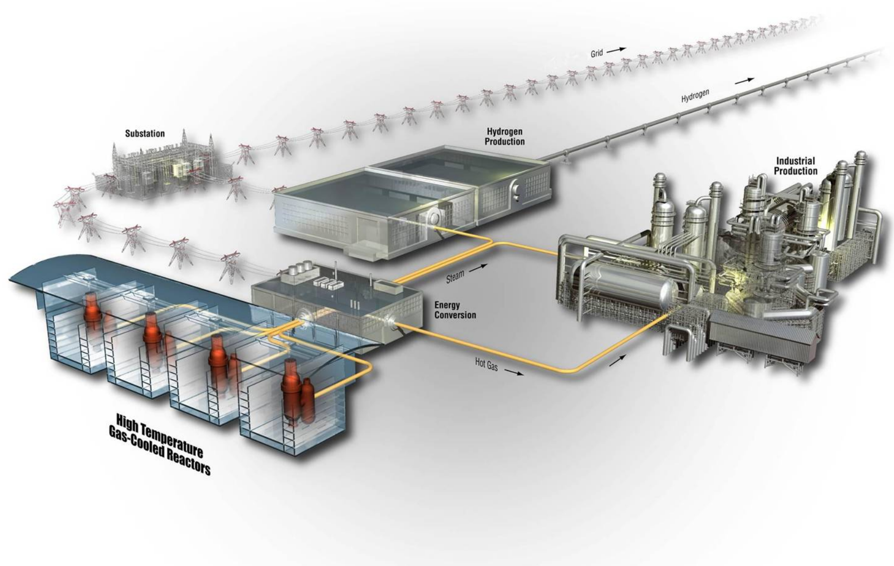
INL/EXT-14-33137

Opportunities in SMR Emergency Planning

October 2014



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Opportunities in SMR Emergency Planning

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October 2014

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SUMMARY

Using year 2014 cost information gathered from twenty different locations within the current commercial nuclear power station fleet, an assessment was performed concerning compliance costs associated with the offsite emergency Planning Standards contained in 10 CFR 50.47(b). The study was conducted to quantitatively determine the potential cost benefits realized if an emergency planning zone (EPZ) were reduced in size according to the lowered risks expected to accompany small modular reactors (SMR).

Licensees are required to provide a technical basis when proposing to reduce the surrounding EPZ size to less than the 10 mile plume exposure and 50 mile ingestion pathway distances currently being used. To assist licensees in assessing the savings that might be associated with such an action, this study established offsite emergency planning costs in connection with four discrete EPZ boundary distances, i.e., site boundary, 2 miles, 5 miles and 10 miles. The boundary selected by the licensee would be based on where EPA Protective Action Guidelines are no longer likely to be exceeded. Additional consideration was directed towards costs associated with reducing the 50 mile ingestion pathway EPZ.

The assessment methodology consisted of gathering actual capital costs and annual operating and maintenance costs for offsite emergency planning programs at the surveyed sites, partitioning them according to key predictive factors, and allocating those portions to individual emergency Planning Standards as a function of EPZ size. Two techniques, an offsite population-based approach and an area-based approach, were then employed to calculate the scaling factors which enabled cost projections as a function of EPZ size. Site-specific factors that influenced source data costs, such as the effects of supplemental funding to external state and local agencies for offsite response organization activities, were incorporated into the analysis to the extent those factors could be representatively apportioned.

Assessment results are presented as a range of expected costs for the startup and the annual operating and maintenance of offsite emergency planning programs; onsite emergency planning program costs were not considered in the analysis. Source data are summarized and presented in conjunction with the current 10 mile EPZ standard and translated into projected costs attributable to reduced EPZ sizes. Projected costs are also apportioned according to each of the sixteen individual emergency Planning Standards.

For the current operating fleet surveyed, the mean annual operating and maintenance cost associated with an offsite emergency planning program is $2.25M/yr. Startup costs for these programs approximated $10M. Analysis results indicated that if a licensee can establish a technical basis for reducing EPZ size from 10 miles to the site boundary, offsite emergency planning cost factors will be reduced by more than 90% over the 40 year life of a typical single unit nuclear power plant. Reducing the EPZ from 10 miles to 5 or 2 miles also significantly reduces cost but not to the extent if the EPZ were collocated with the site boundary. Costs data associated with reduced ingestion pathway EPZ size could not be similarly quantified and is estimated to be a source of negligible potential cost savings.

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FIGURES

TABLES

ACRONYMS

BWR	boiling water reactor
CR	control room
EOF	emergency operations facility
EP	emergency planning
EPA	Environmental Protection Agency
EPZ	emergency planning zone
ERO	emergency response organization
ETE	evacuation time estimate
FEMA	Federal Emergency Management Agency
HTGR	high temperature gas-cooled reactor
INL	Idaho National Laboratory
IPAWS	Integrated Public Alert and Warning System
IPZ	ingestion pathway emergency planning zone
JIC	joint information center
MWt	megawatt thermal
NEI	Nuclear Energy Institute
NGNP	Next Generation Nuclear Plant
NRC	Nuclear Regulatory Commission
O&M	operating and maintenance
ORO	offsite response organization
OSC	operations support center
PAG	Protective Action Guidelines
PRA	probabilistic risk assessment
REP	radiological emergency preparedness
SMR	small modular reactor
SMS	short message service
TSC	technical support center

Opportunities in SMR Emergency Planning

1. INTRODUCTION

This paper discusses results of a cost/benefit-oriented assessment related to emergency planning zone (EPZ) sizing around advanced, small modular reactors (SMR). Contingent upon the reactor technology deployed, a smaller yet appropriately sized EPZ could result in significant cost savings for licensees without compromising the health and safety of the surrounding public. Papers recently published by the U.S. Nuclear Regulatory Commission (NRC) and other organizations discuss the applicability of current emergency preparedness regulatory requirements to SMRs and include information on determining appropriate EPZ sizes. However, relatively little information is publicly available concerning the actual costs associated with the individual regulatory factors that comprise an overall offsite emergency planning program or how those costs may be affected by EPZ resizing. Both the NRC and the industry recognize that a methodology should be developed for determining appropriate EPZ size for SMRs.

The relative cost factors for the smaller EPZs envisioned for SMRs have been qualitatively assessed in prior publications and are also discussed in this paper. Building off the foundation provided in these documents, this study provides a quantitative assessment of offsite emergency planning costs for EPZ sizes that may be justified for many SMRs. Assessment results are derived from actual costs (incurred as of the year 2014) for offsite emergency planning activities as reported by a substantial portion of the current U.S. nuclear power plant fleet.

The assessment establishes that if a licensee can utilize a smaller EPZ size, significant savings in offsite emergency planning costs can be realized over the lifetime of an SMR. Projected data indicate that if a the plume exposure pathway EPZ is reduced from 10 miles to the site boundary, offsite emergency planning costs could be reduced by more than 90% over the nominal 40 year life of a typical single unit nuclear power plant.

