Jordan's Nuclear Energy Program: an Update

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Nuclear power ambitions in Middle East and beyond

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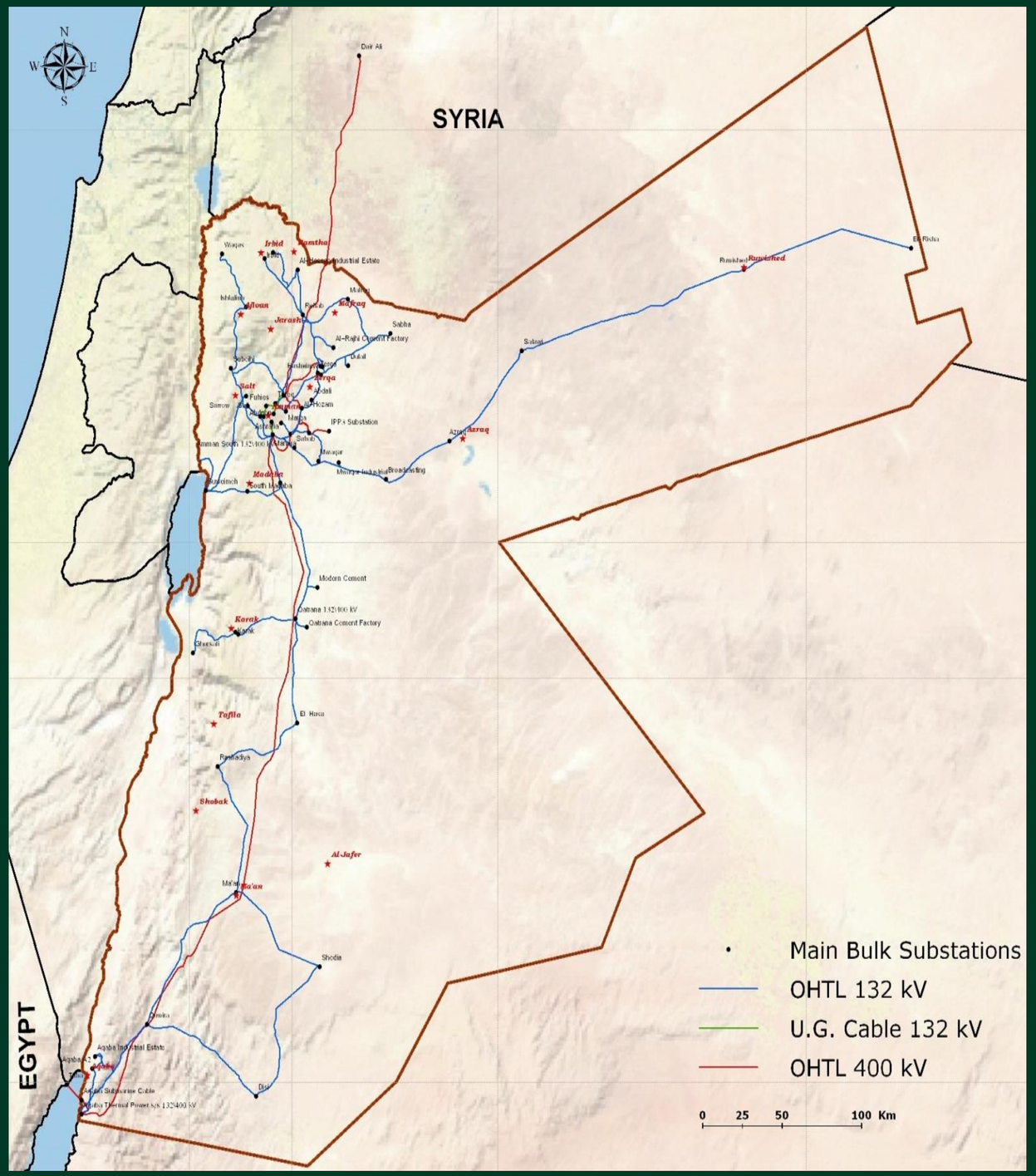

