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Comparative Analysis Between US NRC Requirements and US DOE Orders – 13402

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ABSTRACT

Small modular reactor (SMR) is a nuclear reactor design approach that is expected to herald in a new era of clean energy in the U.S. These reactors are less than one-third the size of conventional large nuclear power reactors, and have factory-fabricated components that may be transported by rail or truck to a site selected to house a small nuclear reactor. To facilitate the licensing of these smaller nuclear reactor designs, the Nuclear Regulatory Commission (NRC) is in the process of developing a regulatory infrastructure to support licensing review of these unique reactor designs. As part of these activities, the NRC has been meeting with the Department of Energy (DOE) and with individual SMR designers to discuss potential policy, licensing, and key technical differences in SMR designs. It is anticipated by the NRC that such licensing interaction and guidance early in the design process will contribute towards minimizing complexity while adding stability and predictability in the licensing and subsequent regulation of new reactor designs such as SMRs.

In conjunction with the current NRC initiative of developing the SMR licensing process, early communication and collaboration in the identification and resolution of any potential technical and licensing differences between NRC requirements and similar requirements applicable at DOE sites would help to expedite demonstration and implementation of SMR technology in the US. In order to foster such early communication, Savannah River Nuclear Solutions (SRNS) has begun taking the first steps in identifying and evaluating potential licensing gaps that may exist between NRC and DOE requirements in siting SMRs at DOE sites.

A comparison between the existing NRC regulations for Early Site Permits and the DOE Orders was undertaken to establish the degree of correlation between NRC requirements and compliance methods in place at DOE sites. The ability to use existing data and information to expedite the development of the Environmental Report is being evaluated at the Savannah River Site as a case study for application across the DOE Complex. This paper will present areas of direct correlation as well as those where the need for site specific data for either DOE operations or NRC compliance warrant additional interaction between the agencies. Areas where further refinement of the SMR technologies may drive collaborative development of revised regulations through such means as industry consensus standards will also be highlighted. Both NRC and DOE have requirements that mandate public involvement in their processes. The importance and value of early engagement with the public as well as collaborating regulatory agencies is of critical importance when deploying new technologies.

INTRODUCTION

Small modular reactor (SMR) is a nuclear reactor design approach that is expected to herald in a new era of clean energy in the U.S. The International Atomic Energy Agency (IAEA) defines small reactors as producing equivalent electric power less than 300 MWe. These reactors are less than one-third the size of conventional large nuclear power reactors, and have factory-fabricated components that may be transported by rail or truck to a site selected to house a small nuclear reactor. SMR reactors are generally categorized into two groups: light water reactor designs (LWR) and those that require a coolant other than water (non-LWR) such as helium to pursue a high-temperature gas-cooled reactor.

There are several U.S. SMR designs that are currently being pursued by numerous companies. These designs all share a number of essential characteristics that differ from existing designs including; modularity, fewer components, and small dimensions. Each of these features brings a unique benefit to SMR technology. With a modular design the construction schedules would shorten. The components of the reactor would be constructed at an off-site factory and delivered to the plant for final assembly and installation. Since they require a reduced amount of components and smaller size, the need for ultra-heavy forged components currently made only in Japan and South Korea are no longer necessary and could be domestically supplied. Their small size and output make them advantageous for industrial or district heating applications rather than large reactors that would produce far too much energy and not be cost efficient. These designs could also be used for generating electricity in isolated areas. These benefits would expand and create U.S. economic opportunities and jobs, potentially increase exports of SMR components to international customers, and re-establish the U.S. technical leadership in nuclear technology. However, even with these benefits, SMR designs must be deployed with the same safety and security measures as current larger reactors.

THE NEED FOR EARLY COMMUNICATION

Nuclear reactors have a long life, generate nuclear waste, and have the necessary safeguards to minimize the potential for a serious accident. SMRs are no different from their larger counterparts in these aspects and because of this, a thorough design certification and licensing process must be in place for SMRs. The new SMR designs will need to be carefully evaluated and early communication between manufacturers and the Nuclear Regulatory Commission (NRC) will ensure that the NRC can identify and resolve potential licensing issues early in the process.