1.1 Background

Qualitative cost/benefit assessments of EPZ size were discussed in “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR” (INL 2010) and in “Proposed Methodology and Criteria for Establishing the Technical Basis for Small Modular Reactor Emergency Planning Zone,” (NEI 2013). These papers described processes for establishing generic methodologies in determining the appropriate EPZ size for a SMR. To provide further insight beyond these qualitative assessments, a quantitative cost/benefit assessment of emergency planning costs for smaller EPZ sizes is presented in this report.

1.2 Scope of the Assessment

The assessment identified relative cost contributors associated with the qualitative statements presented in Table 3-1 of the Idaho National Laboratory (INL) High Temperature Gas-Cooled Reactor (HTGR) HTGR EPZ white paper, “Consideration of 10 CFR 50.47 Emergency Planning Standards for the HTGR” (INL 2010). Cost contributors were evaluated with respect to their impact on offsite emergency planning costs associated with EPZ boundaries at the site boundary, two miles, and at five miles. Reducing the ingestion pathway EPZ to less than 50 miles is also examined in this assessment.

1.3 Information Sources

Data for this study was collected from 20 nuclear power plants operating across the U.S. This sampling included a variety of geographic locations (covering multiple NRC and Federal Emergency Management Agency [FEMA] regions), different surrounding population densities, various light water reactor (LWR) technologies, and one or more reactor units per site. Information about each plant is located in Appendix A; Site identification information is withheld to maintain confidentiality.

1.4 Methodology

A survey was performed to obtain information related to the cost to implement and maintain a nuclear power plant offsite emergency preparedness programs at 20 operating reactor sites. Sufficient diversity in this data, such as varied geographic areas and population densities, was sought to ensure a representative range of costs were obtained. Follow-up telephone interviews with utility representatives were conducted to aid in distributing the cost information among the sixteen Planning Standards established in 10 CFR 50.47(b).

Initial reviews of the data showed large variations in operating and maintenance (O&M) costs associated with offsite emergency planning. This was largely due to the existence of state and local agreements or contracts between the licensee and offsite response organization (ORO) authorities for support of ORO costs. At some sites, these agreements stipulated that reimbursements are in addition to baseline funding provided by local and state taxes, while other sites provided little or no additional funding and the majority of ORO financial resources came from local and state taxes. To account for these different funding mechanisms in the assessment, stipulated reimbursements which were in addition to state and local taxes were first assigned to the Planning Standard cited in §50.47(b)(3), Emergency Response Support and Resources, before the remaining budget was apportioned among the remaining Planning Standards.

Where costs could not be directly tied to a single Planning Standard, a cost distribution was made based on the site's emergency planning staff time spent in maintaining the program areas related to these standards.

Each of the sixteen Planning Standards was then subjected to a sensitivity assessment which compared their offsite emergency planning costs to EPZ size. Any cost within the Planning Standard which would scale based on EPZ size was identified and assigned a scalable value.

Figure 1 provides a graphical representation of each surveyed sites' offsite emergency preparedness costs versus population within the plume exposure pathway EPZ. Full cost data, which includes costs from state and local agreements or contracts between the licensee and ORO authorities, varied widely and does not correlate with population size. If the cost of these agreements (i.e., "stipends" in the figure) are removed, then offsite emergency preparedness costs correlate well with population size. This correlation of cost (without stipend) to EPZ population reflects one of the methods used in developing the cost/benefit analysis.

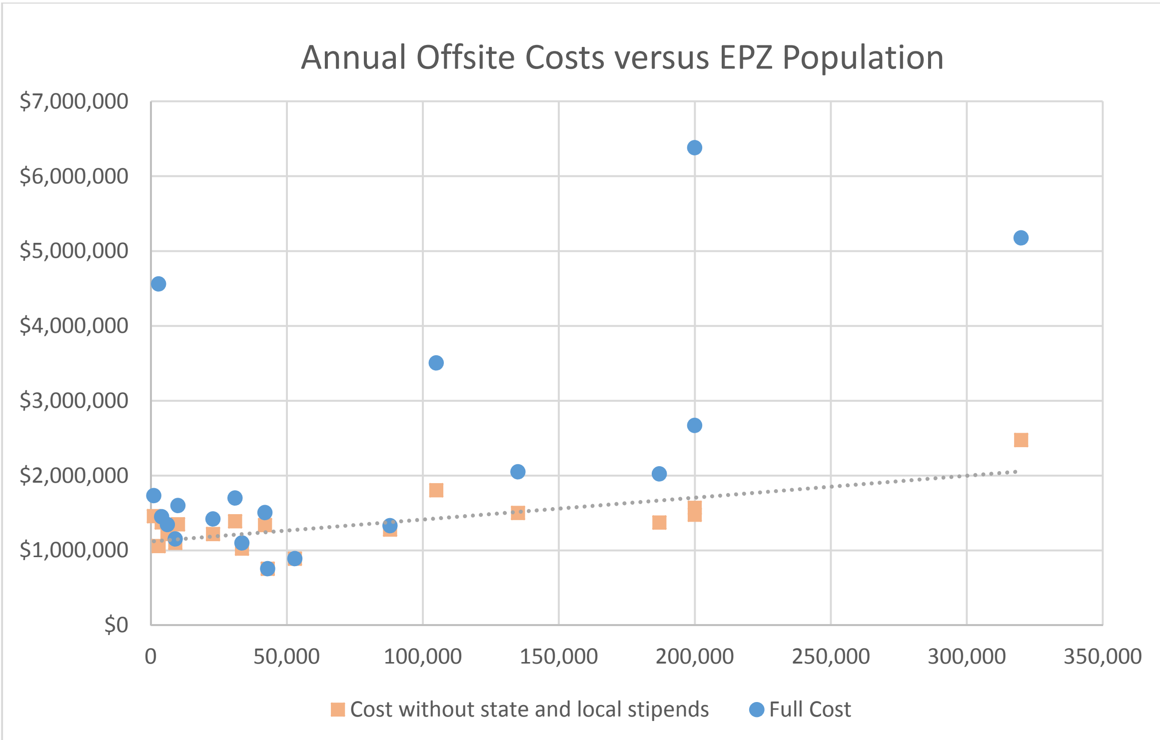

Figure 1. Annual Cost of Offsite Emergency Preparedness by EPZ Population.

As an example of cost variance influence due to a stipend, note the two sites in Figure 1 with EPZ populations of approximately 200,000 people which have full costs of approximately $2.8M and $6.3M respectively. These plants have budgets that are almost identical when the state and local reimbursements are excluded. However, a $3.5 million difference can be seen to exist between the reimbursements that are paid to state and local agencies to fund offsite preparedness.

The number of state and local agencies with which a site needs to coordinate, and therefore their exposure to highly variable reimbursement agreements, is directly correlated with the land area (i.e., size) of their EPZ. Analysis of land area covered by the EPZ was another method used to identify costs associated with appropriately sized EPZs.

2. ASSESSMENT OF PERTINENT DOCUMENTS

2.1 SECY-11-0152

SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors" (NRC 2011), was promulgated by NRC staff to inform the Commission of staff actions to develop an emergency planning and preparedness framework for SMR sites. NRC has already licensed various facilities with a reduced EPZ size, including several small reactors, fuel facilities, material facilities, and independent spent fuel storage installations. These facilities relied on a dose/distance approach to establish the boundary of their planning areas based on U.S. Environmental Protection Agency (EPA) Protective Action Guidelines (PAGs) (EPA 1992).