Jordan's Country Profile

- Area: 89,342 Km^2
- Population: + 10.2 million
- Electrification rate: 99.9%
- Economy is services-driven
- Lacks natural resources (especially oil and gas)
- Only one seaport

Jordan's Nuclear Energy Project Background

Jordan Atomic Energy Commission (JAEC) is the entity in charge of implementing the nuclear energy strategy in Jordan:

- Developing and eventual deployment of commercially viable Nuclear Power Plants.
- Developing the capacities and human cadres necessary to implement the Jordanian nuclear energy program.
- Strengthening the infrastructure of nuclear science and its applications in education, scientific research and community service.

Human Resources Development

- Jordan Research and Training Reactor (JRTR)
- Jordan Sub-critical Assembly
- Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME)

Uranium Project

- Exploration
- Mining
- Production

Nuclear Power Plant Project

- Electricity Production
- Water Desalination

Jordan Research and Training Reactor (JRTR)

The JRTR is a **5 MW** multipurpose research reactor with utilization purposes that include:

1. Training, research, and education
2. Radioisotope production
3. Neutron beam applications
4. Neutron Transmutation Doping
5. Neutron Activation Analysis

Owned and operated by JAEC and located on the campus of Jordan University of Science & Technology (JUST)

- Jordan's first nuclear reactor

- First critically on April 25, 2016

- Fully operated and maintained by JAEC's cadre

Central Jordan Uranium Project (CJUP)

Resource Estimation

Prospecting → Exploration → Mine Planning

Process Development

Amenability → Process Design → Pilot Testing → Demo Plant

Mine Deployment

Mine → Extract & Purify → Produce Yellow Cake

Uranium Resource Estimation: Measured Resources (2018)

Category	Surficial			Deep			All		
	Tonnage	Grade (U_3O_8)	Metal (U_3O_8)	Tonnage	Grade (U_3O_8)	Metal (U_3O_8)	Tonnage	Grade (U_3O_8)	Metal (U_3O_8)
	[Mt]	[ppm]	[kt]	[Mt]	[ppm]	[kt]	[Mt]	[ppm]	[kt]
Measured	7.4	164	1.2				7.4	164	1.2
Indicated	13.5	167	2.3	34.2	132	4.5	47.6	143	6.8
Inferred	82.4	151	12.4	165.2	126	20.9	247.7	134	33.3
Total	**103.3**	**154**	**15.9**	**199.4**	**127**	**25.4**	**302.7**	**137**	**41.3**

Production of Yellowcake

- ✓ **Alkaline heap leaching method of agglomerated ore**
- ✓ **Lab, semi-pilot & pilot scale hydrometallurgical tests**
- ✓ **Product meets ASTM standards**
- ✓ **Purity is more than 97%**

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Jordan announces uranium production

13 May 2022

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The Jordan Uranium Mining Company (JUMCO) has announced the production of 20 kg of yellowcake from 160 tonnes of uranium ore at a newly operational processing facility.

Jordan’s Nuclear Power Plant Project

Nuclear Power Plant (NPP) Project

Rationale

Energy

- Competitive Electricity Source
- Stability of Electricity Price
- Reduction of Imported Fuel Bill
- Fuel Diversity and Security of Supply

Social

- National Higher Education System and Workforce Skills Development
- Jobs Creation (direct & indirect)

