Spent Nuclear Fuel Aspects in Evaluating Jordan's Options for the First NPP in The Kingdom: The Unique Nature of HTGRs

Technical Meeting on the Management of Spent Fuel (Pebbles and Compacts) from High Temperature Reactors

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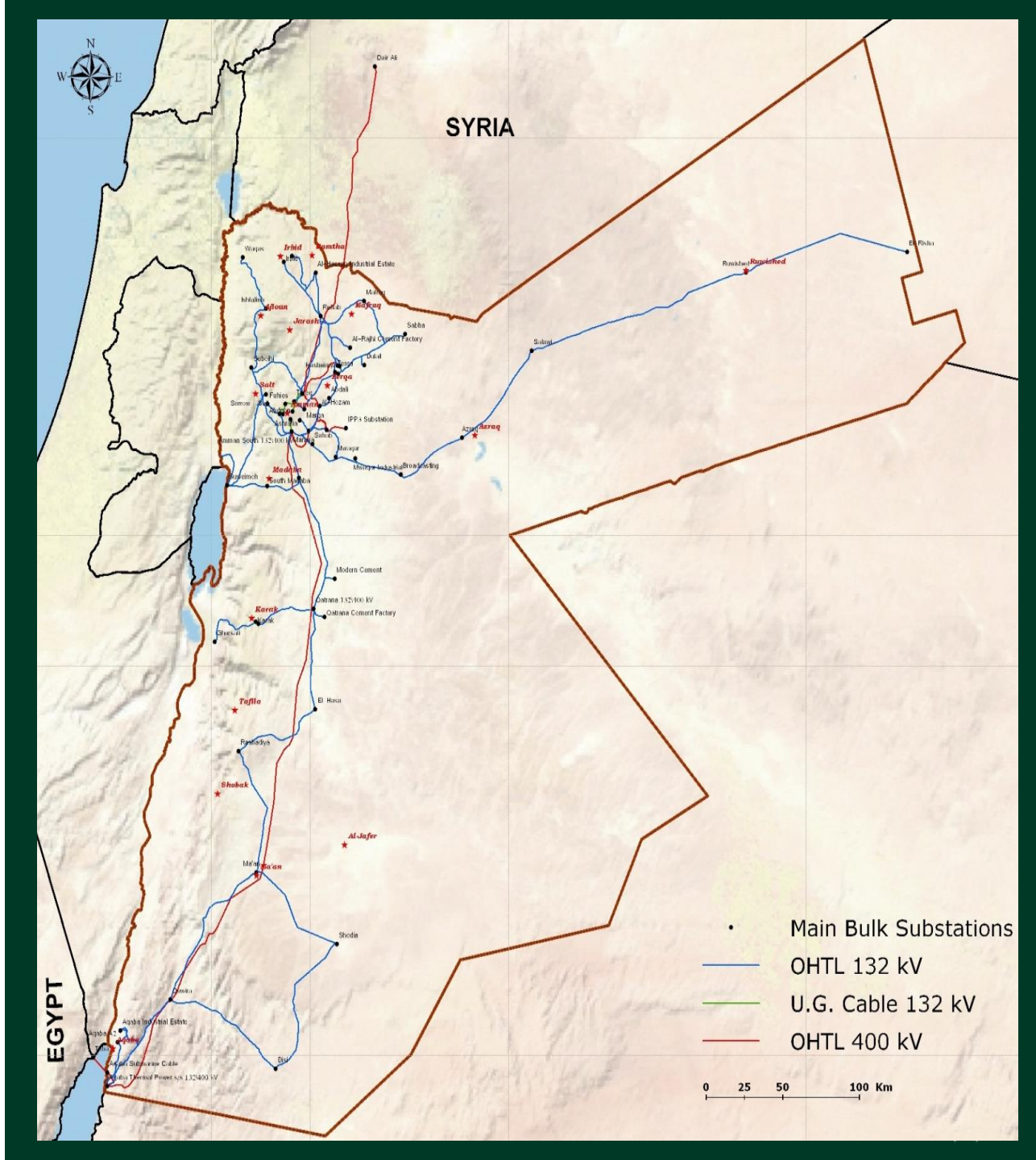
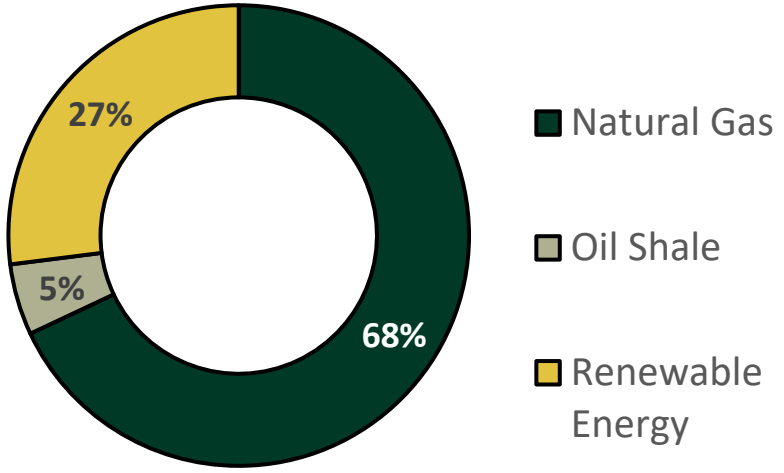
07-11/07/2025