NRC staff recognizes that the onus falls on individual licensees to provide a well-justified technical basis for reducing EPZ size to less than the 10 mile plume exposure and 50 mile ingestion pathway distances recommended in NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants" (NRC 1978). Technological challenges exist to justify such reductions and include determining the accident source term and fission product release characteristics. In order to facilitate developing the framework, the NRC staff plans to continue working with stakeholders to provide implementation details and detail the changes necessary to emergency planning (EP) requirements and related guidance documents where warranted.

In addressing likely policy issues, the NRC suggested that offsite EP requirements be scaled to appropriate size depending on the SMR accident source term, fission product release, and associated dose characteristics (NRC 2011). NRC discussed four examples of discrete EPZ boundaries that might be used for evaluation: site boundary, 2 mile, 5 mile and 10 mile EPZs. The boundary would be selected based on where EPA PAGs are no longer likely to be exceeded. Additionally, the timeline of an event leading to an offsite dose should be considered with regard to the need for a planned mobilization of resources.

2.2 NEI EP/EPZ Paper

The Nuclear Energy Institute (NEI) released a white paper in December 2013 titled "Proposed Methodology and Criteria for Establishing the Technical Basis for Small Modular Reactor Emergency Planning Zone" (NEI 2013). Using an expectation of enhanced inherent design safety, emergency preparedness regulatory framework and dose savings criteria, and the body of risk information which will be developed for each plant in a final safety analysis report, the white paper discussed a generic methodology and criteria to establish a design- and site-specific technical bases for determining the appropriate EPZ size for a SMR.

The NEI white paper summarized the benefits of appropriate SMR EPZ sizing to stakeholders. These benefits include increased siting possibilities and optimizing resources for emergency response without sacrificing protection of public health and safety.

The white paper proposed using a design- and site-specific probabilistic risk assessment (PRA) to create the technical justification for appropriately sized EPZs. This approach provides for a quantitative risk analysis that is consistent with the NUREG-0396 framework for determining EPZ size. Additional steps are proposed in order to address various uncertainties. Examples of some uncertainties that fail to be represented by a quantitative PRA include human factors considerations, implementation of first of a kind technology, and very low frequency events.

2.3 Sandia Report (SAND2013-3683)

In the 2013 Sandia National Laboratories report, "Evaluation of the Applicability of Existing Nuclear Power Plant Regulatory Requirements in the U.S. the Advanced Small Modular Reactors" (Sandia 2013), the applicability of current regulations to advanced SMRs is examined. In its review of NUREG-0396 and NUREG-0654, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," (NRC 1980) the report concluded that these documents generally establish an EPZ-plume radius of 10 miles and an EPZ-ingestion of 50 miles. This report notes that "In a NUREG-0654 footnote, it is stated that these radii are applicable to light water nuclear power plants, rated at 250 MWt or greater. Small water cooled power reactors (less than 250 MWt) and the Fort St. Vrain gas cooled reactor may use a plume exposure emergency planning zone of about 5 miles in radius and an ingestion pathway emergency planning zone of about 30 miles in radius. The alert and notification system will be scaled on a case-by-case basis. These are based on the lower potential hazard from these facilities, with lower radionuclide inventory and longer times to release significant amounts of activity for many accident scenarios. A similar argument may be able to be used for SMRs."

Additionally, Section 7.3, "Summary of Emergency Planning Requirements Applicability to Advanced SMRs" of this report states "In SECY-11-0152, there is a discussion on an emergency preparedness framework for SMRs that includes an example of a scalable EPZ, based on the dose a distances from the site and utilizing the EPA PAGs. The NRC has licensed several small reactors with an

EPZ of 5 miles for plume (and 30 miles for ingestion), including Fort St. Vrain HTGR (842 MWt), Big Rock Point BWR (240 MWt) and La Crosse BWR (165 MWt). With the SMR passive safety features and the potential for reduced accident source terms and fission product releases, it may be appropriate for SMRs to develop similarly reduced EPZ sizes using a dose/distance approach."

2.4 INL HTGR EPZ White Paper (INL/MIS-10-19799)

In the HTGR EPZ paper (INL 2010) developed by the INL's Next Generation Nuclear Plant (NGNP) project, the scope of emergency planning commensurate with a smaller EPZ size is analyzed. After investigating the regulatory foundations for HTGR emergency planning, the paper qualitatively analyzed the effects of an appropriately sized EPZ on emergency planning as a whole. This paper noted the reduced complexity of fulfilling the sixteen Planning Standards associated with emergency planning commensurate with smaller EPZs.

Table 3-1 of the white paper discussed how qualitative considerations for implementing each Planning Standard will change for the HTGR, assuming an appropriately sized EPZ is in place. These considerations identify key changes in emergency planning complexity such as limited scope, fewer offsite agencies involved, and reduced staffing among others.

While this paper focused primarily on modular HTGR technology, the key attributes which affect emergency planning are common to other types of SMR technologies as well. The emergency planning insights developed in this paper were therefore considered potentially applicable to SMRs in general.

2.5 Commonalities and Differences

The SECY, NEI, INL and Sandia documents acknowledge the benefits in establishing appropriately sized EPZs for advanced SMRs provided there is technical justification to do so. In SECY-11-0152, the NRC outlined a justification based on previously licensed and existing sites with EPZs that are smaller than the 10 mile plume exposure pathway EPZ required for large LWRs. NRC regulations (see 10 CFR 50.33(g), §50.47(c)(2)) provide that the size of the EPZ may also be determined on a case-by-case basis for high temperature gas-cooled reactors and for reactors with an authorized power level less than 250 MWt. Based on these provisions (for HTGRs and SMRs with a power rating less than 250 MWt) and considering precedents associated with smaller nuclear plants, an appropriately sized EPZ based on accident source term, fission product release and associated offsite dose characteristics is warranted. Using this concept as a baseline, NEI's white paper proposed a methodology for sizing an EPZ at an advanced reactor site.

The Sandia report supports the EPZ sizing framework presented by the NEI white paper, and also identifies several areas of potential savings for further consideration. These include extended notification times, shared facilities/staffing, co-location with other SMRs and other nuclear power reactors, and reduced number and/or extended augmentation times for staffing positions.

In the HTGR EPZ white paper, the same stakeholder insights and suggested approaches for appropriately sized EPZs are presented, albeit specific to the HTGR technology. The paper discusses how these attributes influence emergency planning as a whole and provides insight on the reduced complexity of implementing the sixteen Planning Standards.

3. EMERGENCY PLANNING OFFSITE COST CONTRIBUTORS

3.1 Summary of Previous Qualitative Analysis

Table 3-1 of the HTGR EPZ white paper (INL 2010) provided a qualitative analysis of the potential effects of reducing the EPZ size for a modular HTGR design on the sixteen emergency Planning Standards. This table suggested potential cost savings exist in all Planning Standards except for those in §50.47(b)(9), Accident Assessment, and §50.47(b)(13), Recovery and Reentry Planning and

Post-Accident Operations. These assumptions were made with the inherent safety of the modular HTGR design in mind, but may be applicable to other advanced SMRs (depending on the design).