Industry

- National Industry Development
- Improve the Quality Assurance Systems

Environment

- Reduce CO_2 Emissions, to mitigate climate change

Water

- Water Desalination Capabilities, to meet water demand

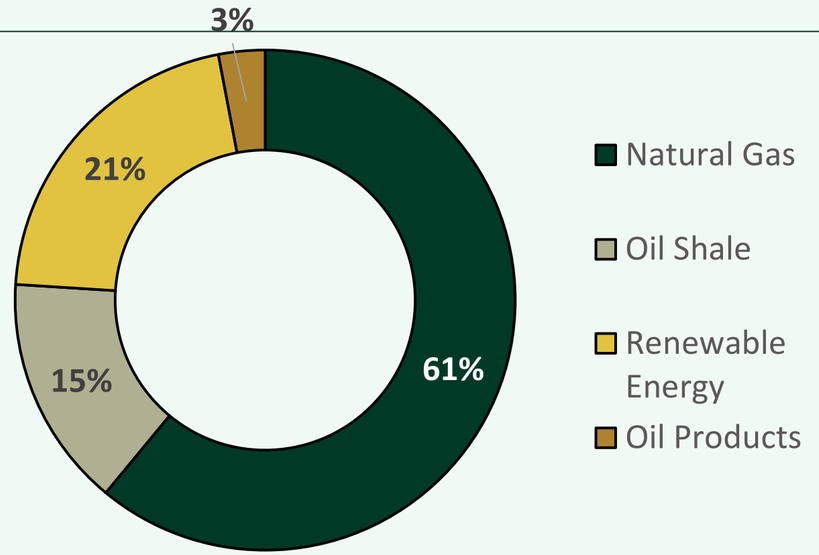
Energy-related Challenges Facing Jordan

Current installed capacity is 6063 MW and peak load is 3770 MW.

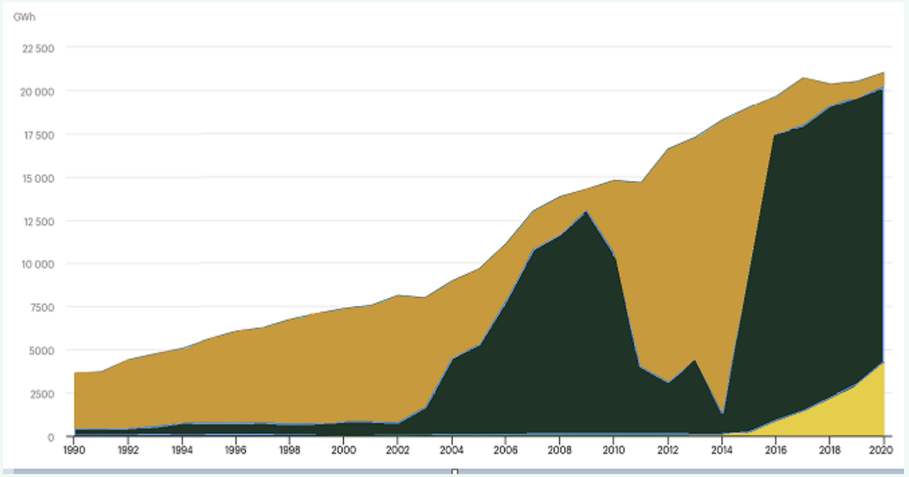
Heavy dependency on imported energy to cover electricity needs with an ever-growing demand

After 2030:

- Alternatives for natural gas should be considered
- Decommissioning of several conventional and renewable power stations



Current electricity generation mix



Graph showing gas interruption

Imported Natural Gas (1.6 trillion cubic feet over a period of 15 years, ends in 2031)

Renewable sources mainly solar and wind

Oil shale (470 MW Power Plant)

- 30-year power purchase agreement started recently
- Capital investment of **2.1 billion USD**

Water-related Challenges Facing Jordan

- Jordan has one of the lowest water availability per capita levels in the world (60 m^3/capita/year). There is also a supply-demand deficit.

- **Desalination** of sea and brackish water is considered the most important and vital supply of renewable water in the near future, **Aqaba-Amman Water Desalination and Conveyance Project (AAWDCP):**
  - 300 million cubic meters per year (MCM/year) will be desalinated from the Red Sea in Aqaba and then pumped approximately 450 km to Amman. **The total power required is around 320 MW**.
  - The project is expected to start operation in 2030.
  - The capacity of the project is expected to increase in 2035.

