COLA
  - Vogtle COLA and all Subsequent Licensing Work
  - VC  Summer COLA  and all Subsequent Licensing Work

# New Nuclear Build Services

## *Selected Key Projects*

New Nuclear Build Services

- Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)
  - SNC's VEGP Units 3 & 4 closure work
  - SCANAs VC  Summer 2 and 3 closure work
- Small and Advanced Reactors
  - All LWR, Molten Salt, HTGR, Fast Neutron Designs
- 10 CFR 50 and 52 Training
  - Westinghouse Corporation
  - KHNP/KEPCO E&C

# EXCEL Global Impact

EXCEL has worked in countries around the world highlighted in blue



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# New Nuclear Build Challenges and Strategies for Success

# Nuclear Challenges

1. Political Will / Risk
2. Public Acceptance – Opinions and Perceptions
3. Reputation Risk
4. Nuclear Non-Proliferation; IAEA safeguards; export controls, nuclear liability and insurance limitations
5. Financial Backing/Investments/Contractual Framework
6. Nuclear Infrastructure Establishment (Including Independent Regulator)
7. Environmental/ Siting
8. Reactor technology selection

# Nuclear Challenges (2)

9. Licensing Strategy
10. Construction Strategy
11. Local Nuclear Education and University Program
12. Work Force Establishment and Local Nuclear Supply Chain Industry – Human Resources and Skills
13. Radioactive waste treatment; disposal
14. Decommissioning

# Political Will / Risks

- There is a strong need for a National Policy for nuclear power program planning.
- The decision to develop a nuclear power program means ~100+ year commitment for the country based on development, operation and final decommissioning of the NPPs, as well as managing and storing the Used Fuel.

# Public Acceptance – Opinions and Perceptions

- The public and stakeholders must have an understanding and appreciation of the nuclear program and its benefits

# Reputation Risk

1. All participants concerned: All project participants will be concerned with project risks
2. Risk Appetite: Each participant will have a different risk appetite
3. Risk-adverse: Investors and lenders are likely to be the most risk-adverse
4. Protection from exposure: Lenders will want to ensure they are not exposed/exposure is strictly limited

# Nuclear Infrastructure Establishment

## Nuclear Non-Proliferation; IAEA Safeguards; Export Controls, Nuclear Liability & Insurance Limitations

- IAEA membership
- Nuclear Non-Proliferation Treaty
- Ratification of Key International treaties – see below

No Western Nuclear Vendor will deliver w/o these Treaties in place

Your Country

- Treaty on Non-Proliferation of Nuclear Weapons
- Comprehensive Safeguards Agreement (CSA)
- Additional Protocol to CSA
- Convention on Physical Protection of Nuclear Material
- Convention on the Suppression of Acts of Nuclear Terrorism
- Convention on Early Notification of a Nuclear Accident
- Convention on Assistance in the Case of Nuclear/Radiological Emergency
- Convention on Nuclear Safety
- Joint Convention on the Safety of Spent Fuel Management
- Liability Conventions
  - Vienna Convention on Civil Liability for Nuclear Damage (and Protocol to Amend Vienna Convention)
  - Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention
  - Convention on Supplementary Compensation for Nuclear Damage

# Nuclear Infrastructure Establishment

## Nuclear Non-Proliferation; IAEA Safeguards; Export Controls, Nuclear Liability & Insurance Limitations

No Nuclear Vendor belonging to the Nuclear Suppliers Group (NSG, 46 countries) will deliver w/o these minimum requirements in place.

- **National Atomic Law** – incorporating required International Treaties
  - Establish independent Nuclear Regulatory Authority (IAEA SSG-16)
  - Establish Nuclear Regulations (minimum IAEA SSG-12)
  - Establish "Intelligent" Regulator (can outsource to TSOs as needed):
    - Site Licensing and permitting
    - NPP Licensing (Construction, Startup & Operating License)
    - Inspections and enforcement (during Construction and Operation)
    - Radiation Protection (both nuclear and non-nuclear facilities)
    - Nuclear Radiation Safety (Emergency Preparedness Planning)
    - Reload Fuel licensing (including Inspections)
    - Nuclear Waste and Used Fuel management
    - Nuclear Liability and Insurance cover
    - Nuclear Safeguard and export/import controls
    - Future NPP changes / upgrades and refurbishment
    - Periodical Safety reviews of NPP (typically 10 years)
    - Decommissioning planning
- Establish bi-lateral agreements with NPP Vendor country (at project start)
- Enter into a protocol with Regulator who issued the Design Certification

# Financial Backing

- The Financial Institution must have confidence in the capability to design, license, construct and place in operation the nuclear facility on schedule and on budget

