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Siting Considerations of Small Modular Reactors Near Populated Areas

A Case Study of Kuwait

Using the NuScale US460 as a Reference Design



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Presentation Outline

1. **Introduction**
   Background, Problem Statement & Purpose
2. **Literature Review**
   NuScale, siting & EPZ
3. **Methodology**
   Screening-level MCDA
4. **Kuwait Case Study**
   Hazards & candidate areas
5. **Results**
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6. **Conclusion**
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1. Introduction:
Why Kuwait? An Energy System on a Crowded, Hot Coast

17,610 MW

Peak electrical load reached in 2025

> 50°C

Summer temperatures, with frequent dust storms

> 98%

Of the population lives in urban areas, concentrated on the Gulf coast

462 MWe

Six-module NuScale US460 ≈ 2.6% of 2025 peak demand

An SMR could support power and desalinated water, but it would have to sit on the same coast as the population.

1. Introduction: Problem Statement & Purpose

Can the enhanced safety features of SMRs support siting closer to populated areas in Kuwait, without compromising public protection?

Remote sites

Pros Easier emergency planning and land-use control

Cons More transmission, infrastructure and logistics

Existing power & industrial areas

Pros Grid, cooling-water and desalination infrastructure in place

Cons External industrial hazards and closer population

Purpose:

- To evaluate the feasibility of siting an SMR near populated areas in Kuwait as a case-study
- To develop the key siting factors relevant to Kuwait

2. Literature Review: NuScale US460 Reference Design

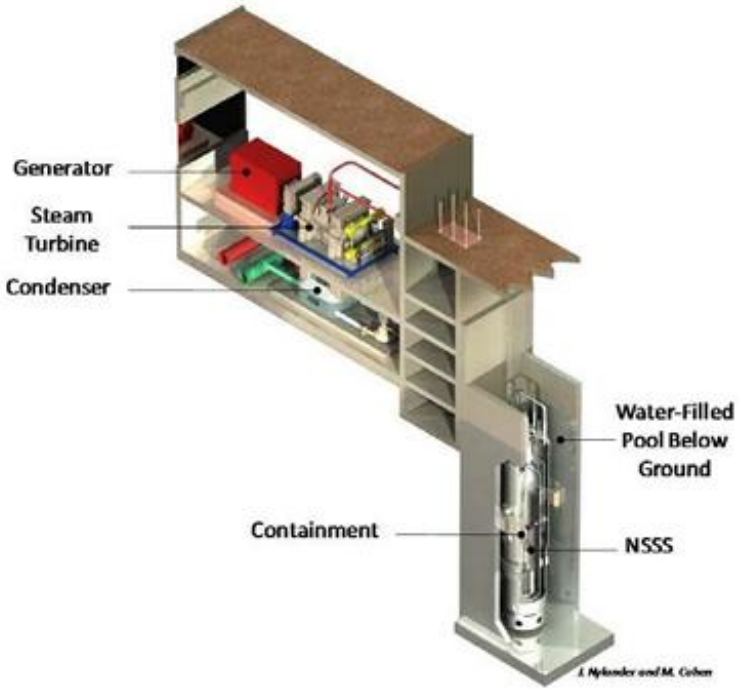


Figure: NuScale module submerged in a below-grade, steel-lined concrete pool (thesis Figure 1).

6 × 77 MWe = 462 MWe

First and only SMR with NRC Standard Design Approval, May 2025

- Integral PWR: core, pressurizer and steam generators inside the vessel.
- Natural circulation: no reactor coolant pumps.
- Small steel containment immersed in the reactor-building pool
- Used as a reference, not a procurement recommendation

2. Literature Review: Siting Requirements and Emergency Planning Zones

IAEA SSR-1: site evaluation

- Identify natural and human-induced hazards
- Assess release pathways and consequences
- Population distribution and projected growth
- Feasibility of emergency arrangements

Plume-exposure EPZ

Conventional approach

Fixed large-reactor emergency planning distance (≈ 16 km)

NRC SMR framework (RG 1.242)

EPZ set by the distance at which dose criteria could be exceeded. Performance-based and risk-informed.

A smaller EPZ must be demonstrated with design-specific source terms, site-specific meteorology, population data and uncertainty analysis.