Table 3-1 of the HTGR EPZ paper also suggested that offsite planning, which is a major contributor to Planning Standards §50.47(b)(3), Emergency Response Support and Resources, and §50.47(b)(16), Responsibilities for Emergency Planning, could be integrated into an all-hazards planning approach with a significantly limited scope. This is based on an assumed EPZ at the site boundary for the modular HTGR design. However, cost savings would still be realized for 2 and 5 mile EPZs dependent on the specific local geopolitical boundaries involved. Planning Standard §50.47(b)(14), Exercises and Drills, will also be reduced in scope as the EPZ reduces in size due to more limited involvement of fewer participating offsite agencies and jurisdictions.

Addressing the remaining Planning Standards would result in scope reduction as the EPZ is reduced due to the need to address a less complex geographical and political infrastructure and a smaller population within the downsized EPZ boundary. With the exception of an EPZ boundary coinciding with the site boundary, the amount of this reduction will vary according to site-specific conditions (e.g., demography, jurisdictions involved, etc.).

3.2 Quantitative Analysis of Costs by Planning Standard

Figure 2 shows the average cost (per year) of offsite emergency preparedness at the twenty sites surveyed during this assessment. Cost data is distributed across the sixteen Planning Standards that appear in 10 CFR 50.47(b). A description of each Figure 2 Planning Standard can be found in text contained in the first column of Table 1.

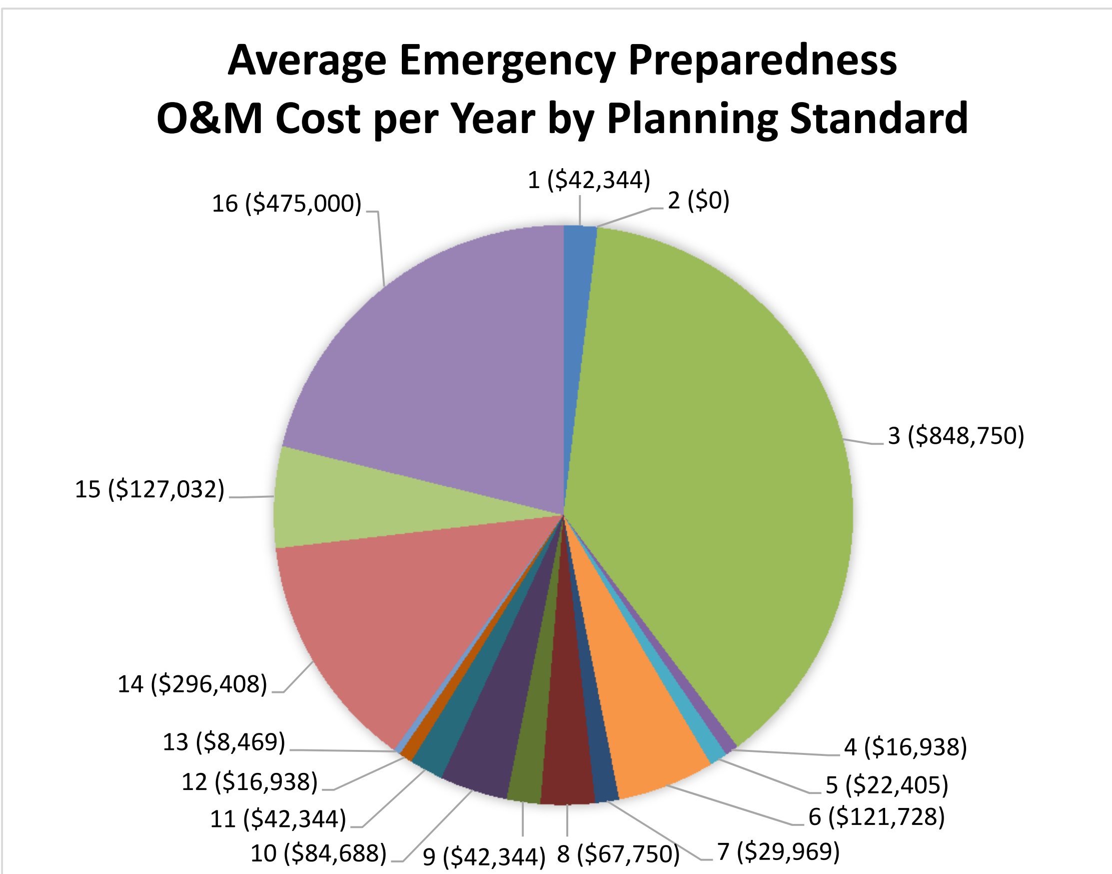

Figure 2. Average Annual Cost of Surveyed Sites by 10 CFR 50.47(b) Planning Standard.

Planning Standard §50.47(b)(2), Onsite Emergency Organization, has no offsite cost because it deals exclusively with licensee onsite emergency response organization (ERO) costs (which is outside the scope of this assessment). Otherwise, the data shown in Figure 2 represents an average annual offsite planning cost profile covering the twenty operating nuclear plants surveyed for this study. Data supporting this figure can be found in Appendix B.

The cost allocations associated with Planning Standards §50.47(b)(3), Emergency Response Support and Resources, §50.47(b)(7), Public Education and Information, and §50.47(b)(16), Responsibilities for Emergency Planning, were reported by each surveyed site as discrete or distinct budget items and are not based on a proportion of total budget. Once costs for these three Planning Standards were subtracted from the total annual cost, the remaining cost information was distributed among the other Planning Standards based on a percentage of the staff time an average emergency preparedness program spends addressing each remaining Planning Standard.

Using this cost distribution, inspection of Figure 2 indicates there are three major O&M cost contributors to offsite emergency planning. These are Planning Standards §50.47(b)(3), Emergency Response Support and Resources, §50.47(b)(14), Exercises and Drills, and §50.47(b)(16), Responsibilities for Emergency Planning.

3.3 Categories of Cost

3.3.1 Capital Costs

Capital costs are typically associated with equipment purchases and installation or major program changes driven by regulatory requirements. Capital costs identified in this assessment are predominantly associated with Planning Standards §50.47(b)(1), Assignment of Responsibility, §50.47(b)(6), Emergency Communications (public warning system), and §50.47(b)(8), Facilities and Equipment, and §50.47(b)(10), Protective Response.