To facilitate licensing, communication, and collaboration, the NRC is developing a regulatory approach that supports the unique aspect of SMR designs. This approach includes identifying and resolving policy, developing strategies for efficient and timely reviews, engaging the designers, potential applicants, and the Department of Energy (DOE), and coordinating activities

with stakeholders. For 2012 and beyond, the NRC is focused on completing licensing activities for the design certifications, expanding implementation of the construction inspection program, and to begin the review of applications for the SMR designs.

A decision by the NRC to issue a license to an applicant to operate an SMR must ensure that such a license will not be detrimental to the health and safety of the public or undermine national security. Reviews by the NRC are based on careful assessments of design and operation, accident prevention, accident mitigation, the protection of the release of radioactive materials, and offsite consequences. For LWR technologies, the review criteria have been established over the past 50 years. The U.S. and international research community have developed analysis tools, and conducted experiments and laboratory testing that support these criteria. However, for non-LWR reactor technologies the research base is limited and almost nonexistent. For this reason, the NRC expects significant efforts to be undertaken to support non-LWR licensing decisions. Figure 1 depicts the key areas of the regulatory analysis conducted to support the NRC's licensing process. This figure clearly shows that a broad scope effort is needed to obtain supporting data the NRC would need to certify a design.

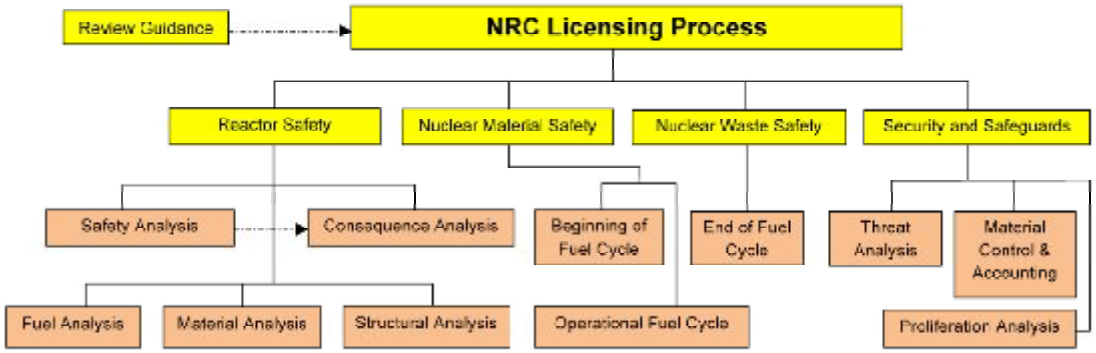

Figure 1. Key Aspects of the NRC Licensing Process

The licensing process for SMRs is being developed by the NRC in view of all of the above considerations and thus underscores the importance of early communication with the DOE to address any potential differences that may exist between NRC and DOE requirements in case an SMR is constructed at a site within the DOE complex. In order to foster such early communication, the Savannah River Nuclear Solutions (SRNS) has taken the first step in identifying and evaluating potential gaps that may exist between NRC and DOE requirements with respect to the possibility of siting SMRs at DOE sites. This paper presents the results of a comparative analysis of the NRC requirements for an Early Site Permit (ESP) to the requirements of any corresponding DOE Order(s) for the siting of an SMR at a DOE site.

BASELINE AND SCOPE FOR COMPARATIVE ANALYSIS

Since the primary intent of the comparison was to identify if DOE has any potential gaps in its current requirements for siting an SMR, the NRC requirements for an ESP application mandated in 10 CFR 52, Subpart A, were used as the *baseline* for the comparison. Based on an initial review of the NRC requirements in 10 CFR 52, a typical ESP application submitted to the NRC must address the following three issues:

- Site Safety (*how would the site and its environment affect the proposed design*)
- Environmental Protection (*how would the design affect the site and its environment*)
- Emergency Preparedness and Planning

In addition to 10 CFR 52, Subpart A, the NRC also outlines standard procedures and requirements for reviewing an ESP application. Two such key documents included in the comparison are the following:

- NUREG-1555, "*Standard Review Plans for Environmental Reviews for Nuclear Power Plants*"
- Nuclear Reactor Regulation (NRR) Review Standard RS-002, "*Processing Applications for Early Site Permits*"

Table 1 lists the set of documents included in the scope of this comparison.

