Design Requirements & Site Characterization for SMR deployment in Jordan
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Contents Outline

- Jordan – Overview
- Jordan Nuclear Program
- SMR activities
Jordan’s Country Profile

- Total Area: 89,213 Km²
- Sea Port: Aqaba
- Coastline: 26 Km
- Population: 8.1 million (2016)
  - 60% (15-64)
  - 35% (below 15)
- Climate: Mediterranean & Arid Desert
- GDP: $39.45 billion (2016)
- GDP Growth: 2.8% (2016)
Population

- Jordan is characterised by strong population growth over the past few years resulting from the in-streem of refugees from neighbouring countries.
- It increases the energy and water demand.
- Future population is difficult to estimate, which eventually increase the uncertainty of estimation the future energy demand.
• According to projections from the Ministry of Finance and the International Monetary Fund (IMF), future GDP will increase.

• From 2019, a fixed annual growth rate of 4% is projected.
Primary energy and electricity consumption

Share of electrical energy consumption between sectors in 2015:

15% Household and governmental buildings
15% Industrial
15% Commercial
23% Agriculture
2% Street lighting

Energy sources:
- Crude Oil and Products
- Coal
- Renewable Energy
- Natural Gas
- Imported Electricity

71% Crude Oil and Products
21% Coal
2% Renewable Energy
2% Natural Gas
2% Imported Electricity
The electrical energy consumed in 2015 reached 16,059 GWh compared to 15,391 GWh in 2014, representing a growth rate of 4.3%.

According to the EMRC Brochure 2015, the average electrical energy consumed per capita reached 1,685 kWh in 2015 compared to 2,358 kWh in 2014, a significant decline of -28.5%.

The annual peak is expected to grow to 6.4GW, 13.4GW and 27.1GW by 2055 for the low, baseline and high load growth scenarios respectively.

Transmission and distribution losses are not taken into account.
Water

- Jordan which is considered to be one of the 10 poorest countries worldwide in water resources and often suffers from water deficit
- the main source of water is natural rainfall
  - annual rainfall of less than 200 mm on 90 percent of its land.
  - The total annual water deficit is around 500 CM.
- increasing Jordan’s water capacity
  - Building additional dams
  - Strategic projects such as Red-Dead Canal
  - Water desalination
Jordan Nuclear Program

- Ensure the security of energy supply;
- Diversify the electricity generation sources;
- Provide competitive energy source;
- Reduce the imported fossil fuel bill;
- Exploit the national uranium resources;
- Encourage partnerships between the public and private sectors;
- Ensure the transfer of optimum technology and national worker’s contribution in all stages;
- Develop industries related to the energy sector; and
- Reduce the GHG emissions from power generation.
Jordan Nuclear Program

- Jordan Research and Training Reactor, JRTR
- Uranium Ore
- Nuclear Power Plant Project

- SMR???
NPP Model

- VVER-1000 AES-92.
- Our NPP is an inland NPP that will rely on treated waste water as its cooling water
- This is very similar Palo Verde/USA use of waste water for cooling
- We anticipate the need of 20 M m³/1,000 MWe unit per year
Palo Verde Inland NPP Site – Arizona, USA

Example of inland NPP using wastewater for cooling
Challenges of Large NPP

- Cooling Source
- Grid
- Funding and Financing

- SMRs may resolve these challenges!
Applications of Interest for SMRs (Jordan)

• Some are factory built and enjoy the advantage of being transported as is (one module) to the operation site thus make use of assembly like cost savings.

• SMR designs incorporate innovative approaches to achieve simplicity, modularity, and speed of built.

• Some of the attractive characteristics of SMRs include:
  – Passive safety features
  – Reduce financial risk,
  – Siting flexibility,
  – Reduced dependence on cooling water (dry cooling)

• For Jordan, these attractive new designs would play an essential goal in solving power and water issues the country is currently facing and is only expected to get more severe in the future.

• JAEC has considered SMRs as an option for several years and conducted several studies internally for the viability and attractiveness of SMRs as an option for Jordan.
Applications of Interest for SMRs (Jordan)

- Replace aging fossil plants.
- Offshore nuclear power plant (Floating SMRs).
- Can be located close to population areas.
- In-land away from water.
- Seismic locations.
- Cogeneration of heat & electricity.
- Water and Air Cooled Condensers
The technical requirements of Jordan with respect to SMR designs

- SMR design shall ensure the fundamental safety functions:
  - Control of the reactivity
  - Heat removal
  - Confinement / No radioactive releases

- The SMR design shall be such that its sensitivity to Postulated Initiating Events is minimized with no severe accidents.