- Energy component of water desalination and conveyance is the largest (**60%**).
  - If the cost of energy cannot be accurately forecasted (is not stable), then it can prove to be a very expensive endeavor (and thus not economically feasible).

A base-load, reliable and scalable energy source is required post 2030 to ensure the success of the desalination and conveyance projects in Jordan.

NPP Project Background (2008-2017)

Large NPPs were initially considered, and various technical studies were performed.

1. **Water cooling studies**
2. **Electricity grid studies**
3. **Stakeholder involvement strategies**
4. **National infrastructure surveys and studies**
   - Localization/ national industry
   - Transportation
5. **Siting studies**
   - Country Wide Survey (CWS) and Site Selection studies
   - Full site Characterization studies are still not performed.
   - Meteorological data collection at the selected site was started in 2018.

It was concluded that large NPPs do not match Jordan's situation:

- Financial burden and capital investment
- Water cooling requirements
- Grid compatibility

NPP Project Background (2017- Present)

Jordan requirements for NPPs were clearly defined:

- **Low capital costs and initial investment**
- **Low cooling water requirements**
- **Compatible with the small electricity grid**
- **Scalable to match the gradual increase in electricity demand**
- **Transportable to inland sites**
  - Heaviest component weight limitation due to the seaport capacity and exiting road infrastructure.
- **Deployable post 2030**
  - Increase power demand from water desalination and conveyance
  - Decommissioning of several conventional and renewable power stations
  - Expiration of natural gas import agreements

These requirements match the business model for SMRs.

- Technical and economic assessment to down-select to the most viable SMR
- Issue a BIS/RFP for a binding proposal from technology vendors

Why SMRs for Jordan?

Small Size and Mass Modularity

Produced in a factory setting and assembled on site;

- Higher quality standards
- Improving quality and efficiency of construction

Passive and Inherent Safety

Encourages countries with less nuclear experience and smaller electricity grids to deploy nuclear power

Lower Requirements for Cooling Water

Suitable for remote regions and for specific applications such as mining and desalination

Economies of Production

- Lower capital investments
- Mass production in factory settings

Faster Deployment Time

- From commitment of equity to commissioning, SMRs require a shorter time to construct
- A more attractive proposal for investors (allowing for lower interest rates)

In-situ Decommissioning

Ability to remove reactor module on in-situ decommissioning at the end of the lifetime

SMRs Under Consideration

Rolls-Royce

British Compact PWR

- 470 MWe / module
- > 0.3 g seismicity
- Passive (backed-up by active) safety trains
- 18-24 months refueling cycle

HTR-PM

Chinese HTR

- 110.5 MWe (Gross) / module
- 103 MWe (net) / module
- 0.3 g seismicity
- 2 Passive safety trains
- Online refueling

ACP-100

Chinese iPWR

- 125 MWe (Gross) / module
- 112.5 MWe (net) /module
- 0.3 g seismicity
- 2 passive safety trains
- 24 months refueling cycle

NuScale

American iPWR

- 77 MWe (Gross) / module
- 74 MWe (net)/ module
- 0.5 g seismicity
- 2 passive safety trains (baked up by active systems)
- 24 months refueling cycle

Xe-100

American HTR

- 81.5 MWe (Gross) / module
- 75 MWe (net) / module
- 0.3 g seismicity
- 2 passive (inherent) safety trains
- Online refueling

RITM-200

Russian iPWR

- 57 MWe (Gross) / module
- 52.5 MWe (net)/ module
- 0.3 g seismicity
- 4 safety trains (2 active and 2 passive)
- 48-72 months refueling cycle