3. Methodology: Screening-Level Workflow

1. Define reference plant

NuScale US460, full six-module configuration

2. Identify candidate areas

Kuwait's main power & water production areas

3. Apply exclusion criteria

Remove areas with unacceptable conditions

4. Score with weighted Multi-criteria Decision Analysis

Eight criteria, 1–5 scale, weighted sum

Scope

- **A screening study based on public data and assigned scores.**
- **Not a site license, source-term or dose calculation.**

3. Methodology: Basis for Siting Criteria

IAEA SSG-35

Site Screening & Ranking

- Identify siting factors
- Apply Exclusion screening
- Compare candidate areas using safety and non-safety factors

IAEA NG-T-3.7

Suitability Scoring Approach

- The 1–5 suitability scale
- Weighted-sum approach to compare candidate sites

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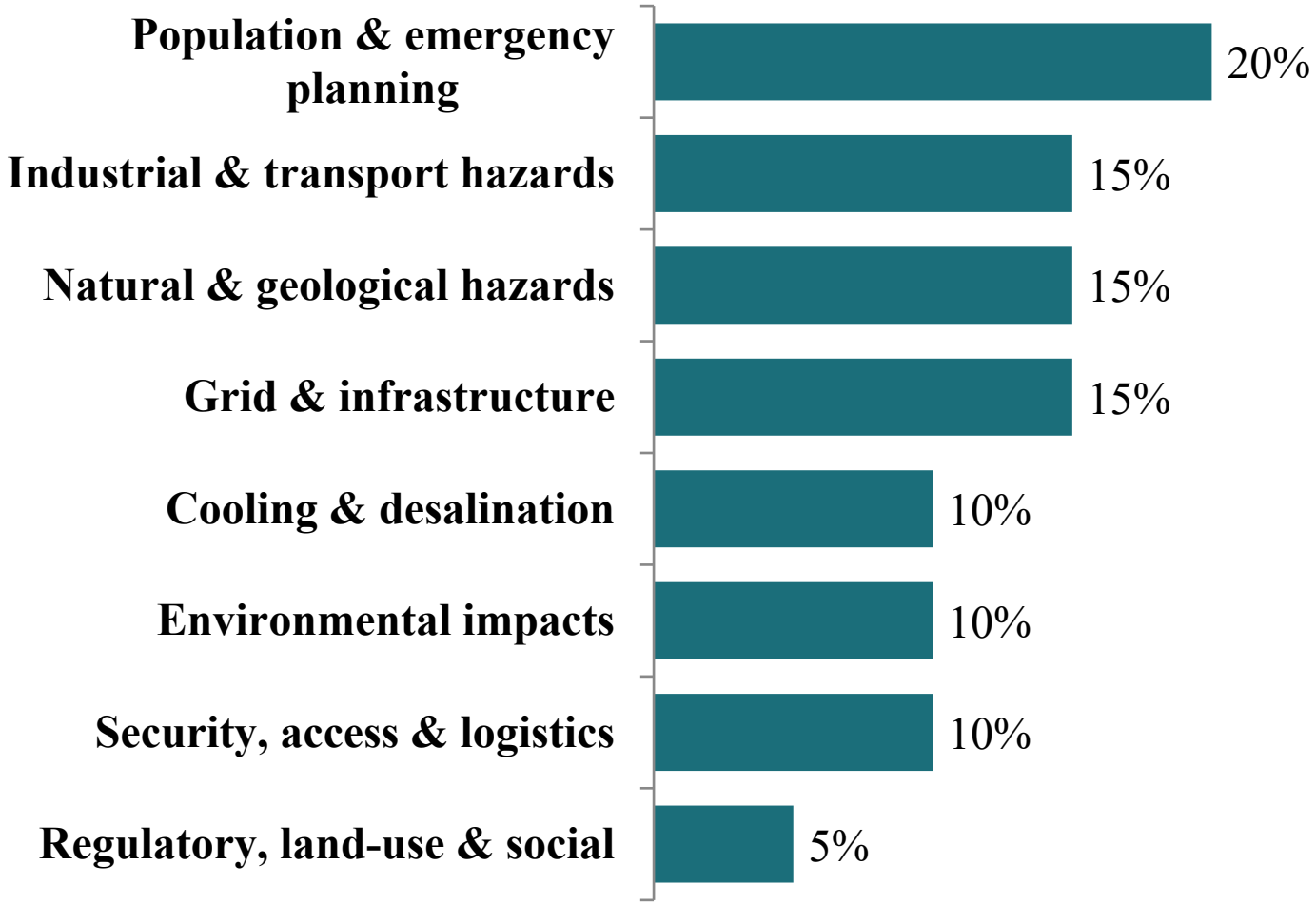
MCDA for Nuclear Siting

- Weighted MCDA for nuclear site ranking
- Model for grouping criteria into safety, infrastructure, environmental and social families

The eight criteria, weights, and the score descriptions were developed for Kuwait's conditions.

Considering the public protection and emergency planning as the governing objective.

3. Methodology: Criteria and Weights



Weighted score

$$S_j = \Sigma\, w_i \times x_{ij}$$

Maximum = 5.0 (weights sum to 100%)

1: Least preferable
3: Further investigation
5: Most preferable conditions

- Weights reflect the study's objective: public protection and emergency planning.
- An economics or grid focused weighting could rank sites differently.