- §50.47(b)(1), Assignment of Responsibility - Initial development and training for implementation of the plans and procedures required to establish a fully functional offsite response organization for each local and state authority within the current 10 mile EPZ is a significant startup expense for any new reactor site. Initial development cost is typically capitalized with other plant startup expenses and can be expected to range from approximately $3,500,000 to $5,000,000 for a proposed "green field" site (i.e., a site where a license application has been submitted but no operating nuclear plant currently exists). Because the number of jurisdictions needing to develop radiological emergency response plans is related to the size of the EPZ, both the initial cost of establishing, as well as the ongoing cost of maintaining these plans, would be reduced for a smaller EPZ.
- §50.47(b)(6), Exercises and Drills – Currently, public warning systems consist of installed outdoor sirens located throughout the EPZ to ensure sufficient sound coverage. A public warning system of fixed sirens carries an upfront cost of approximately $30,000 per siren, including associated control and monitoring systems and radio license costs. With the average respondent site having a system of 67 sirens, this is an upfront capital cost of more than $2,000,000. Because the size of the public warning system is directly related to the size of the EPZ, both the initial as well as the ongoing costs of establishing and maintaining this system would result in significant reduction for a smaller EPZ. For a postulated 5 mile EPZ with uncomplicated topography, a full coverage system of approximately 20 sirens would cost approximately $600,000 (upfront) with associated annual costs for control and monitoring systems and radio license.
- §50.47(b)(8), Responsibilities for Emergency Planning - Licensee facilities such as the control room (CR), technical support center (TSC), and operations support center (OSC) will not vary significantly due to reductions in EPZ size alone. The capabilities and structure of these facilities will be more affected by factors associated with design specific postulated offsite radiological release characteristics. However, the size and complexity of the emergency operations facility (EOF) and

joint information center (JIC) should be impacted by any reduction in EPZ size due to the smaller number of potentially affected members of the general population, reduced number of offsite response organizations, and potentially reduced facility staff. Recent construction costs of combination EOF/JIC facilities located just outside existing EPZ boundaries typically are in the range of $4,000,000 to $7,000,000.

- §50.47(b)(10), Protective Response - Initial development of an evacuation time estimate (ETE) is another capital expense associated with siting and licensing a new reactor. Current initial ETEs for new reactor sites cost approximately $125,000 to develop. Additional costs associated with addressing regulatory review comments could increase the total ETE cost to $200,000 to $250,000. Because the scope of the ETE is directly related to size of the EPZ and the population contained within its borders, an EPZ boundary at either 2 or 5 miles would significantly reduce this cost.

3.3.2 NRC/FEMA Fees

The NRC's baseline emergency planning inspection program results in an estimated 60 inspection hours per year. Billed at the current (2014) rate of $272/inspector hour, an annualized NRC inspection cost of $16,320 can be expected. This represents an annual baseline NRC inspection budget just for the EP-related baseline inspection modules for a plant in the Licensee Response Column of the action matrix of IMC 0305, "Operating Reactor Assessment Program." This cost should not vary with EPZ scaling.

The NRC fees are not included in the resulting cost breakdowns contained in this report. Baseline annual or recurring inspections are predominantly onsite EP-focused and are a source of negligible offsite planning cost. NRC inspection costs are also lumped into a site bill where EP-related inspector hour fees are not itemized. Although a site can request itemization, most do not. Instead, charges are addressed by budget items like "inspections" or "licensing actions" that do not reflect the offsite EP O&M values used in this report.

Annual FEMA fees to implement the Radiological Emergency Preparedness (REP) program are established by 44 CFR 354. These fees include a site-specific, biennial exercise-related component and a flat fee component. The site-specific component is set to recover that portion of the REP program budget associated with the biennial plume pathway EPZ exercise-related activities, and the flat fee component is the same for each site and recovers the remaining portion of the REP program funding. While the fixed fee component will not vary based on EPZ size, the exercise-related component will vary directly with EPZ size and be reduced as the number of OROs is reduced.

The FEMA fees are not reflected in results contained in this report. Since the only FEMA cost affected by an EPZ size reduction is the cost recovery component for biennial exercise oversight, FEMA's recent reduction in biennial exercise evaluation team size makes this cost component of minimal impact for any EPZ size reduction other than co-location at the site boundary.

3.3.3 Operating and Maintenance Costs

Of the twenty sites surveyed, annual O&M budgets for maintaining offsite emergency preparedness ranged from $755,000 to $6,379,000. This results in a mean O&M budget of $2.25 million, and a median value of $1.6 million. The large variation in these offsite planning costs exist mostly due to state or local differences in ORO funding regulations and/or historic commitments for reimbursement of costs incurred by the offsite organizations made by the licensee. An accounting for these local differences is discussed in Section 1.4 "Methodology."

Certain costs are directly related to the population within the EPZ, such as the public information requirements of §50.47(b)(7), Public Education and Information, and can be easily scaled to EPZ size for each site based on census data. Other costs related to baseline response capabilities will scale in relation to a reduction in EPZ size, but the exact cost will depend on local and state jurisdictional boundaries.

3.4 Cost Susceptibility to EPZ Scaling

The three major O&M cost contributors to offsite emergency planning (based on Figure 2 information) are Planning Standards §50.47(b)(3), Emergency Response Support and Resources, §50.47(b)(14), Exercises and Drills, and §50.47(b)(16), Responsibilities for Emergency Planning. Table 3-1 of the HTGR EPZ paper (INL 2010) suggested that offsite planning, which is a major contributor to Planning Standards §50.47(b)(3), Emergency Response Support and Resources, and §50.47(b)(16), Responsibilities for Emergency Planning, could be integrated into an existing all-hazards planning approach with a significantly limited scope. This is based on an assumed EPZ at the site boundary. However, cost savings could still be realized for 2 and 5 mile EPZs dependent on the specific local geopolitical boundaries involved. Planning Standard §50.47(b)(14), Exercises and Drills, will also reduce in scope as the EPZ shrinks in size due to lesser involvement from fewer participating offsite agencies and jurisdictions.

Efforts and costs to implement the remaining Planning Standards will be generally lessened as the EPZ size is reduced due to the need to address a less complex geographical and political infrastructure, as well as a smaller "at risk" population. With the exception of cases where an EPZ boundary coincides with the site boundary, the amount of this reduction will vary based largely upon site-specific conditions (i.e., state/local jurisdictional boundaries).

To develop a range of potential cost savings that accounts for these site-specific conditions, two methods were used to calculate cost scaling factors for a smaller EPZ; a population-based approach and an area-based approach.

1. The population-based approach uses the cost survey's median population for the 2, 5, and 10 mile EPZ boundaries. The ratio of these 2 and 5 mile values to the full 10 mile EPZ is the population-based cost scaling factor for these EPZ boundaries. The resultant cost scaling factor for the 5 mile EPZ is 10% and 1% for the 2 mile EPZ.
2. The area-based approach determines the ratio of area (in square miles) contained within the 5 mile, and 2 mile EPZs compared to the full 10 mile EPZ. These ratios are used as the area-based cost scaling factors. The resultant cost scaling factor for the 5 mile EPZ is 25% and 4% for the 2 mile EPZ.

For an EPZ at the site boundary, a cost scaling factor of zero is used to represent the absence of additional ORO preplanning beyond that already existing in an all-hazards plan. Onsite response from offsite agencies, such as fire and ambulance, were not considered in the cost scaling as these services are independent of EPZ size.

Scaling factors were then applied to the average annual cost of implement offsite planning for each of the Planning Standards. Results are shown in Table 1.

Table 1. Qualitative Impact of Reduced EPZ Size on the Planning Standards of 10 CFR 50.47(b).