Jordan
Country Profile

- Area: 89,342 km^2
- Population: 11M
- Electrification rate: 99.9%
- The economy is services-driven
- The country lacks natural resources (especially oil and gas)
- Only one seaport (and 26 km coastline)



National Energy Mix after 2030



2022 Electricity Generation Mix[1]

Natural Gas (340 million cubic feet per day)
- **1.8%** sourced from *Risha Gas Field*
- **300 million cubic feet per day (88%)** from Israel over a period of 15 years ends in 2031

Oil shale (235 MW x 2 Units)
- First unit commenced operations on Oct. 25, 2022
- Second unit to start in Q2 2023
- Expected to meet up to **15%** of the annual electricity demand
- Capital investment of **2.1 Billion USD**[2]
- **30-year** power purchase agreement was signed.

- Heavy dependency on imported energy to cover electricity generation needs
- After **2030**,
  - Alternatives for natural gas should be considered
  - Decommissioning of several conventional and renewable power stations
- This puts huge uncertainties to the National Conveyance Project implementation and freshwater cost forecasting

Reliable and domestically produced base-load electricity source is a prerequisite to long-term **energy and water** security and independence

Sources:

1. Ministry of Energy and Mineral Resources, Annual Report, 2022.
2. Attarat Power Company (APCO) https://attaratpower.com.jo/

Jordan's Nuclear Energy Project

Human Resources Development

- Jordan Research and Training Reactor (JRTR)
- Nuclear Engineering Department at Jordan University of Science and Technology (JUST)
- 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

Nuclear Power Plant Project Background

Jordan requirements 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**
- **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 Small Modular Reactors (SMRs)

How Nuclear Power Could Contribute to the Sustainability of the Water Sector in Jordan?

Energy and Water Security

- National energy mix after 2030
- Capital intensive energy source
- Operational Expenditure accurate forecasting