Table 1. List of Documents Included in Comparative Analysis

DOE Orders and other documents	**NRC regulations**
Environmental Permitting and Reporting DOE O 435.1, DOE O 436.1, DOE O 450, DOE O 458.1 **Quality Assurance** DOE O 243.1, DOE O 234.2, DOE O 414.1C, DOE O 482.1ANSI/ASQ E 4, EPA QA R-5, EPA/540/R-93/071, EPA/SW 846 **Emergency Management & Fire Safety** DOE O 150.1, DOE O 151.1C, DOE O 153.1, DOE O 420.1B	10 CFR 50 10 CFR 51 10 CFR 52 10 CFR 70 10 CFR 72 NUREG-1555 NUREG 0849 NUREG 0654 NRC regulatory guide 1.101

It should be noted that the comparison presented here has been performed at the DOE "Order" level so that the results from the comparison would be universally applicable to all DOE sites across the DOE complex. Because the site-specific requirements of other documents such as manuals, site-specific implementation guides, and/or contractor requirements documents (CRD) may differ from one DOE site to another, the results from a comparison based on these more

detailed documents would not be applicable across the entire DOE complex. Therefore the comparison was limited to DOE Orders and site-specific documents were not included in the scope for this comparison.

TECHNICAL APPROACH

A qualitative (high-level) comparison was performed first where all of the DOE Orders and other documents listed in Table 1 were reviewed to identify those DOE documents that have requirements that are similar in intent and objective to the NRC ESP application requirements. The high-level review and comparison of NRC and corresponding DOE documents confirmed that there are current DOE Orders that address the same general subject matter as addressed by the NRC in their requirements. Thus the qualitative analysis did not identify any major gaps between the two sets of documents.

The information compiled in the qualitative analysis laid the basis for a more detailed, quantitative comparison and gap analysis. Each NRC requirement was expanded into its subcategories and then to the extent possible, the specific technical requirements of each subcategory were compared with the technical requirements of each corresponding DOE Order.

The following generalized definitions were formulated to summarize the *degree of comparability* that exists between the NRC requirements and the DOE Orders:

- *Comparable*—The DOE Order(s) were considered to be "*comparable*" to the NRC requirement if the level of detail and the specific requirements stipulated in the DOE Order(s) indicated that complying with the DOE Order would most likely meet or exceed the substantial majority of the detailed requirements in the NRC regulations.
- *Functionally Equivalent*—The two sets of requirements were considered to be "*functionally equivalent*" if the comparison showed that the DOE Orders were written to accomplish similar objectives (e.g., safety and protection of workers from radiation) but may not have the same specific requirements as the NRC. In such cases, complying with the DOE Orders (as written) would accomplish the same "function" but would need to be augmented with additional specificity of data requirements to ensure compliance with the NRC requirements.
- *No Equivalent DOE Order*—This designation was applied to all cases where no equivalent DOE Order was found within the scope of this comparison that directly addresses the NRC requirements. It should be noted that in such cases there may be additional detailed documents available at the DOE sites that address the NRC requirements but were outside the scope of this comparison. Examples of such additional documents include site-specific implementation guides, site manuals, and/or contractor requirements documents among others.

RESULTS OF COMPARATIVE ANALYSIS

Tables 2 through 4 use the above scheme to summarize the results for each of the three general areas of NRC requirements (i.e., site safety, environmental protection, and emergency preparedness and planning).

Table 1. Summary Comparison of Site Safety Report Requirements

Summary of NRC Site Safety Report Requirements	Equivalent DOE Requirement(s)
Natural Phenomena Historical Information Requirements The NRC requires historical information and characteristics of the site as it relates to potential seismic, meteorological, hydrologic, and geologic events	*DOE O 420.1B is functionally equivalent*. It does not specifically require historical information but does require a NPH mitigation assessment for all potential types of natural phenomena hazards.
Site Safety Assessment Requirements Must include an analysis and evaluation of the major structures, systems, and components of the facility and address postulated fission product release and any fission product cleanup systems intended to mitigate the consequences of the accidents	DOE O 420.1B and 10 CFR 830 refer to nuclear facility safety analysis, and the specific requirements of Chapter I (Nuclear and Explosives Safety Design Criteria) in DOE O 420.1B may be adequate to meet the majority of the NRC site safety requirements. Therefore the DOE requirements are *considered as comparable to the NRC requirements.*
Requirements to Propose Major Features of Emergency Plan The site safety analysis report may also propose complete and integrated emergency plans for review and approval by the NRC, in consultation with Department of Homeland Security (DHS)	Emergency planning is addressed by DOE under DOE O 151.C but there is *no equivalent DOE Order within the scope of comparison* that mandate the inclusion of the emergency plan as part of the Site Safety Report requirements
Quality Assurance Program Requirements (App B, 10 CFR 50) Site Safety Report must include details of the QA program to be applied to the design, fabrication, construction, and testing of the structures, systems, and components of the facility. QA program must also address several specific requirements for organizational authority, design control, document control, and other criteria.	DOE O 414.1D and 10 CFR 830 Subpart A address QA requirements but *are not at the same level of detail to enable comparison* with the NRC requirement. Thus, no equivalent DOE requirement was found within the scope of this comparison.