Planning Standard	Impact of 5 mile EPZ	Impact of 2 mile EPZ	Impact of EPZ at EAB
§50.47(b)(1): Assignment of Responsibility (Organizational Control)	ORO structure is simplified (fewer jurisdictions) Scaling factors of 10% and 25% applied	ORO structure is simplified (fewer jurisdictions) and all hazards planning approach could be warranted. Scaling factors of 1% and 4% applied	ORO structure is eliminated and all hazards planning is adequate. Scaling factor of 0.0 applied

Table 1. (cont'd)

Planning Standard	Impact of 5 mile EPZ	Impact of 2 mile EPZ	Impact of EPZ at EAB
§50.47(b)(2): Onsite Emergency Organization	No reduction compared to current costs	No reduction compared to current costs	No reduction compared to current costs
§50.47(b)(3): Emergency Response Support and Resources	Fewer ORO jurisdictions included in footprint of EPZ. Scaling factors of 10% and 25% applied	Fewer ORO jurisdictions included in footprint of EPZ. Scaling factors of 1% and 4% applied	No ORO jurisdictions included in footprint of EPZ. Scaling factor of 0.0 applied
§50.47(b)(4): Emergency Classification System	No reduction compared to current costs	No reduction compared to current costs	No reduction compared to current costs
§50.47(b)(5): Notification Methods and Procedures	Number of participating agencies/jurisdictions is reduced. Scaling factors of 10% and 25% applied	Number of participating agencies/jurisdictions is reduced. Scaling factors of 1% and 4% applied	Number of participating agencies/jurisdictions is reduced. Scaling factor of 0.0 applied.
50.47(b)(6): Emergency Communications	Design of alert and notification system and supporting materials is reduced doe to smaller EPZ footprint. Scaling factors of 10% and 25% applied	Design of alert and notification system and supporting materials is reduced doe to smaller EPZ footprint. Scaling factors of 1% and 4% applied	No alert and notification system is needed. Scaling factor of 0.0 applied
§50.47(b)(7): Public Education and Information	Information dissemination needs are reduced due to smaller population potentially affected. Scaling factors of 10% and 25% applied	Information dissemination needs are reduced due to smaller population potentially affected. Scaling factors of 1% and 4% applied	Information dissemination needs are eliminated. Scaling factor of 0.0 applied
§50.47(b)(8): Emergency Facilities and Equipment	Size of EOF and JIC are reduced, and less equipment needs to be maintained for offsite response. Scaling factors of 10% and 25% applied	Size of EOF and JIC are reduced, and less equipment needs to be maintained for offsite response. Scaling factors of 1% and 4% applied	EOF and JIC functions are consolidated into onsite facilities as necessary. No equipment needs to be maintained for offsite response. Scaling factor of 0.0 applied
§50.47(b)(9): Accident Assessment	No reduction compared to current costs	No reduction compared to current costs	No reduction compared to current costs
§50.47(b)(10): Protective Response	Reduced planning for offsite protective actions due to smaller EPZ footprint. Scaling factors of 10% and 25% applied	Reduced planning for offsite protective actions due to smaller EPZ footprint. Scaling factors of 1% and 4% applied	No planning for offsite protective actions. Scaling factor of 0.0 applied.

Table 1. (cont'd)

Planning Standard	Impact of 5 mile EPZ	Impact of 2 mile EPZ	Impact of EPZ at EAB
§50.47(b)(11): Radiological Exposure Control	ORO emergency worker dosimetry and KI needs are reduced. Scaling factors of 10% and 25% applied	ORO emergency worker dosimetry and KI needs are reduced. Scaling factors of 1% and 4% applied	ORO emergency worker dosimetry and KI needs are eliminated. Scaling factor of 0.0 applied.
§50.47(b)(12): Medical and Public Health Support	Still required due to 1986 FEMA Medical Services Guidance Memorandum. No reduction compared to current costs	Still required due to 1986 FEMA Medical Services Guidance Memorandum. No reduction compared to current costs	Still required due to 1986 FEMA Medical Services Guidance Memorandum. No reduction compared to current costs
§50.47(b)(13): Recovery and Reentry Planning and Post-Accident Operations	Number of participating agencies/jurisdictions is reduced. Scaling factors of 10% and 25% applied	Number of participating agencies/jurisdictions is reduced. Scaling factors of 1% and 4% applied	No offsite agencies/jurisdictions. Scaling factor of 0.0 applied.
§50.47(b)(14): Exercises and Drills	Number of participating agencies/jurisdictions is reduced. Scaling factors of 10% and 25% applied	Number of participating agencies/jurisdictions is reduced. Scaling factors of 1% and 4% applied	No offsite agencies/jurisdictions. Scaling factor of 0.0 applied.
§50.47(b)(15) Radiological Emergency Response Training	Number of participating agencies/jurisdictions is reduced. Scaling factors of 10% and 25% applied	Number of participating agencies/jurisdictions is reduced. Scaling factors of 1% and 4% applied	No offsite agencies/jurisdictions. Scaling factor of 0.0 applied.
§50.47(b)(16): Responsibilities for Emergency Planning	Number of participating agencies/jurisdictions is reduced. Scaling factors of 10% and 25% applied	Number of participating agencies/jurisdictions is reduced. Scaling factors of 1% and 4% applied	No offsite agencies/jurisdictions. Scaling factor of 0.0 applied.

Table 2 shows the annual cost to implement offsite planning for each Planning Standard of 10 CFR 50.47(b) after application of Table 1 scaling factors. Costs for the 2 and 5 mile EPZ boundaries are shown as a budget range to separately reflect the application of both the population-based and area-based scaling factors.

Table 2. Quantitative Impact of Reduced EPZ Size on the Planning Standards of 10 CFR 50.47(b).

Planning Standard	Current 10 Mile EPZ Cost	Projected 5 Mile EPZ Cost	Projected 2 Mile EPZ Cost	Projected Site Boundary EPZ Cost
§50.47(b)(1) Assignment of responsibility	$42,344	$3,800 – $10,500	$425 – $1,700	$0.00

Table 2. (cont'd)

Planning Standard	Current 10 Mile EPZ Cost	Projected 5 Mile EPZ Cost	Projected 2 Mile EPZ Cost	Projected Site Boundary EPZ Cost
§50.47(b)(2) Onsite Emergency Organization	$0.00	$0.00	$0.00	$0.00
§50.47(b)(3) Emergency Response Support and Resources	$848,750	$76,000 – $212,000	$8,500 – $34,000	$0.00
§50.47(b)(4) Emergency Classification System	$16,938	$16,938	$16,938	$16,938
§50.47(b)(5) Notification Methods and Procedures	$22,405	$2,000 – $5,600	$225 – $900	$0.00
§50.47(b)(6) Emergency Communications	$121,728	$11,000 – $30,500	$1,200 – $4,900	$0.00
§50.47(b)(7) Public Education and Information	$29,969	$2,700 – $7,500	$300 – $1,200	$0.00
§50.47(b)(8) Emergency Facilities and Equipment	$67,750	$6,100 – $17,000	$700 – $2,700	$0.00
§50.47(b)(9) Accident Assessment	$42,344	$42,344	$42,344	$42,344
§50.47(b)(10) Protective Response	$84,688	$7,600 – $21,000	$850 – $3,400	$0.00
§50.47(b)(11) Radiological Exposure Control	$42,344	$3,800 – $10,500	$425 – $1,700	$0.00
§50.47(b)(12) Medical and Public Health Support	$16,938	$16,938	$16,938	$16,938
§50.47(b)(13) Recovery and Reentry Planning and Post-Accident Operations	$8,469	$750 – $2,100	$100 – $350	$0.00
§50.47(b)(14) Exercises and Drills	$296,408	$27,000 – $74,000	$3,000 – $12,000	$0.00
§50.47(b)(15) Radiological Emergency Response Training	$127,032	$11,500 – $32,000	$1,300 – $5,100	$0.00
§50.47(b)(16) Responsibilities for Emergency Planning	$475,000	$42,750 – $119,000	$4,800 – $19,000	$0.00