3. Methodology: Scoring Guide for the Eight Criteria

Criterion	Score 1: least preferable	Score 3: moderately preferable	Score 5: most preferable
Population distribution and emergency planning	Dense or rapidly growing population; evacuation or sheltering not credible	Moderate population; protective actions feasible with major improvements	Low nearby population; controlled growth; robust access and shelter
External industrial and transportation hazards	Multiple high-consequence sources at close range; common infrastructure	Hazards present but potentially mitigable by layout and protection	No significant nearby external hazard or large separation
Natural hazards and geological conditions	Poorly characterizable or unacceptable flood, fault, soil, or climate hazard	Manageable hazards requiring substantial engineering	Well-characterized conditions with strong natural margins
Grid connection and existing infrastructure	Major new transmission and access required	Connection feasible with significant upgrades	Strong transmission, roads, construction, and services
Cooling water and desalination integration	Unreliable heat sink or severe environmental constraints	Adequate water with engineered diversity and mitigation	Reliable heat sink, diverse backup, and integration potential
Environmental impacts	Protected or highly sensitive area; unacceptable cumulative impact	Impacts potentially manageable after detailed assessment	Low sensitivity and practical mitigation
Security, access, and logistics	Insufficient controlled land or difficult protection and access	Security and logistics possible with major investment	Large controlled area, strong stand-off, redundant access
Regulatory, land-use, and social considerations	Land conflict, strong opposition, unclear ownership or jurisdiction	Conditional planning compatibility and engagement needs	Clear site control, compatible land-use, and credible engagement

4. Kuwait Case Study: Kuwait-Specific Hazards

Natural hazards

Extreme heat
Higher ventilation load; reduced seawater cooling margin

Dust & sandstorms
Filters, intakes, sensors, visibility, worker access

Coastal flooding
Storm surge, sea-level rise, intake blockage; flash floods

Seismic & geological
Regional earthquakes; coastal sabkha and weak soils

Human-induced hazards

Petroleum facilities
Fires, vapor-cloud explosions, toxic releases

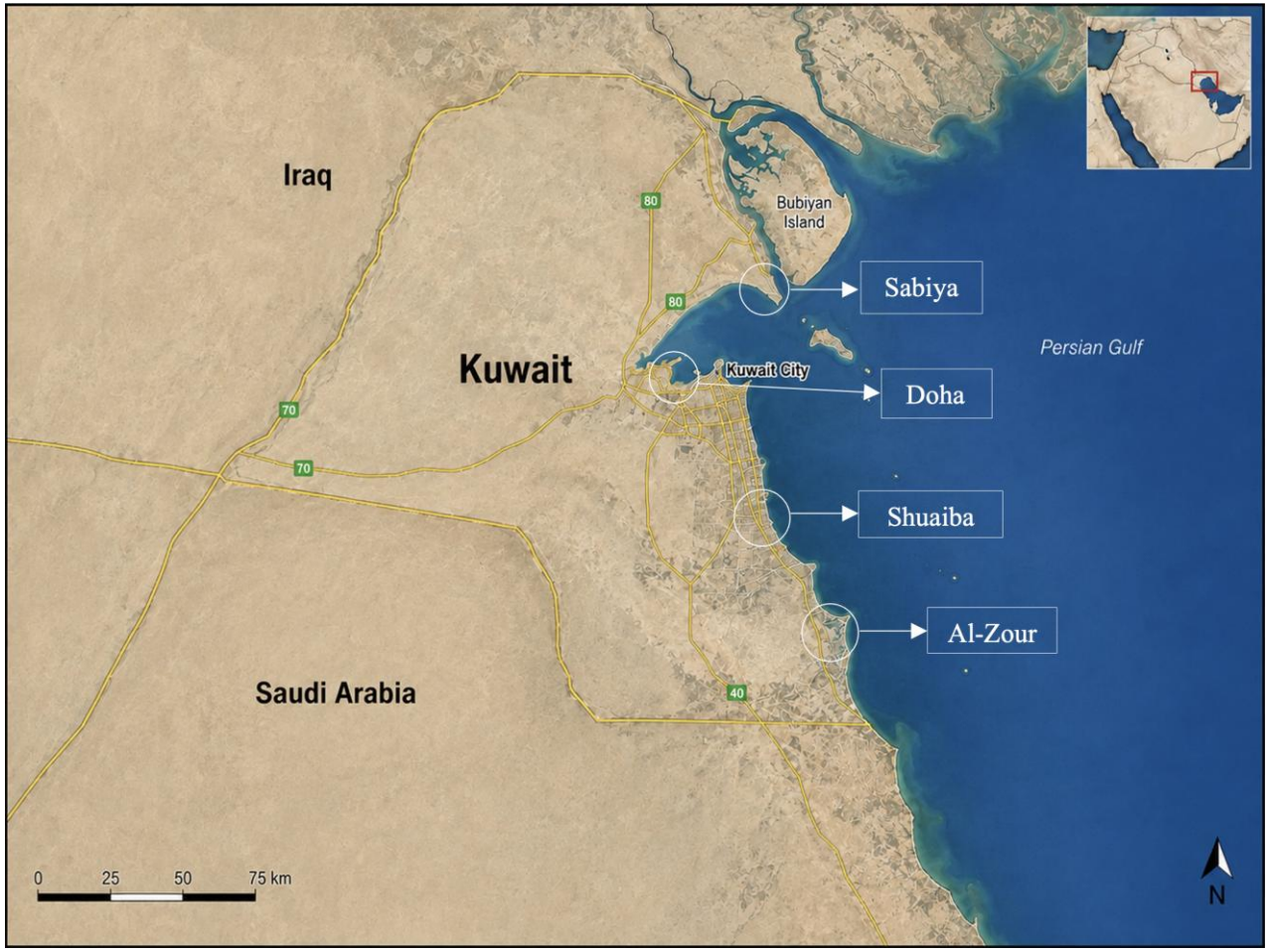
Ports & shipping
Ship collisions, fuel spills, marine accidents