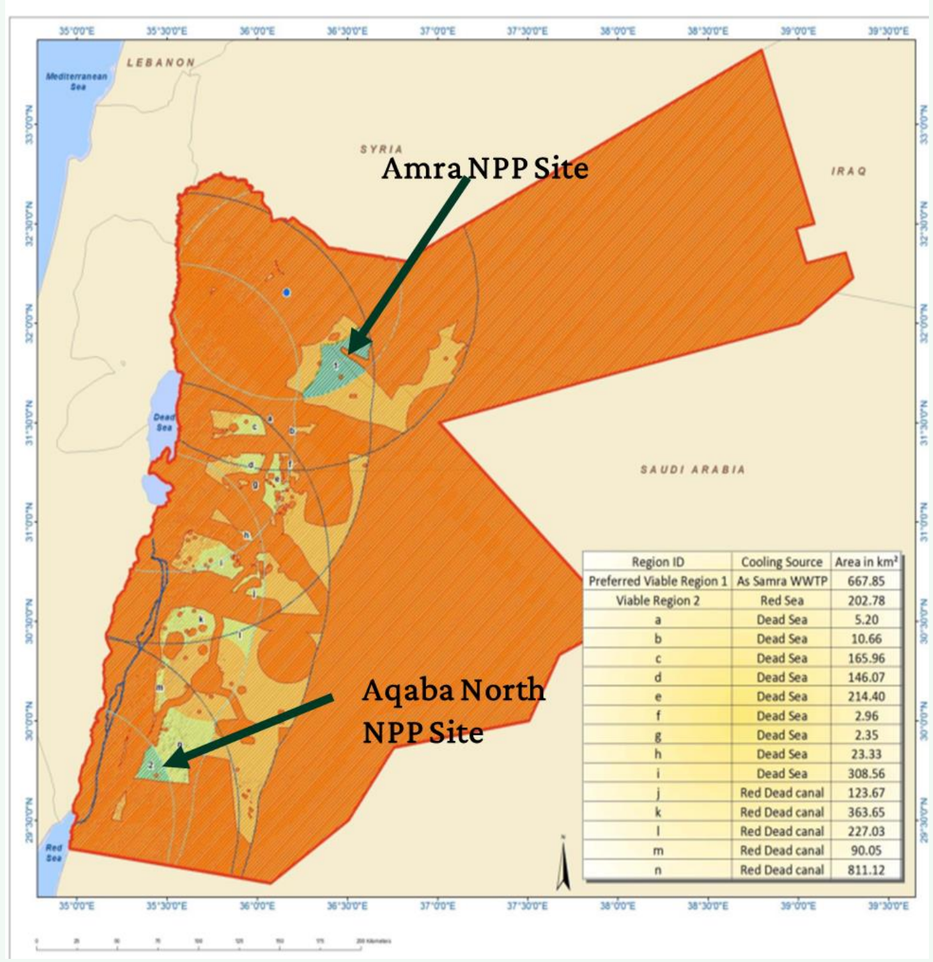
NPP Siting

- **Nuclear Power Plant Country Wide Survey (CWS) siting study was conducted by JAEC:**

  - Siting exclusion criteria domain: geosciences, cooling, flooding, demography, external human induced hazard, meteorology, and environment