Table 2. (cont'd)

Planning Standard	Current 10 Mile EPZ Cost	Projected 5 Mile EPZ Cost	Projected 2 Mile EPZ Cost	Projected Site Boundary EPZ Cost
TOTAL annual costs for implementing the offsite portions of §50.47(b) Planning Standards for each EPZ size in $/year	$2,250,000	$268,500 – $618,000	$98,000 – $163,000	$76,000
Potential savings in $/year	$0.00	$1,632,000 – $1,981,500	$2,087,000 – $2,152,000	$2,174,000

3.5 Ingestion Pathway Emergency Planning Zone

As information was being collected for cost analysis, it was recognized that establishing an ingestion pathway EPZ (i.e., IPZ) at a distance less than 50 miles offered a minimal opportunity for meaningful savings. This was attributed to factors that included:

1. Costs associated with maintaining a 50 mile IPZ are typically very small when compared to the nominal costs for overall offsite emergency planning. In fact, most surveyed sites tracked the cost of only one IPZ-related item (a public information mail-out to local authorities). This item generally costs $5,000-$10,000 which in some cases was absorbed by state authorities as part of their existing regional radiological control program training and education materials budget.
2. Although IPZ exercise costs are transferred back to the site operator, developing protective action strategies in this area requires only limited planning and an exercise once during an 8 year cycle. Exercise completion may incur as little as one man-week of billable time. A lack of cost data specific to this area made assessing the financial impact of a reduced IPZ size difficult to quantify.
3. Information concerning a former nuclear site where the IPZ was in-fact reduced to less than 50 miles indicated that IPZ costs varied little relative to other sites that maintained a 50 mile IPZ.

Because of the problems associated with acquiring reliable source data, a cost differential analysis on a reduced IPZ size was not performed. Therefore, this study does not separate IPZ costs from the overall offsite emergency planning cost information reported by surveyed sites.

4. RECOMMENDATIONS TO ADDRESS SECY-11-0152

Developing a licensing framework and implementing guidance for a scalable EPZ is a critical step in SMR deployment. While §50.33(g) and §50.47(c)(2) currently provide for alternate EPZ sizes on a case-by-case basis for HTGRs and for reactors with an authorized power level less than 250 MWt, a technology-neutral and dose-based scalable methodology would create a more efficient and predictable licensing framework conducive to the development of all new and advanced reactor technologies.

The information presented in this report should be coupled with prior work, such as the prelicensing actions conducted by INL's NGNP project and the information contained in the INL HTGR EPZ white paper, as well as future studies to assist in formulating a licensing framework appropriate to advanced reactors. Development of a methodology supportive of that framework is recommended.

5. OTHER COST INFLUENCES

The implementation of Planning Standards §50.47(b)(2), Onsite Emergency Organization, §50.47(b)(6), Emergency Communications, and §50.47(b)(8), Emergency Facilities and Equipment, could realize a potential reduction in complexity due to advanced reactor technology features. This is because smaller reactors and advanced technology designs are expected to generate smaller releases of radioactive material with a later release start time in the unlikely event of release. However, these mechanistic source term characteristics are not dependent on the size of the EPZ.

One potential influence on future capital EP costs is the ongoing development of FEMA's Integrated Public Alert and Warning System (IPAWS). This system is designed to integrate the different emergency alert systems and add a warning capability via cellular telephone and short message service (SMS), satellite and cable television, electronic billboards and the internet. Once this system has matured and is credited in the FEMA REP Manual, it could significantly reduce the need for the outdoor warning systems now used by plants to meet Planning Standard §50.47(b)(6), Emergency Communications. However, the cost savings potential of this new development was not considered in this assessment.

Perhaps the largest potential influence on future O&M costs for offsite EP is contained in Revision 2 of NUREG-0654, which is currently being drafted by a joint NRC/FEMA task team. While this revision will not address the EPZ sizing considerations contained in this paper, it will influence the scale of costs incurred by an organization when implementing a radiological emergency plan. This revision will reflect updates necessitated by the 2011 revision of 10 CFR 50.47 and 10 CFR 50, Appendix E, but will also include insights based on Fukushima "lessons learned". Early (prepublication) drafts of this revision indicate that drill and exercise costs could increase for OROs due to an increase in the required number and frequency of ORO drills and exercises. Costs for these additional activities will be directly or indirectly passed back to licensees.

The draft Revision 2 of NUREG-0654 is currently not expected to be released for public comment until late 2014. Final rulemaking is not scheduled until 2017.

6. SUMMARY AND CONCLUSIONS

Table 3 summarily shows the potential impact, both in capital and O&M costs, of reducing the size of the plume exposure EPZ. The reduced capital cost associated with the EOF and JIC at less than a 10 mile EPZ assume a smaller facility will be needed to address the reduced scope of a potentially affected EPZ population and fewer offsite response organizations with which to coordinate responses.

Table 3. Summary of Offsite Planning Implementation Costs at Varying EPZ Size.

		10 mile EPZ (current fleet)	5 mile EPZ	2 mile EPZ	EPZ at EAB
Capital Costs	Initial ORO Plan Development	\$3,500,000 – \$5,000,000	\$1,500,000 – \$2,500,000	\$500,000 – \$1,000,000	\$0
	Alert and Notification System	\$2,000,000	\$600,000	\$60,000	\$0
	EOF/JIC	\$4,000,000	\$2,000,000	\$2,000,000	\$2,000,000
	Evacuation Time Estimate	\$125,000	\$100,000	\$50,000	\$0
	TOTAL CAPEX	\$9,625,000 – \$11,125,000	\$4,200,000 – 5,200,000	\$2,610,000 – \$3,110,000	\$2,000,000
O&M	Average annual O&M for offsite planning only	\$2,250,000	\$268,500 – \$618,000	\$98,000 – \$163,000	\$76,000

The reader is again reminded that the costs appearing in Table 3 represent only those costs related to implementation of the offsite portion of the sixteen Planning Standards; onsite EP implementation costs are not reflected in this summary.

7. APPENDIXES

Appendix A, Data from Sites Surveyed

Appendix B, Allocation of Current Plant Costs to the Planning Standards of 10 CFR 50.47(b)

8. REFERENCES

EPA 1992, U.S. Environmental Protection Agency, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," EPA 400-R-92-001, May 1992.

INL 2010, Idaho National Laboratory, "Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR," INL/MIS-10-19799, October 2010.

NEI 2013, Nuclear Energy Institute, "Proposed Methodology and Criteria for Establishing the Technical Basis for Small Modular Reactor Emergency Planning Zone," December 2013.