# Financial Backing (2)

Successful financing of a nuclear power plant has to take into account key areas in nuclear project development:


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# Financial Backing (3)

- Intergovernmental and Host Government Agreements
- Shareholders Agreement
  - Attractive to future equity investors?
- Power Purchase Agreement
  - Who absorbs price / volume risk?
  - Payment guarantee?
  - Risk of construction delays?
- EPC Contract
  - Price and incentive / delay penalty structure
  - Contractual structure -- EPC v. Island v. Multi-Contract
- O&M Contracts
- Nuclear Fuel Supply Agreements
- Project Finance
  - As a model, not used for nuclear projects but disciplined approach to risk assessment is highly beneficial

# Financial Backing (4)

Technical and Commercial Feasibility

- Licensing / design certification
- Prototype
- Independent Assessment (Technical Advisory Group)
- Experienced and Committed Management and Team
- IP

Business Structure

- Financially attractive
- Flexible
- IP considerations

Market

- Viable business plan
- Letters of Intent

# Nuclear Infrastructure Establishment
# Setting up a Robust/Credible Regulator

| | Steps | Requirement |
|---|---|---|
| **1** | National Nuclear Policy | International Conventions and independent Regulatory Power and Duties of Regulator |
| **2** | Set up Independent Nuclear Regulator | Independent Nuclear Regulator empowered to enact credible and transparent Nuclear Regulations, Oversight and has the Powers to ensure safety of nuclear facilities |
| **3** | Develop Nuclear Regulations | Use existing international Nuclear Regulations - customized to new Country (about 30 – 40 needed) |
| **4** | Buildup Local Regulatory Organization to required capacity | Bring in the required experts (initially mainly Expats) to be able to issue the required initial Licenses within 12 -18 months for Site / Construction License |
| **5** | Train and mentor the local Regulator | Expat experts will provide continuous training / mentoring to buildup local competence |
| **6** | Startup, Operations, Decommissioning | Expat experts will provide continuous training / mentoring to buildup required competence before needed |



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# Environmental / Siting

- Need an Environmental Impact Assessment (EIA) of a potential NPP Site to be approved by Regulatory Authorities
- Based on a number of considerations
  - Seismology
  - Geography
  - Cooling
  - Proximity to public

# Reactor Technology Selection

- Multiple large build and small build technologies available
- Each have their unique strengths and weaknesses
- Perform a technology assessment that addresses your country needs

# Reactor Technology Selection (2)

| | Russia | China | S. Korea | USA (GE) | USA (W) | France | Japan | Canada |
|---|---|---|---|---|---|---|---|---|
| **Company** | **Rosatom** | **CNNC, CGN, SPIC** | **KHNP** | **GE-H H-GE** | **W** | **AREVA EDF** | **Toshiba Hitachi Mitsubishi** | **SNC Candu Energy** |
| **Intl Markets TODAY** | Belarus, Hungary, Finland, Turkey, Bangladesh, India, China, Vietnam, Jordan, Egypt, Armenia, Ukraine, Argentina | UK, Romania, Pakistan, Argentina | UAE | Japan, Taiwan, UK | China | China, Brazil, India, Turkey? | Taiwan, UK?, Turkey? | Romania, Argentina |
| **Intl Markets FUTURE** | Bulgaria, S. Africa, Brazil | UK, S. Africa, Argentina, Saudi Arabia, Turkey, Brazil, Egypt, Sudan, Algeria, Uganda | S. Africa, UK, Saudi Arabia | India? Saudi Arabia | India? Depends on Future Owner | S. Africa | BWR? | CANDU? |



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# Licensing Strategy

- Determined by Technology Chosen
- Design Certification or Licensing in the country of origin
- Efficient and Effective Approach

# Construction Strategy

## Cost and Time Overruns of a NPP Project

- FOAKE and incomplete design at construction start
- Vendor's lack of experience in new markets
- Owner's lack of strong top-down QA management
- Lack of experience from Reference Plant in operation
- Lack of independent 3rd Party Inspections (ASME-III)
- Lack of Lessons Learned from previous NPP projects
- Lack of supply chain company oversight & control
- Lack of experienced OE and TSOs
- Lack of effective Contract Incentives for Vendors

# Construction Strategy (2)

## Key Elements of an Effective Project Management Method

- Top-down QA management
- Establish Nuclear Safety Culture
- Experience from previous NNB projects
- Efficient PM Tools to keep track near real time
- Efficient Risk Management procedure
- Efficient Corrective Action Program (CAP)
- Efficient Document Control Program
- Support from independent TSO's
- Close/continuous contact with relevant Authorities