Table 2. Summary Comparison of Environmental Protection Requirements

Summary of NRC Environmental Protection Requirements	Equivalent DOE Requirement(s)
General Requirements General requirements are outlined in NUREG-1555 require a variety of information, including environmental and plant descriptions, impacts of construction and operations, monitoring programs, accident impacts and mitigation, power needs, and alternatives and consequences to the proposed action.	DOE O 458.1 has a few sections on radiation protection that are functionally equivalent to a few of the NUREG-1555 requirements. DOE Order 451.1B outlines DOE's NEPA compliance program and 10 CFR Part 1021 documents DOE's NEPA implementing procedures. *These orders are not as detailed as NUREG 1555 and do not have the level of detail as the NRC's ESP requirements.* However, a lot of the information required by the NRC may be found in site-specific documents (e.g., the MOX ER in case of SRS) including those programs and procedures that implement DOE O 458.1
Environmental Description Requires detailed description to establish facility location and environmental characteristics	DOE Order 451.1B outlines DOE's NEPA compliance program and 10 CFR Part 1021 documents DOE's NEPA implementing procedures but they *do not match this specific NRC requirement in the level of details*. However, the majority of the information required for this section is specific to the site and facility design and therefore should be readily available once the design and location are finalized or may be found in existing site-specific documents (e.g., the MOX ER in case of SRS)
Plant Description Requires a detailed description of the planning, layout, and appearance of the proposed plant and existing station structures and any related offsite structures	

Table 3. Summary Comparison of Environmental Protection Requirements (cont'd)

Summary of NRC Environmental Protection Requirements	Equivalent DOE Requirement(s)
Environmental Measurements and Monitoring Programs Requires a description of the applicant's preoperational and operational radiological, ecological, and chemical monitoring programs.	DOE O 458.1 *Radiation Protection of Public and The Environment* has *several sections that are functionally equivalent* with the NRC in demonstrating compliance with the public dose limits and with environmental monitoring. Most of the other requirements should be fulfilled from facility and site specific information supplied by the vendors
Impacts of Accidents Involving Radioactive Materials Requires evaluation of design basis accidents, risks of accidents, accident mitigation, and treatment and assessment of transportation accidents.	*No DOE Order is available within the scope of comparison* that has the same level of detail but the majority of the NRC requirements are specific to the site and design and should be available from the vendor's design and from existing site-specific documents.
Power Requirements Requires documentation of power demand, power supply, and assessment of the need of power.	
Alternatives to the Proposed Action Requires the review and summarization of the no action alternative, energy alternatives, analysis and evaluation of alternatives to the applicant's proposed site for the construction and operation, and alternative plant and transmission systems	
Environmental Consequences of the Proposed Action Requires identification and description of the predicted adverse environmental impacts of plant or project construction and operation that cannot be avoided	

Table 4. Summary Comparison of Emergency Preparedness and Planning Requirements

Summary of NRC Emergency Preparedness Requirements	Equivalent DOE Requirement(s)
Organization Requires details of organizational authorities, responsibilities, and duties of individuals assigned to the licensee's emergency organization and the means for notification	DOE O 151.1C *Comprehensive Emergency Management System, Attachment 2 – Contractor Requirements Document, has functionally equivalent requirements*. However, unlike the DOE Order, the NRC asks for specific descriptions of the coordinated activities.
Assessment Actions Requires description of the means to be used for determining the magnitude of the impact of the release of radioactive materials	DOE O 151.1C *Comprehensive Emergency Management System, Attachment 2 – Contractor Requirements Document, is functionally equivalent* and requires a consequence assessment while the NRC takes another step requiring the applicant to state the means to be used for determining that consequence.
Activation of Emergency Organization Requires detailed description of the entire set of emergency conditions that would require activation and alerting the organization	No equivalent DOE Order was found within the scope of the documents included in this comparison that addresses this specific NRC requirement.
Notification Procedures Requires description of administrative and physical means for notifying local, State, and Federal officials and agencies	DOE O 151.1C, *Attachment 2 – Contractor Requirements Document, Notifications and Communications (12)* has several notification requirements that are *comparable to the NRC requirements*. Key differences is that NRC may delegate direction to FEMA whereas the DOE interfaces with FEMA but does not delegate direction to FEMA