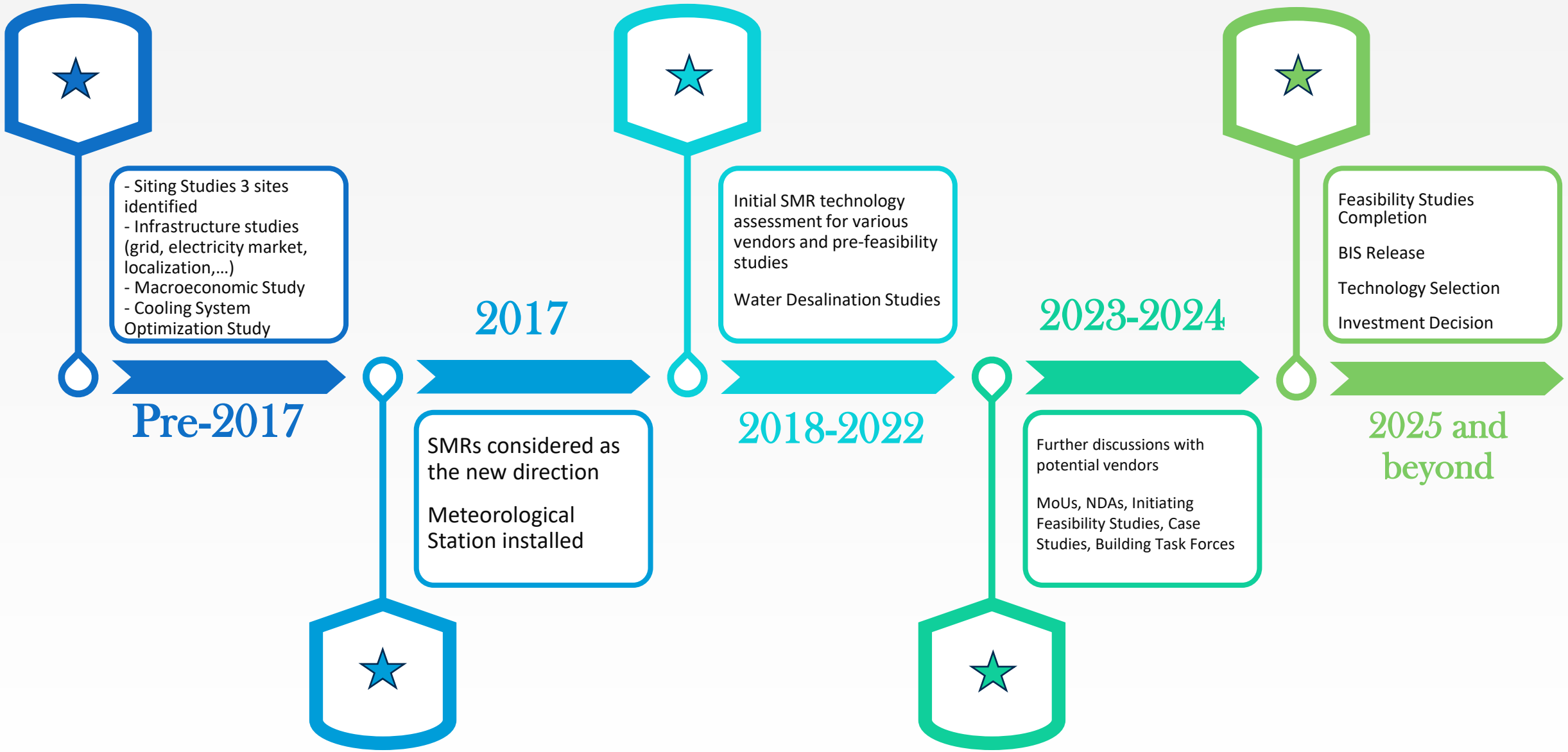
Economic Feasibility

- Stable and Cheap Electricity Price
- Minimal Government Subsidies

Environment Protection

- CO_2 emission per m^3 of freshwater produced and conveyed

Jordan’s SMR Project - Timeline



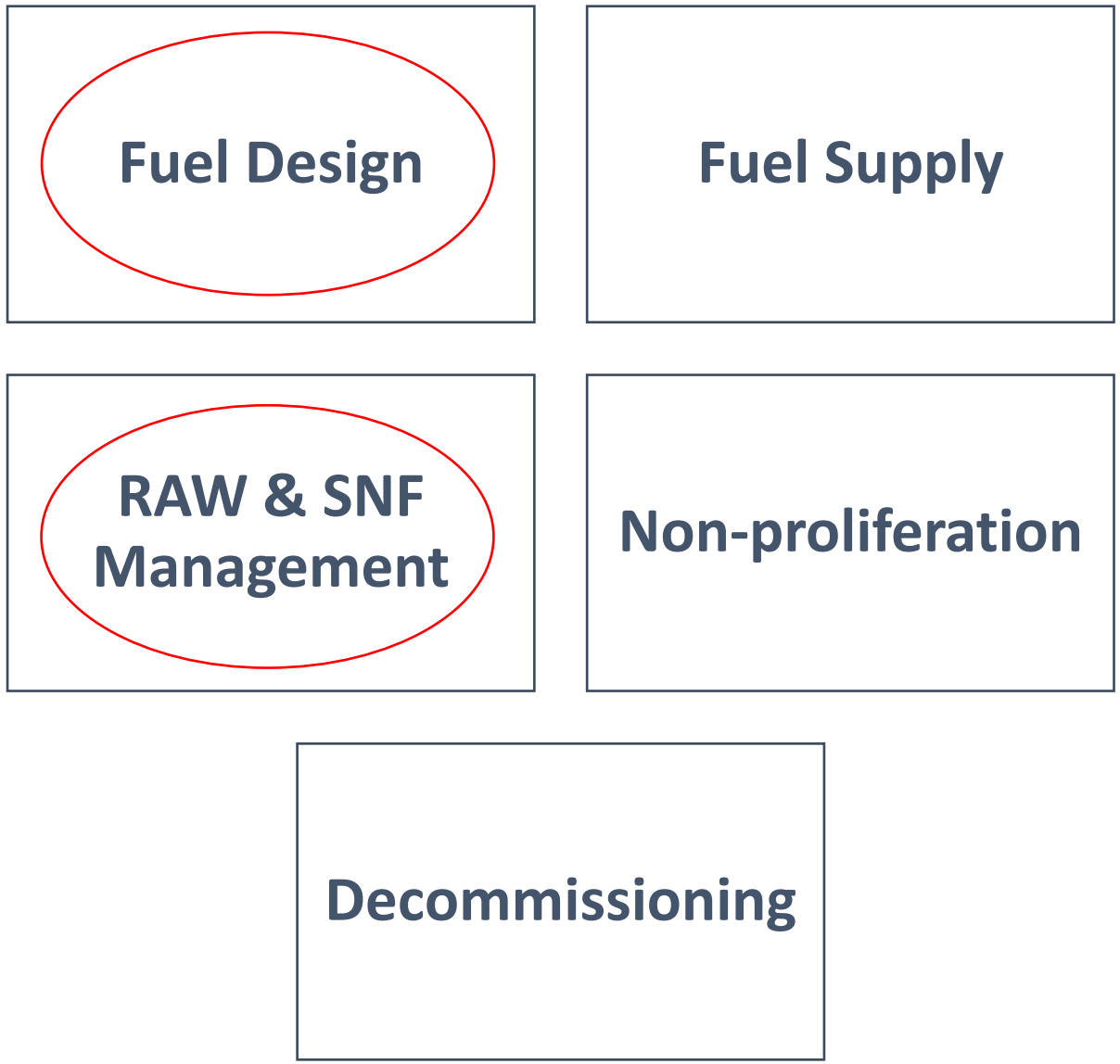
Evaluation of SMRs

- Preliminary Assessment of different SMR technologies.
- The first phase is a generic assessment aiming to down-select the most suitable and competitive technologies that are viable to Jordan.
- The second phase is to dive into deep discussions with vendors, signing certain agreements such as MoUs and NDAs, as well as providing them with information request lists, meetings, and visits.