# Local Nuclear Education and University Program

- University Nuclear Program
- Recruitment and Hiring
- Utility and Business Partnership in Education and Training
- Nuclear Training Institute

# Work Force Establishment and Local Nuclear Supply Chain Industry

- Following are minimum staffing requirements for new build NPPs today:
  - Owner Organization 100 – 150 / NPP
  - Operator Organization 300 – 500 / NPP
  - Regulatory Body 100 – 150 / first 2 Units
- Initially up to 80+% of expert staff could be Expats.
- In the longer term the local staff should reach 50+%.
- During planning, licensing and construction an Owners Engineer (OE) can bring in about 100 Expat experts.
- Commercial Operation can be outsourced to an experienced nuclear Fleet Operator.

# Work Force Establishment and Local Nuclear Supply Chain Industry (2)

- Time-Phased Approach to Localization and Integration with a Global Supply Base of a Vendor:
  - Not a "one-size-fits-all" approach
  - Initial level is determined by Local supply capacities and capabilities
  - Phased-in over time based on development of skills and investment
  - Driven by local supplier readiness to schedules and compliance to regulatory and QA requirements of technology supplier
  - Can evolve to include JVs and Technology Transfer if/when appropriate.

# Radioactive Waste Treatment and Disposal

- Radioactive Waste Treatment and Disposal methods need to be evaluated to determine the best option (s) for each country / region
- There are multiple options available across the global industry

# Decommissioning

- Decommissioning planning and setting up a Decommissioning Fund at the beginning of the life of the nuclear plant will assist in ensuring there are adequate funds for decommissioning the site and returning it to some agreed to status
- This timeframe may be between 40 and 100 years

# Overall Nuclear vs. Conventional Power Plant Risks

| Conventional Power Plant | Nuclear Power Plant |
|---|---|
| Proven technology | Possibly first of a kind (FOAK) technology; design certification required |
| No special requirements for supporting infrastructure | Development of a nuclear power program with specialised supporting industry and organisations |
| No special siting requirements | Site selection and characterisation is complex |
| Established regulatory oversight | Extensive, specialist and ongoing licensing and regulatory oversight |
| Supply chain relatively secure | Long lead time; possible global supply chain bottlenecks. Highly regulated international commerce of nuclear equipment and technologies |
| No equivalent spent fuel/radioactive waste issues | Spent fuel and radioactive waste management and disposal and funding requirements |
| No special decommissioning requirements | Special decommissioning requirements and funding obligations |
| No special liability arrangements | Special nuclear liability arrangements |
| No special insurance requirements | Nuclear insurance requirements |

# Overall Nuclear vs. Conventional Power Plant Risks (2)

| Conventional Power Plant | Nuclear Power Plant |
|---|---|
| Lower capital cost | High capital cost and liquidity required |
| Ascertainable political risk | High level of political risk = benefit/requirement of government support |
| Projects often financed on non/limited recourse basis – models/precedents exist (eg IPP/IWPPs) | No nuclear project financing to date; limited financing model/precedent |
| Short construction period: 2-3 years | Long construction period: 5-6 years |
| Shorter tenor for debt repayment | Longer tenor for debt repayment |
| Vendor may be replaced | Vendor usually not replaceable |
| Enforcement of security and lender step-in rights | Lender-step in rights and security over assets in the context of nuclear? |
| Higher fuel price as a % of levelized cost of electricity | Lower fuel price as a % of levelized cost of electricity |
| Limited import/export controls | Strict import/export controls |

# Summary & Conclusions

- NNB Challenges & Lessons Learned must be well understood to make the best, most well-informed decisions
- Strategies for success are available to effectively mitigate many of the risks inherent in large complex NNB Projects
- Teaming arrangements and partnerships with experienced global nuclear experts can provide significant benefits in navigating through a complicated process

# Questions?

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# BACK-UP MATERIAL

# Fuel Cycle Strategies

## a) Closed / Reprocessing

- To utilize reprocessed fuel requires a MOX Plan and only France has an operational one

## b) Direct Disposal (OPEN FC):

- China opted for a closed cycle
- Sweden developed and Finland licensed the world's first commercial Final Nuclear Repository
- This option will come into commercial operation in Finland around 2025 and in Sweden around 2045 (based on the Swedish KBS-3 technology, 500 meters underground)

## c) CANDU DUPIC Fuel cycle

- One CANDU EC-6 can run on Used Fuel from (3 - 4) LWRs, means 3xtimes longer than using natural Uranium fuel (reducing waste volume and "getting paid" for taking the LWR Used Fuel) --- but not yet implemented commercially