Design Requirements & Site Characterization for SMR deployment in Jordan
Mohammad Rababah

IAEA TM on Technology Assessment of SMR for near term deployment
2-5 October 2017
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)

* WORLD BANK
† Forecasted
Population

- Jordan is characterised by strong population growth over the past few years resulting from the instream of refugees from neighbouring countries.
- It increases the energy and water demand.
- Future population is difficult to estimate, which eventually increases the uncertainty of estimation for future energy demand.
Economy

- 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

- Household and governmental buildings: 45%
- Industrial: 15%
- Commercial: 15%
- Agriculture: 23%
- Street lighting: 2%

Primary energy sources:
- Crude Oil and Products: 71%
- Coal: 21%
- Renewable Energy: 2%
- Natural Gas: 2%
- Coke: 2%
- Imported Electricity: 2%
Primary energy and electricity consumption

- 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 Atomic Energy Commission

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>
</table>
| Plant Configuration                | Modules or single unit  
Undergroung  
Onshore offshore  |
| Foot print                         | This will affect the siting flexibility  |
| Seismic design                     | 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 |
| Emergency planning zone            | 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. |
| Aircraft crash                     | 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 |
| Cooling water ( is not a requirement, not required for licensing process) | It is preferred that the design may offer solutions for dry cooling and minimizing the use of water. |
Proposed sites
Proposed sites
# Aqaba Site

![Map of Aqaba Site](image)

## Table

<table>
<thead>
<tr>
<th>Geosciences considerations</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the Fault</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant Cooling</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>450 - 470m Elev</td>
<td></td>
<td>500 - 580m Elev</td>
<td>500 - 580m Elev</td>
<td>500 - 580m Elev</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant Lay-out</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elongated Profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume of spoil to be excavated</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distance from Saudi Arabian border</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>~ 1.5 km</td>
<td></td>
<td>~ 1.5 km</td>
<td>~ 3 km</td>
<td>~ 4 km</td>
</tr>
</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.
Thank you