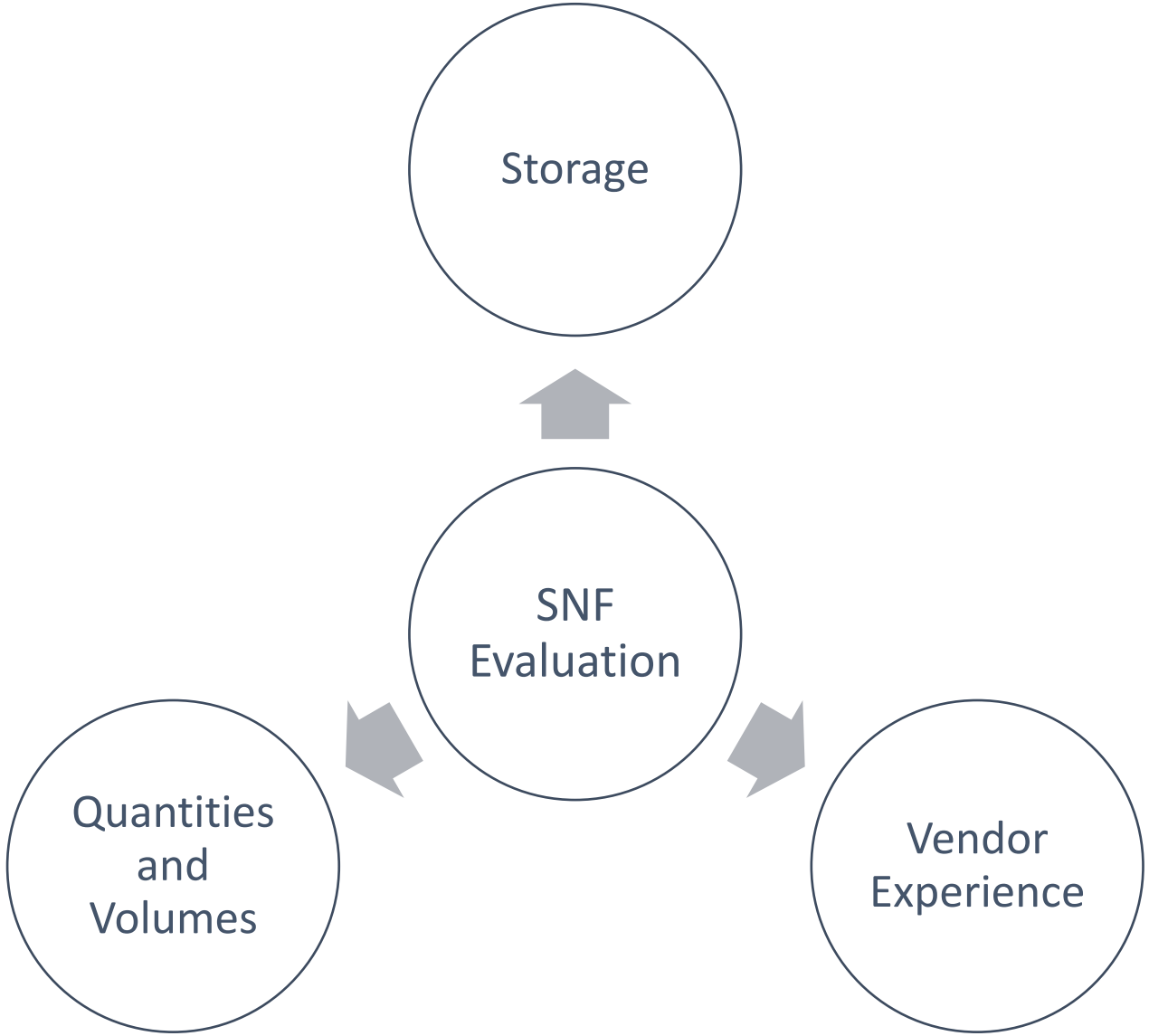
Evaluation of HTGRs

- Fuel Design
- Fuel Supply
- RAW & SNF Management
- Non-proliferation
- Decommissioning