Table 4. Summary Comparison of Emergency Preparedness and Planning Requirements (cont'd)

Summary of NRC Emergency Preparedness Requirements	Equivalent DOE Requirement(s)
Training Requires the emergency program to provide training of employees and exercising by periodic drills of emergency plans.	DOE O 151.1C, *Attachment 2 – Contractor Requirements Document, Training and Drills (5)* requires a comprehensive, coordinated, and documented program of training and drills that is *functionally equivalent to the NRC requirements*
Maintaining Emergency Preparedness Requires description of how the emergency plan, procedures, and emergency equipment and supplies are maintained up to date	The DOE documents have more detailed requirements and therefore *are comparable to the NRC.* DOE O 151.1C, *Attachment 2 - Contractor Requirements Document, Readiness Assurance (2),* and *Emergency Facilities and Equipment (10)* require that facilities and equipment are maintained.
Recovery Requires detailed description of the entire set of emergency conditions that would require activation and alerting the organization	DOE O 151.1C addresses the requirements for *Termination and Recovery (17)* and *Protective Actions and Reentry (14)* and has *a very detailed set of requirements that are comparable to the NRC.*
Onsite Protective Actions During Hostile Action Implementing Procedure Requirements for Emergency Plan Emergency Response Data Systems Requirements Requires periodic testing and maintenance of the Emergency Response Data System (ERDS) to ensure that the ERDS is able to interface with the NRC receiving system Emergency Planning Zone (EPZ) Requirements Exact size and configuration of the EPZs surrounding a particular nuclear power reactor shall be determined in relation to the local emergency response needs and capabilities.	No equivalent DOE requirements were found within the scope of this comparison that are functionally equivalent to these NRC requirements

CONCLUSIONS AND RECOMMENDATIONS

The conclusions from the comparative analysis of NRC requirements for an Early Site Permit for a nuclear power reactor with corresponding DOE Orders are organized below in the following categories:

- General Conclusions
- Specific Conclusions for Site Safety, Environmental Protection, and Emergency Planning Requirements

General Conclusions

The following general conclusions can be made based on the results of the comparative analysis:

- There is no single DOE Order that specifically addresses comprehensive requirements for siting nuclear power reactors. This makes it difficult to compare DOE requirements to the NRC's 10 CFR 52 Subpart A as the two sets of requirements were not written for the same original purpose.

- The level of detail in corresponding DOE Orders is often less than the NRC requirements.

- Where comparable DOE requirements are available that relate to the NRC ESP requirements, these DOE requirements are often scattered over many different DOE Orders with varying levels of detail; this presents consistency issues in identifying specific DOE data requirements that would be suitable for comparison with the NRC.

- Lack of a specific and prescriptive set of data acceptance requirements is a gap between the NRC requirements and the DOE Orders that will require further resolution based on the specific mission objective and applicability of the NRC requirements(s).

The NRC requirements for an ESP were drafted specifically for nuclear power reactors and therefore include very specific and detailed requirements for technical data, information, and data acceptance criteria for site safety, environmental protection, and emergency planning that only relate to nuclear power reactors. In contrast, the DOE Orders compared as part of this study were drafted for applicability throughout the entire DOE complex to establish general management objectives and requirements and also to assign responsibilities consistent with DOE policy and regulations. Thus, the DOE Orders were not written to specifically address nuclear power reactors unlike the NRC's ESP requirements in 52.17 Subpart A, and this presented a problem in developing a list of specific gaps in this comparative analysis.

The comparison found that in general, the NRC requirements are very prescriptive in specifying what type of information should be included in the technical contents of an ESP, including an additional level of detail and specific acceptance criteria for the required data. Unlike the NRC requirements, the DOE Orders did not specify acceptance criteria for any of their requirements and this is a gap that may require further resolution in the future unless there are site-specific documents already available that contain the necessary level of details.

