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Siting Considerations of Small Modular Reactors Near Populated Areas: A Case Study of Kuwait

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1. Introduction

Small modular reactors (SMRs) are increasingly considered for electricity systems that require reliable low-carbon generation, modular deployment, and integration with industrial applications such as desalination. Compared with conventional large nuclear power plants, their smaller unit size, integral configurations, and passive safety systems may provide greater flexibility in plant siting. However, reduced reactor power alone does not demonstrate that an SMR can safely be located near a populated area. Siting remains dependent on the reactor design, site hazards, population distribution, accident consequences, and emergency-response capability [1,2]. Kuwait presents a distinctive case because most of its population, electricity-generation facilities, desalination plants, ports, and major industrial activities are concentrated along a relatively narrow coastal corridor. Electricity demand is strongly influenced by extreme summer temperatures, and the maximum electrical load reached 17,610 MW in 2025 [3]. These characteristics create both opportunities and constraints for SMR deployment. This study evaluates the principal considerations for siting an SMR near populated areas in Kuwait using the NuScale US460 as a reference design. Four established power and water-production areas compared using a screening-level multi-criteria decision analysis (MCDA). The objective is not to select a final nuclear site, but to identify areas that justify more detailed investigation.

2. Methods and Results

2.1 Reference Design and Kuwait Siting Conditions

The NuScale US460 consists of six integral pressurized-water reactor modules, each producing approximately 77 MWe, for a total plant output of approximately 462 MWe [4]. Each module incorporates the reactor core, pressurizer, and steam generators within the reactor pressure vessel and uses natural circulation in the primary system. The modules are installed within a water-filled reactor building pool. These characteristics, together with a smaller radioactive inventory per module and passive heat-removal features, may reduce some accident consequences and dependence on active support systems. Nevertheless, a standard design approval does not constitute approval of a specific site. Kuwait-specific conditions such as extreme air and seawater temperatures, dust and sandstorms, coastal flooding, soil conditions, industrial hazards, population distribution, and emergency access must be included in a site-specific safety assessment. The candidate areas were selected because they already contain major electricity and desalination infrastructure. Sabiya provides relative separation from the main metropolitan population while retaining access to power and water infrastructure. Al-Zour has strong grid, desalination, port, and industrial infrastructure but is exposed to refinery, pipeline, storage, and marine hazards. Shuaiba has extensive existing infrastructure but a high concentration of petrochemical, refinery, port, and transportation hazards. Doha benefits from developed infrastructure but is located close to the densely populated metropolitan region.

2.2 Site-Screening Methodology



Figure I: A map of Kuwait's candidate areas

The assessment combines literature review, reference-design analysis, Kuwait-specific conditions, exclusion criteria, weighted MCDA, and sensitivity analysis. Candidate areas are first screened for conditions that could make nuclear siting unacceptable, including population and emergency-planning constraints, unacceptable seismic or geotechnical conditions, unbounded coastal flooding, external industrial hazards, inadequate land or security boundaries, unreliable heat removal, and unacceptable environmental impacts. Areas remaining after the exclusion stage are evaluated using eight

weighted criteria. Population distribution and emergency planning receive the highest weight at 20%. External industrial and transportation hazards, natural and geotechnical hazards, and grid and infrastructure are each weighted at 15%. Cooling and desalination integration, environmental impacts, and security/access/logistics each receive 10%, while regulatory, land-use, and social considerations receive 5%. Each area is scored from 1 to 5, where 1 represents very poor suitability and 5 represents highly favorable conditions.

$$(1)\quad S_j = \Sigma\,(w_i \times x_{ij})$$

where S_j is the total score for candidate area j, w_i is the normalized criterion weight, and x_{ij} is the score assigned to the area.

2.3 Screening Results

The baseline assessment ranked Sabiya first with a weighted score of 3.85/5, followed closely by Al-Zour at 3.75/5. Shuaiba and Doha received scores of 3.20 and 3.10, respectively.

Area	Score	Norm.	Main consideration
Sabiya	3.85	77%	Lower nearby population
Al-Zour	3.75	75%	Strong infrastructure; industrial hazards
Shuaiba	3.20	64%	High industrial congestion
Doha	3.10	62%	Metropolitan proximity

Table I. Preliminary weighted comparison of candidate areas.

Sabiya performs strongly because its relative separation from the metropolitan area improves emergency planning, land-use control, security, and possibilities for future development while retaining access to power and desalination infrastructure. Its principal uncertainties are coastal and geotechnical conditions, environmental effects, site access, and the need for nuclear-grade supporting infrastructure. Al-Zour performs particularly well in grid connection, cooling-water availability, desalination integration, construction logistics, and existing energy infrastructure. Its principal limitation is the concentration of oil, gas, refinery, storage, pipeline, and marine activities. Detailed separation-distance and domino-effect analyses would therefore be essential. Shuaiba benefits from mature industrial and transmission infrastructure, but its dense concentration of refineries, petrochemical facilities, ports, pipelines, and transportation routes creates substantial external and common-cause hazard concerns. Doha is less favorable primarily because of population density, traffic congestion, emergency-planning challenges, and future urban development. Sensitivity analysis shows that Sabiya remains preferred when greater emphasis is placed on population protection or industrial-hazard separation. Al-Zour becomes the leading candidate when greater weight is placed on infrastructure, cooling, and logistics. Therefore, the small difference between Sabiya and Al-Zour is not sufficient to support a final site decision. Detailed information on population growth, industrial hazards, coastal conditions, and site-specific engineering requirements is required before either area can be preferred.

3. Conclusion

The assessment indicates that Sabiya and Al-Zour are the most promising Kuwaiti areas for detailed SMR siting investigations. Sabiya offers an advantage in population separation and emergency planning, whereas Al-Zour provides stronger existing grid, cooling, desalination, and construction infrastructure. Shuaiba is constrained mainly by industrial congestion, while Doha is constrained by its proximity to the metropolitan population. The NuScale US460 incorporates design characteristics that may support greater siting flexibility, including a smaller inventory per module, an integral primary system, natural circulation, passive decay-heat removal, and a water-filled reactor building pool. These features, however, do not by themselves justify siting near populated areas. A smaller emergency planning zone should result from design- and site-specific accident consequence analysis rather than being assumed in advance [5]. For Kuwait, deployment closer to populated areas could only be considered where accident analysis demonstrates sufficiently low off-site consequences, protective actions remain feasible, population growth can be controlled, and external hazards cannot compromise fundamental safety functions. Kuwait would also require comprehensive nuclear legislation, an independent and competent nuclear regulator, and sustained development of national technical capabilities before a nuclear licensing program could proceed.

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