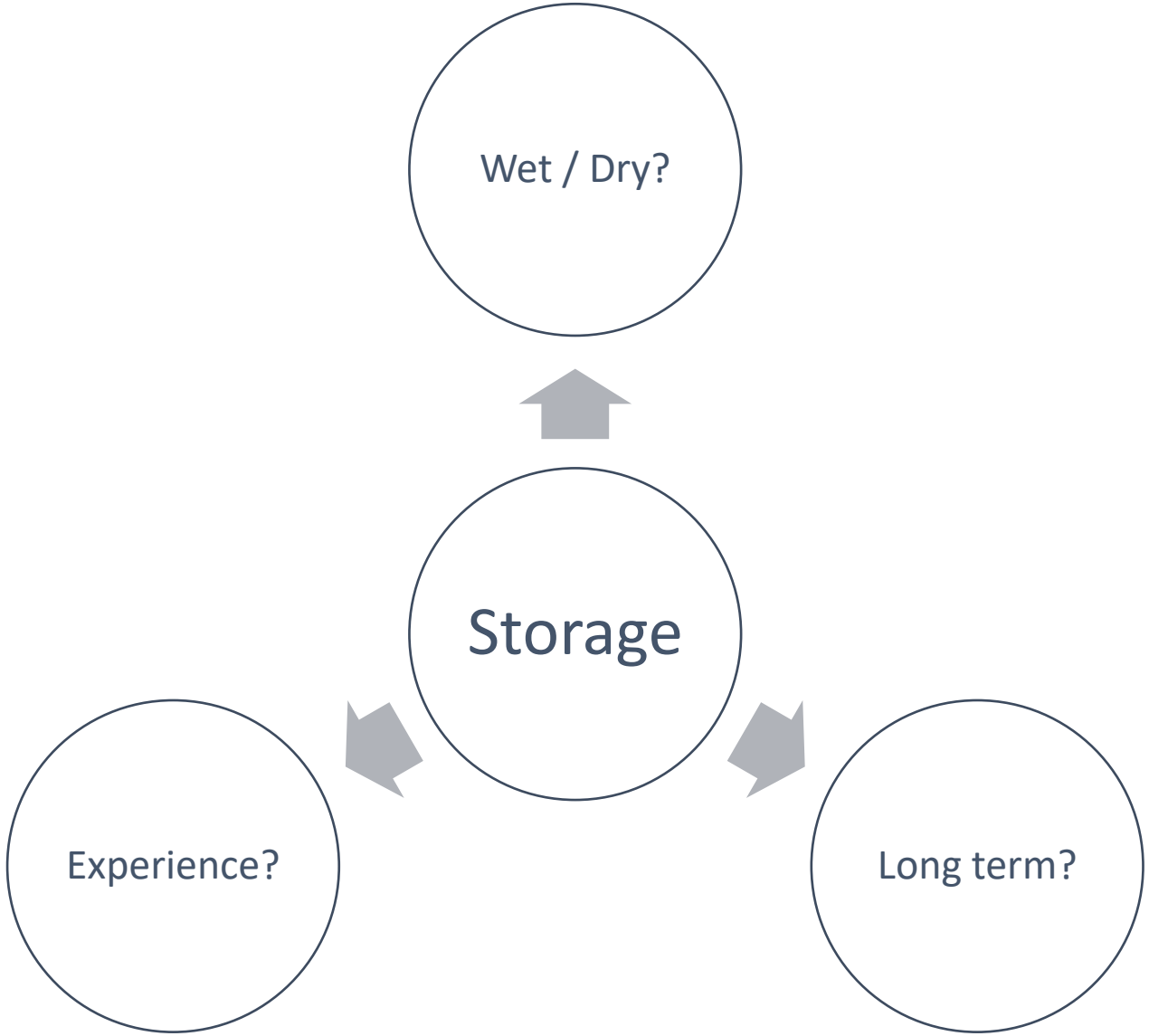
Evaluation of HTGRs



Evaluation of HTGRs - SNF