NRC 1978, U.S. Nuclear Regulatory Commission, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants," NUREG-0396, December 1978.

NRC 1980, U.S. Nuclear Regulatory Commission, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," NUREG-0654/FEMA-REP-1, Rev. 1, November 1980.

NRC 2011, U.S. Nuclear Regulatory Commission, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors," SECY-11-0152, October 28, 2011.

SNL 2013, Sandia National Laboratories, "Evaluation of the Applicability of Existing Nuclear Power Plant Regulatory Requirements in the U.S. to Advanced Small Modular Reactors," SAND2013-3683.

Appendix A

Data from Sites Surveyed

Appendix A
Data from Sites Surveyed

Table A-1. Data from Sites Surveyed.

	NRC Region	FEMA Region	Total Annual O&M Budget for Offsite Preparedness	Approximate 10 Mile EPZ Population	Approximate 50 Mile IPZ Population
Plant A	II	IV	$1,600,000	10,000	465,000
Plant B	II	IV	$1,153,000	9,000	485,000
Plant C	II	IV	$1,450,000	4,000	780,000
Plant D	IV	VII	$1,345,000	6,100	210,000
Plant E	II	IV	$2,670,000	200,000	1,400,000
Plant F	II	IV	$2,051,000	135,000	3,500,000
Plant G	III	VII	$1,420,000	22,886	820,000
Plant H	III	VII	$2,023,000	187,000	685,000
Plant I	I	IV	$6,379,000	200,000	4,400,000
Plant J	IV	VI	$4,560,000	2,875	294,000
Plant K	IV	VII	$1,100,000	33,500	1,800,000
Plant L	IV	VII	$1,505,000	42,000	950,000
Plant M	IV	VII	$1,733,000	1,100	321,000
Plant N	I	II	$5,175,000	320,000	17,200,000
Plant O	IV	VII	$1,330,000	88,000	2,000,000
Plant P	IV	IV	$890,000	53,000	310,000
Plant Q	I	II	$755,000	43,000	910,000
Plant R	II	VII	$1,700,000	31,000	1,300,000
Plant S	I	I	$3,505,000	105,000	4,700,000
Plant T	IV	I	$1,668,000	5,000	163,000

Appendix B

Allocation of Current Plant Costs to the Planning Standards of 10 CFR 50.47(b)

Appendix B
Allocation of Current Plant Costs to the Planning Standards of 10 CFR 50.47(b)

Table B-1. Annual Offsite Emergency Preparedness Cost by Planning Standard.

Plant	TOTAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	$1,600,000	$47,300	$0	$250,000	$18,920	$18,920	$141,900	$4,000	$75,680	$47,300	$94,600	$47,300	$18,920	$9,460	$331,100	$141,900	$400,000
B	$1,153,000	$34,970	$0	$50,000	$13,988	$13,988	$104,910	$3,600	$55,952	$34,970	$69,940	$34,970	$13,988	$6,994	$244,790	$104,910	$400,000
C	$1,450,000	$48,670	$0	$75,000	$19,468	$19,468	$146,010	$1,600	$77,872	$48,670	$97,340	$48,670	$19,468	$9,734	$340,690	$146,010	$400,000
D	$1,345,000	$40,878	$0	$125,000	$16,351	$16,351	$122,634	$2,440	$65,405	$40,878	$81,756	$40,878	$16,351	$8,176	$286,146	$122,634	$400,000
E	$2,670,000	$54,500	$0	$1,100,000	$21,800	$21,800	$163,500	$80,000	$87,200	$54,500	$109,000	$54,500	$21,800	$10,900	$381,500	$163,500	$400,000
F	$2,051,000	$52,350	$0	$550,000	$20,940	$20,940	$157,050	$54,000	$83,760	$52,350	$104,700	$52,350	$20,940	$10,470	$366,450	$157,050	$400,000
G	$1,420,000	$40,542	$0	$200,000	$16,217	$16,217	$121,627	$9,154	$64,868	$40,542	$81,085	$40,542	$16,217	$8,108	$283,796	$121,627	$400,000
H	$2,023,000	$44,910	$0	$650,000	$17,964	$17,964	$134,730	$74,800	$71,856	$44,910	$89,820	$44,910	$17,964	$8,982	$314,370	$134,730	$400,000
I	$6,379,000	$42,450	$0	$4,900,000	$16,980	$16,980	$127,350	$80,000	$67,920	$42,450	$84,900	$42,450	$16,980	$8,490	$297,150	$127,350	$550,000
J	$4,560,000	$32,943	$0	$3,500,000	$13,177	$13,177	$98,828	$1,150	$52,708	$32,943	$65,885	$32,943	$13,177	$6,589	$230,598	$98,828	$400,000
K	$1,100,000	$30,580	$0	$75,000	$12,232	$12,232	$91,740	$13,400	$48,928	$30,580	$61,160	$30,580	$12,232	$6,116	$214,060	$91,740	$400,000
L	$1,505,000	$46,160	$0	$165,000	$18,464	$18,464	$138,480	$16,800	$73,856	$46,160	$92,320	$46,160	$18,464	$9,232	$323,120	$138,480	$400,000
M	$1,733,000	$52,878	$0	$275,000	$21,151	$21,151	$158,634	$440	$84,605	$52,878	$105,756	$52,878	$21,151	$10,576	$370,146	$158,634	$400,000
N	$5,175,000	$57,350	$0	$2,700,000	$22,940	$22,940	$172,050	$128,000	$91,760	$57,350	$114,700	$57,350	$22,940	$11,470	$401,450	$172,050	$1,200,000
O	$1,330,000	$42,240	$0	$50,000	$16,896	$16,896	$126,720	$35,200	$67,584	$42,240	$84,480	$42,240	$16,896	$8,448	$295,680	$126,720	$400,000
P	$890,000	$23,440	$0	$0	$9,376	$9,376	$70,320	$21,200	$37,504	$23,440	$46,880	$23,440	$9,376	$4,688	$164,080	$70,320	$400,000
Q	$755,000	$16,890	$0	$0	$6,756	$6,756	$50,670	$17,200	$27,024	$16,890	$33,780	$16,890	$6,756	$3,378	$118,230	$50,670	$400,000
R	$1,700,000	$48,880	$0	$310,000	$19,552	$19,552	$146,640	$12,400	$78,208	$48,880	$97,760	$48,880	$19,552	$9,776	$342,160	$146,640	$400,000
S	$3,505,000	$48,150	$0	$1,700,000	$19,260	$19,260	$144,450	$42,000	$77,040	$48,150	$96,300	$48,150	$19,260	$9,630	$337,050	$144,450	$800,000
T	$1,668,000	$40,800	$0	$300,000	$16,320	$125,664	$16,320	$2,000	$65,280	$40,800	$81,600	$40,800	$16,320	$8,160	$285,600	$122,400	$550,000

NOTE: *The column TOTAL represents the total annual operation and maintenance (O&M) budget for offsite emergency preparedness activities. The columns labeled 1 through 16 represent the annual cost to support offsite implementation of Planning Standards §50.47(b)(1) through §50.47(b)(16) respectively. All data was collected in during calendar year 2014.*