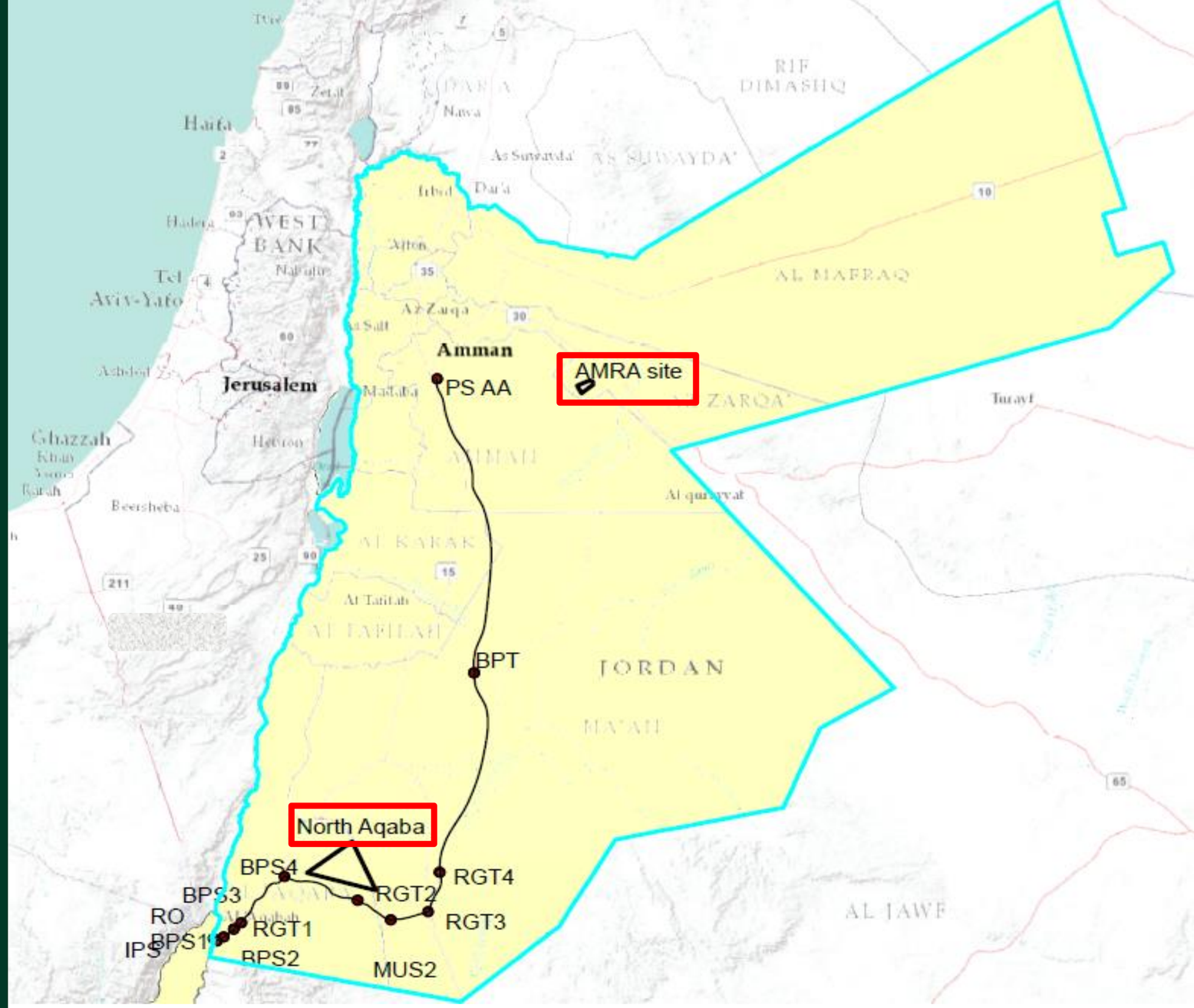
  - Site selection studies have been performed for Amra Site:
    - Cooling studies
    - Electricity and grid studies

  - Full site characterization studies to be performed



Region ID	Cooling Source	Area in km²
Preferred Viable Region 1	As Samra WWTP	667.85
Viable Region 2	Red Sea	202.78
a	Dead Sea	5.20
b	Dead Sea	10.66
c	Dead Sea	165.96
d	Dead Sea	146.07
e	Dead Sea	214.40
f	Dead Sea	2.96
g	Dead Sea	2.35
h	Dead Sea	23.33
i	Dead Sea	308.56
j	Red Dead canal	123.67
k	Red Dead canal	363.65
l	Red Dead canal	227.03
m	Red Dead canal	90.05
n	Red Dead canal	811.12

Integration of SMRs with National Desalination and Conveyance Project



Potential Configurations of the Project

SMR location	Desalination plant location	Desalination technology
Aqaba North Site	Red Sea	Reverse Osmosis
		Thermal
Amra Site	Amra site (**underground aquifers**)	Reverse Osmosis
		Thermal

- Factors to be considered:
  - Siting limitations such as high seismicity
  - Securing water for reactor cooling
  - Electricity transmission losses

Thank you