Evaluation of HTGRs - SNF



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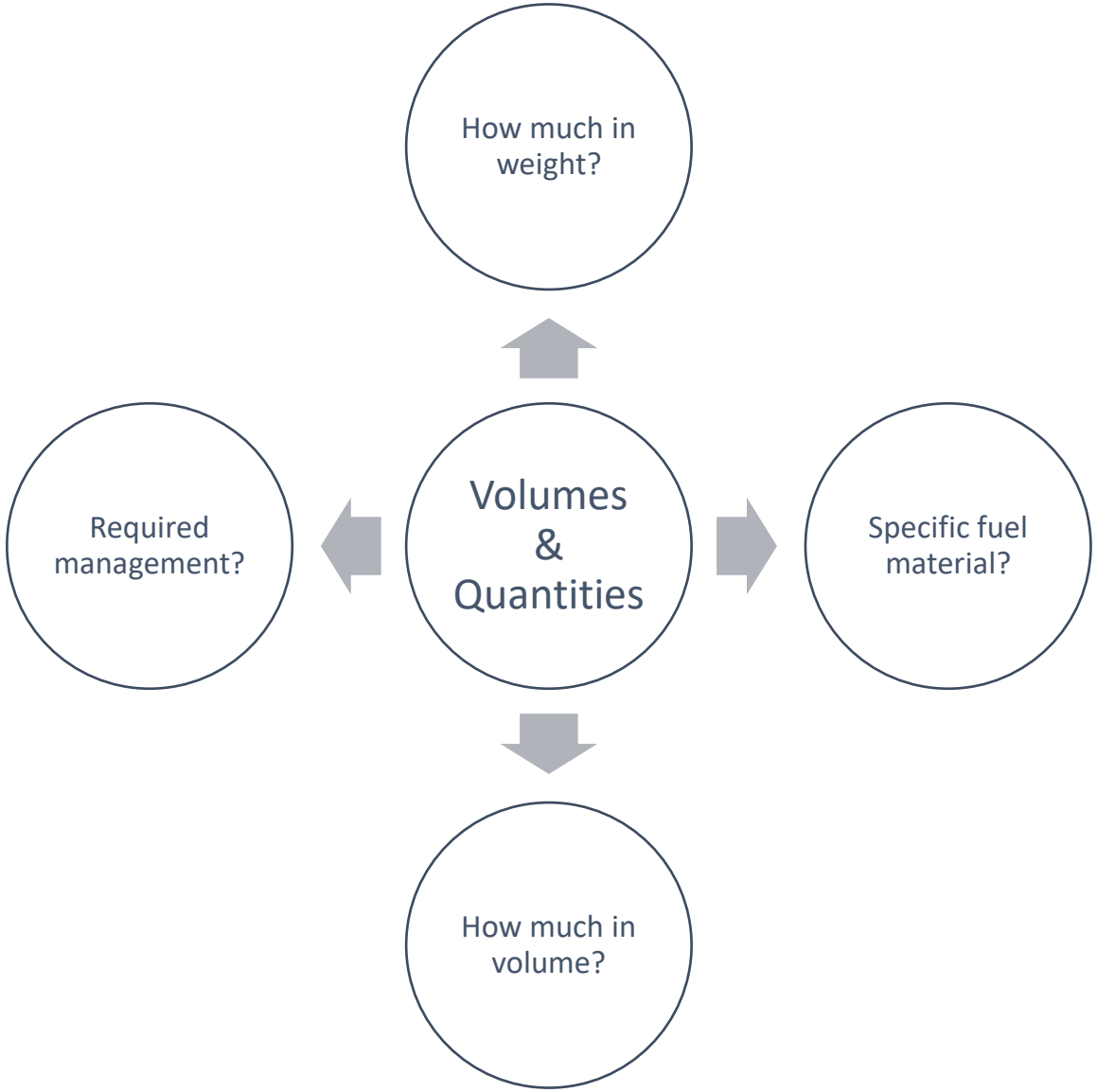