Aviation & military
Aircraft operations, training and installations

Sabotage & cyber
Security and cyber vulnerabilities

Hazards must be assessed in combination; a dust storm with loss of off-site power or an industrial emergency.

4. Kuwait Case Study: Four Candidate Areas



Kuwait's main generation and water-distillation areas (Ministry of Electricity, Water and Renewable Energy).

Sabiya

North; relatively separated from the metropolitan population

Doha

Doha East & West, closer to population

Shuaiba

Established industrial and port hub with refinery and petrochemicals

Al-Zour

Major southern energy hub: power, desalination, refinery, port

5. Results: Score Breakdown by Criterion

Criterion	Weight	Sabiya	Al-Zour	Shuaiba	Doha
Population & emergency planning	20%	5.0	3.0	2.0	1.0
Industrial & transport hazards	15%	4.0	2.0	1.0	3.0
Natural & geological hazards	15%	3.0	3.0	4.0	3.0
Grid & infrastructure	15%	4.0	5.0	5.0	4.0
Cooling & desalination	10%	4.0	5.0	5.0	5.0
Environmental impacts	10%	2.0	3.0	2.0	2.0
Security, access & logistics	10%	4.0	4.0	4.0	4.0
Regulatory, land-use & social	5%	4.0	3.0	3.0	1.0
Weighted total (out of 5)	**100%**	**3.85**	**3.45**	**3.15**	**2.85**

Sabiya

- Best on population and emergency (5)
- Industrial separation (4)
- Environment (2)

Al-Zour

- Top grid & cooling (5)
- Industrial hazards (2)

Shuaiba

- Top grid & cooling (5)
- Lowest on industrial hazards (1)

Doha

- Top Cooling & desalination (5)
- Population (1) and land-use (1)

5. Results: Candidate-Area Evaluation

Sabiya

Priority for detailed investigation

Separated from the metropolitan area: easier land-use control, security and emergency planning.

Watch: marine ecology, soils & groundwater, access, possible unexploded ordnance, regional security.

Al-Zour

Promising, if hazards are controlled

Top scores for grid, cooling water, desalination and logistics.

Watch: separation from oil & gas facilities, fire domino effects, toxic gases, future housing.

Shuaiba

Lower priority

Strong infrastructure, but refineries, petrochemicals, ports and pipelines create cascading-event risk.

Limited space for a controlled nuclear boundary and laydown.

Doha

Not preferred for an initial program

Adjacent to the capital: severe-accident, traffic, hospital, school and acceptance concerns.

Urbanization makes a stable exclusion zone hard to keep.

6. Conclusion & Future Research

CONCLUSION

- The MCDA approach successfully selected the site for further site characterization.
- The eight siting criteria developed in this study provide a practical/useful framework for SMR site selection from candidate sites in Kuwait.

FUTURE RESEARCH

Site-specific studies: Sabiya and Al-Zour

1. **GIS and probabilistic hazard studies**
2. **Meteorological, geotechnical and hydrological surveys**
3. **Population and emergency planning data**

Program-level research

1. **Multi-module PRA in Kuwait's environment**
2. **Climate-change effects on cooling and emergency planning**
3. **MCDA validation with expert panels and sensitivity analysis**
4. **Techno-economic and social studies**

Thank you — Questions?

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