Specific Conclusions for Site Safety, Environmental Protection, and Emergency Planning

The following specific conclusions can be made based on the results of the comparative analysis for each of the three categories of NRC requirements for an ESP:

Site Safety Report Requirements—The NRC site safety report requirements include both safety report requirements and quality assurance requirements for addressing safety. The comparison of these NRC requirements with DOE Orders showed that there are several DOE Orders that are functionally equivalent to those NRC requirements that address site safety although there is no one-to-one match between the two sets. However, the DOE Orders do not include specific quality assurance activities as part of the safety report requirements. In contrast, the NRC has very extensive and detailed set of QA requirements related to site safety that present a gap between the two when compared at the DOE Orders level.

Environmental Protection Requirements—The majority of the NRC requirements for

environmental protection are specific to site and station factors and are very prescriptive in terms of the data that are required as well as the acceptance criteria for the data. DOE Order 451.1B outlines DOE's NEPA compliance program, 10 CFR Part 1021 documents DOE's NEPA implementing procedures, and DOE O 458.1 addresses radiation protection of the public and the environment. However, none of these documents have the level of detail that would enable any sort of direct comparison with the NRC requirements specified in NUREG 1555. Therefore, in general the comparison concluded that there are no DOE Orders that are either functionally equivalent or comparable to the NRC's prescriptive environmental protection requirements.

However, the comparison also found that there are existing site-specific documents that may have already documented a substantial portion of the site-specific information required by the NRC for an ESP. For example, when the NRC requirements were compared with the contents of the MOX Environmental Impact Statement (EIS) (NUREG 1767) prepared for the MOX facility at the Savannah River Site (SRS) the comparison found that the EIS already had historical, meteorological, and environmental information that could be applicable in case an SMR was built at SRS. Similarly, the NRC environmental protection requirements also require detailed information that is specific to the design of the nuclear power reactor and its interaction with the construction location and operating conditions. It is reasonable to assume that this information will be available from an SMR vendor once a design is finalized.

Emergency Preparedness and Planning—The comparative analysis found that there are several existing DOE Orders that are either functionally equivalent or comparable and require a similar or greater level of detail as the NRC requirements. Therefore no major gaps were identified between the NRC requirements and the DOE Orders in the area of emergency preparedness and planning requirements for an ESP.

Recommendations

As a next step, it is recommended that the general areas where gaps have been identified in this comparison should be used to conduct a more detailed analysis by comparing actual site implementation documents for some of these DOE Orders. That process should result in specific implementation actions for the future so that the DOE implementation process is equivalent in intent to that of the NRC requirements.

The following three-step process is recommended to resolve any gaps and ensure consistency and develop additional cross correlation between the two sets of requirements:

- Step 1 - Use the summary results from Tables 2 through 4 as a preliminary screening tool to prioritize and focus efforts on specific areas where gaps have been identified. Thus,

future efforts could focus on areas where either no equivalent DOE documents were identified or on DOE requirements that have been determined to be functionally equivalent to the NRC requirements but lack enough specificity to be comparable to them.

- Step 2 - Check detailed NRC requirements for each of the three major areas listed in Tables 1 through 3 against other existing documents that were not included in the scope of this analysis to determine if these second tier of documents have the necessary level of detail that is comparable to the NRC requirements. If the additional documents have the necessary level of detail, then determine if these documents address the gaps identified in this analysis. Comparison with such other existing documents could include the following:
    - DOE Order implementation guides and site-specific implementation procedures
    - Compare to other applicable Federal, State, and local permit requirements and systems to evaluate how these requirements may affect compliance with the NRC requirements

- Step 3 - Update site-specific documents with new requirements as applicable so that every NRC requirement listed in Tables 2 through 4 can be cross-correlated to a site-specific implementing procedure or document which has an equivalent requirement.

In summary, any DOE site that is considering the siting and construction of an SMR should use the results of this analysis as the first step in determining if their site has the site specific documents and detailed requirements necessary to fill in the specific gaps identified in the summary results presented in Tables 2 through 4. The site user can then proceed to modify their site implementation guides or other documents as necessary to resolve the gaps and differences so that their site procedures are compliant with the NRC requirements.