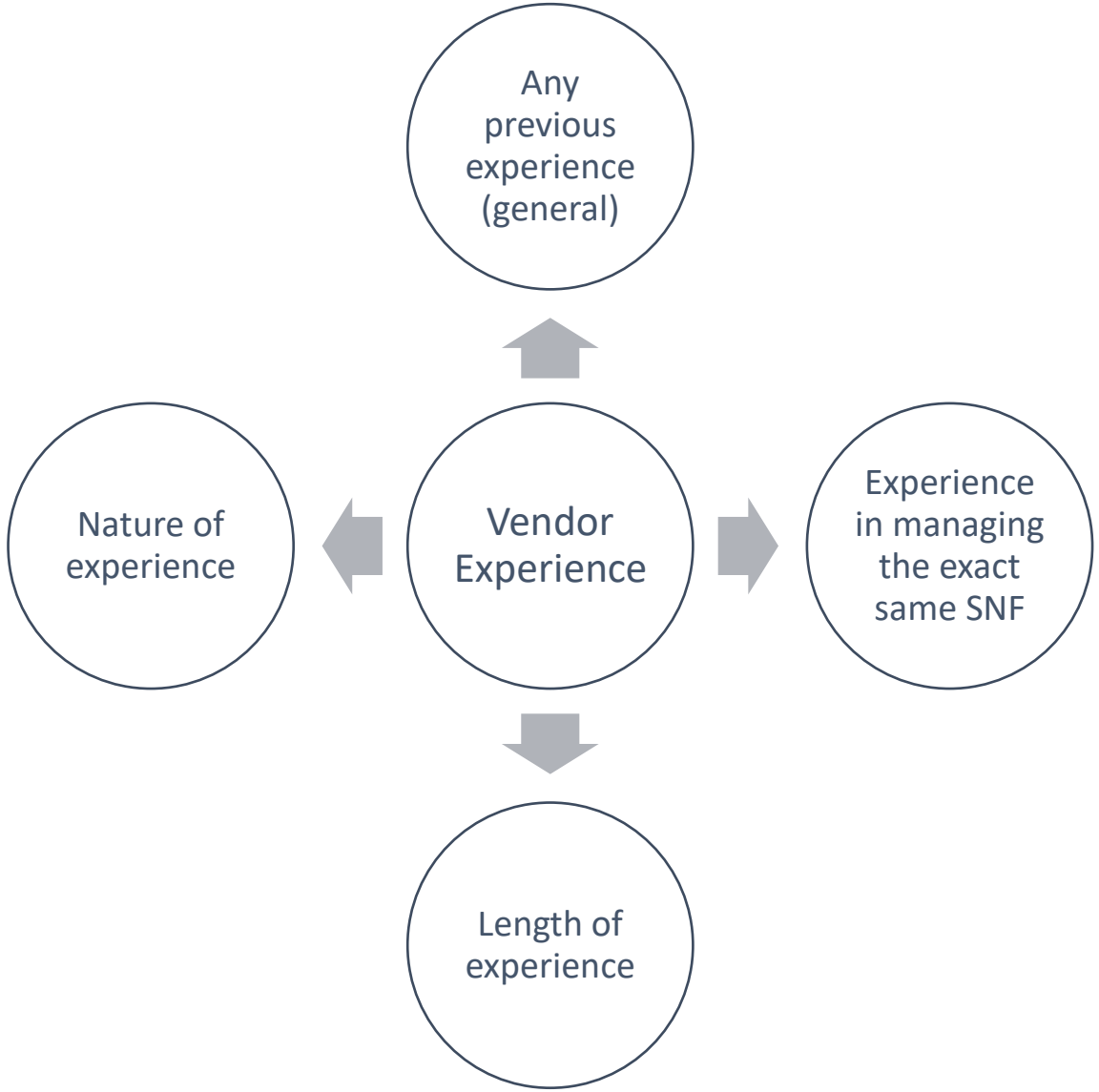
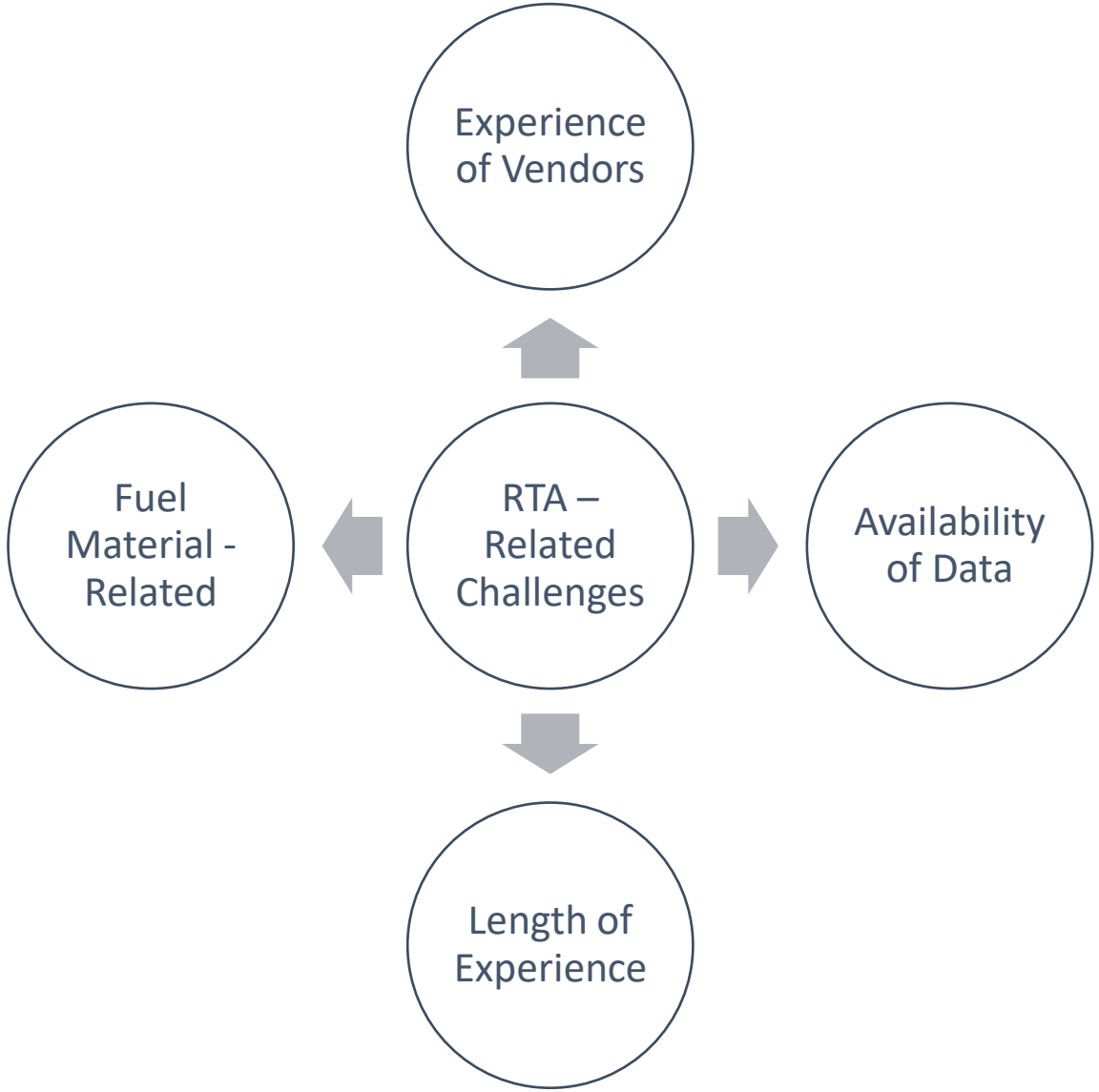