- To ensure that the overall safety concept of defense in depth is maintained in all circumstances.
The technical requirements of Jordan with respect to SMR designs

- Appropriate measures against the effects of single failure or common cause failures shall be taken as far as practicable in SMR plant design:
  - Redundancy
  - Diversity
  - Independence (through functional isolation or physical separation)

- The SMR designs shall take the lessons learnt from Fukushima accident

- A modern digital I&C technology (no common cause failure between the different I&C for each module).
The technical requirements of Jordan with respect to SMR designs

- Safety goals
  - Core damage frequency (CDF) and large early release frequency (LERF) of SMR shall be lower than that one of the current large NPPs (by at least a factor = Power of Large NPP/Power of SMR).
  - The grace period of SMR plant shall be higher than that one of the current large NPPs.
The technical requirements of Jordan with respect to SMR designs

- Air craft impact resistance
  - The design shall meet Jordan’s requirement for the plant to be designed to ensure the safety of the plant in the event of a large commercial airplane crash.

- Proven Design and Licensibility:
  - SMRs shall use proven or conventional NPP coolant, moderator, fuel and proven safety analysis codes.
  - Preferred internationally certified SMR design for commercial deployment and generic design approval.
Strategic issues

- Jordan is requiring that the technology vendors ensure the availability of NPP fuel supply in the long term in a competitive open market and
- the potential for utilization of Jordan’s uranium resources.
- fulfil IAEA non-proliferation and Jordan’s high-level waste management objectives.

- RW and SF: the design should find solution for management of its RW and specially for SF.
- Non LWR needs further verification.
Site Considerations

- Seismicity
- Cooling water
- Meteorology and Environment
- Population
- External Hazards
## Site requirements

<table>
<thead>
<tr>
<th>Key Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Configuration</td>
<td>Modules or single unit</td>
</tr>
<tr>
<td></td>
<td>Underground</td>
</tr>
<tr>
<td></td>
<td>Onshore offshore</td>
</tr>
<tr>
<td>Foot print</td>
<td>This will affect the siting flexibility</td>
</tr>
<tr>
<td>Seismic design</td>
<td>The seismic design of SMR must be able to sustain the Jordan Seismic specifications at proposed site, it can reach 0.4 and 0.5 g</td>
</tr>
<tr>
<td>Emergency planing zone</td>
<td>SMR design shall minimize the size of both the exclusion zone as well as the emergency zone over the large NPPs. Such that no evacuation will be required. Because the location of the proposed site is close to high density population and to Jordan borders.</td>
</tr>
<tr>
<td>Aircraft crash</td>
<td>The Design shall meet Jordan’s requirement for the plant to be designed to ensure the safety of the plant in the event of a large commercial airplane crash</td>
</tr>
<tr>
<td>Cooling water</td>
<td>It is preferred that the design may offer solutions for dry cooling and minimizing the use of water.</td>
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</tbody>
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Proposed sites
Proposed sites
Aqaba Site

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geosciences</td>
<td>On the Fault</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>considerations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant Cooling</td>
<td>450 - 470m Elev</td>
<td>500 - 580m Elev</td>
<td>500 - 580m Elev</td>
<td>500 - 580m Elev</td>
</tr>
<tr>
<td>Plant Lay-out</td>
<td></td>
<td></td>
<td>Elongated Profile</td>
<td></td>
</tr>
<tr>
<td>Volume of spoils</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>to be excavated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance from</td>
<td>~ 1.5 km</td>
<td>~ 1.5 km</td>
<td>~ 3 km</td>
<td>~ 4km</td>
</tr>
<tr>
<td>Saudi Arabian border</td>
<td></td>
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</tbody>
</table>
Jordan energy demand is increasing, on the other hand water demand is also increasing. Finding electricity sources which will minimise the use of water will be in a great benefit to Jordan.

- Nuclear power is foreseen as a viable option for electricity generation and water desalination, however large.
  - Large NPPs has some challenges
  - SMRs are foreseen to resolve these challenges

- Nuclear Industry is mature and proven over many years, however, new design require further validation and verification.
A Memorandum of Understanding (MOU) has been signed between the Jordan Atomic Energy Commission and the King Abdullah City for Atomic and Renewable Energy on March 27, 2017.

The objective of the MOU is the preparation of a Bankable Feasibility Study for the construction of two SMRs for electricity generation and water desalination.

This Bankable Feasibility Study (BFS) will entail an in-depth Technical, Commercial, and Financial assessment of SMR technologies available today for near term deployment.

The outcome expected is a BFS with enough information for a decision to be made on the viability of SMRs as a generation source.

The BFS will be presented to Investors and Lenders as to their appetite for the potential participation in such an investment.

After completion, the BFS will provide the decision makers in the Government of Jordan, represented by JAEC, with sufficient information for the Project feasibility of SMRs and their viability, and sustainability in electricity generation and water desalination along with other options.
MOU Signed on the Development of Bankable Feasibility Study with KACARE (SAUDI ARABIA)

FS on the Construction of two SMRS for Electricity Generation and Water Desalination.

Conducting BFS and Technology Valuation
Technology Evaluation through Technical, Commercial and Financial Assessment for near Term deployment SMRs.
Completion of the BFS with the viable technologies.

Technology Selection / Justification of Investment / and Investment Decision
Assessment of findings vis-a-vis the current requirements. Discussions with potential lenders and investors on their terms and conditions.
Site confirmation, and Investment decision to proceed forward.
Thank you