Evaluation of HTGRs - SNF



Evaluation Challenges



Evaluation Challenges

- RTA has certain items that are not applicable for LWRs and HTGRs, especially pebble bed reactors, such as the refueling processes and handling of SNF. HTGRs are online, and LWRs have certain refueling cycles. How do you score this?
- Based on the fuel design, pebbles include irradiated graphite that is challenging to manage as part of the SNF. This item is not included in the RTA unless you separately account for it and score it.
- The experience of the nuclear industry in managing SNF from LWRs is typically higher than that for HTGRs. This automatically reduces the score of HTGRs under this element, but this does not mean that one fuel is better than the other, it is just different, and we do not have enough data.
- Some vendors have certain experience in large NPPs fuel, but limited or no experience in managing SMRs LWR fuel, for HTGRs, some vendors have zero experience in managing SNF from HTGRs, others have very limited experience.
- The quantities of SNF are very different between the two technologies, so comparison sometimes seems to be irrelevant. [Maybe go further in evaluation and start a higher-level evaluation to pick one of the two at the beginning?]

Conclusions

- Evaluating HTGRs under the same criteria used by the RTA is not always possible due to the significant differences between the technologies (HTGRs and LWRs). Questions asked are not always applicable for both technologies.

- The scarcity of SNF management information regarding the TRISO fuel makes it hard for HTGRs to compete with other technologies (specifically under the SNF management topics).

- The nature of TRISO fuel and the irradiated graphite is still a topic that requires discussions with the vendors, as well as the management of irradiated graphite and the limited experience in dealing with it.

- Facilitating workshops that cover problematic topics is very helpful, especially at the early stages of shortlisting.

- As a newcomer state, the experience of expanding the NEPIO's connections and cooperation between different entities around the globe is crucial for a better evaluation process (IAEA, WNA, WANO, etc..).

- Continuous communication with vendors taking place to update FS's and evaluation based on updated operational history.

Thank you!