OPTIONS AND RECOMMENDATION FOR POPULATION-RELATED SITING CONSIDERATIONS FOR ADVANCED REACTORS

INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) has established regulations and guidance for a broad range of factors to be considered in the siting of nuclear reactors. Some of the requirements and guidance address site-related external hazards that could initiate plant transients and challenge the performance of safety equipment. Examples of such external hazards include seismic events and potential releases from nearby industrial facilities. Other requirements and guidance focus on the potential adverse impacts that a nuclear plant may have on nearby environs as a result of normal operations or potential accidents. A major focus of the NRC's review of applications for licenses, certifications, and approvals for nuclear power plants relates to the potential impact of potential plant accidents on nearby residents. This paper is limited to those siting considerations for advanced reactors related to population density and proximity to population centers.

For the purpose of this paper, the term advanced reactor refers to light-water small modular reactors (SMRs) and non-light-water reactors (non-LWRs). The proposed alternatives in this paper would be applicable to non-LWR designs, microreactors, and light-water SMRs as defined in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 170, "Fees for Facilities, Materials, Import and Export Licenses, and Other Regulatory Services Under the Atomic Energy Act of 1954, as Amended." This usage is included in, but not coextensive with, the definition of "advanced nuclear reactor" in the Nuclear Energy Innovation and Modernization Act (NEIMA; Public Law No: 115-439).

The NRC's guidance and experience for siting nuclear power plants relate to large light-water reactors (LWRs). The population-related siting considerations for large LWRs are based on a fission product release from a major accident, which has generally been assumed to result in substantial meltdown of the core with subsequent release into the containment of appreciable quantities of fission products. Compared to previous generations of reactor designs, advanced reactor designs are expected to have a reduced likelihood of accidents and to involve a smaller and slower release of radioactive material in the unlikely event of an accident. This raises the question of whether current guidance related to the siting of commercial nuclear power plants is appropriate for advanced reactor designs.

In SECY-16-0012, "Accident Source Terms and Siting for Small Modular Reactors and Non-Light Water Reactors," dated February 7, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15309A319), the staff provided the Commission with information on the use of mechanistic source terms and siting of advanced reactors. The staff stated in SECY-16-0012 that it would engage stakeholders and return to the Commission with any policy issues or plans to revise regulatory guidance on siting. In addition, Section 103, "Advanced Nuclear Reactor Program," of NEIMA requires the NRC to develop and implement, where appropriate, strategies for the increased use of risk-informed, performance-based techniques to resolve policy issues facing commercial advanced nuclear reactors. These issues include licensing basis event selection, source terms, containment performance, and emergency preparedness—all of which have a relationship with population-related siting considerations. As a result, the NRC staff has identified guidance for

population-related siting decisions for advanced reactors as a matter that warrants early engagement of the Commission.

The staff has developed several options and a recommendation for consideration by the Commission regarding developing an alternative to the current population-related siting guidance in Regulatory Guide (RG) 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Revision 3, issued March 2014 (ADAMS Accession No. ML12188A053), to address advanced reactors.

BACKGROUND

The NRC has a longstanding policy of siting reactors away from densely populated centers. The agency has implemented this policy through a combination of requirements such as 10 CFR Part 100, "Reactor Site Criteria," and guidance such as RG 4.7 (See Figure 1). Under 10 CFR Part 100, 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," the NRC requires the applicant to determine the following:

- an exclusion area, as defined in 10 CFR 50.2 and 10 CFR 100.3, where the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area. NRC regulations in 10 CFR Parts 50 and 52 specify that the exclusion area boundary (EAB) size is determined based on evaluation of radiation dose to an individual from a postulated fission-product release, for a 2-hour exposure period. Guidance related to this requirement is found in Regulatory Guide (RG) 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Revision 3, issued March 2014 (ADAMS Accession No. ML12188A053);

- a low population zone (LPZ) defined in 10 CFR 50.2 and 10 CFR 100.3 as the area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken in the event of a serious accident. NRC regulations in 10 CFR Parts 50 and 52, as well as guidance in RG 4.7, specify that the LPZ size is determined based on evaluation of radiation dose to an individual during the entire period of passage of a radioactive cloud resulting from the postulated fission-product release; and

- a population center distance defined in 10 CFR 100.3 as the distance from the reactor to the nearest boundary of a densely populated center of more than about 25,000 residents. Under 10 CFR 100.21, "Non-Seismic Site Criteria," the population center distance must be at least 1.33 times the distance from the reactor to the outer boundary of the LPZ.

The NRC's requirements and guidance for large LWRs are based on a major accident with a large release of fission products into a containment structure. Guidance documents such as RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," issued July 2000 (ADAMS Accession No. ML003716792), also discuss the assumed accident source terms for large LWRs. Advanced reactor designs may use different fuel forms, coolants, and barriers for limiting the release of radioactive materials to offsite environments. The design and licensing processes for advanced reactors are expected to use more mechanistic models for estimating source terms and the associated magnitude and timing of potential releases of radioactive materials. As described in SECY-16-0012, the staff

has assessed how these differences might warrant revisions to current guidance related to the siting of commercial nuclear power plants.

Figure 1 summarizes the NRC's existing regulatory requirements and related guidance in RG 4.7 for population-related siting considerations for nuclear power plants.

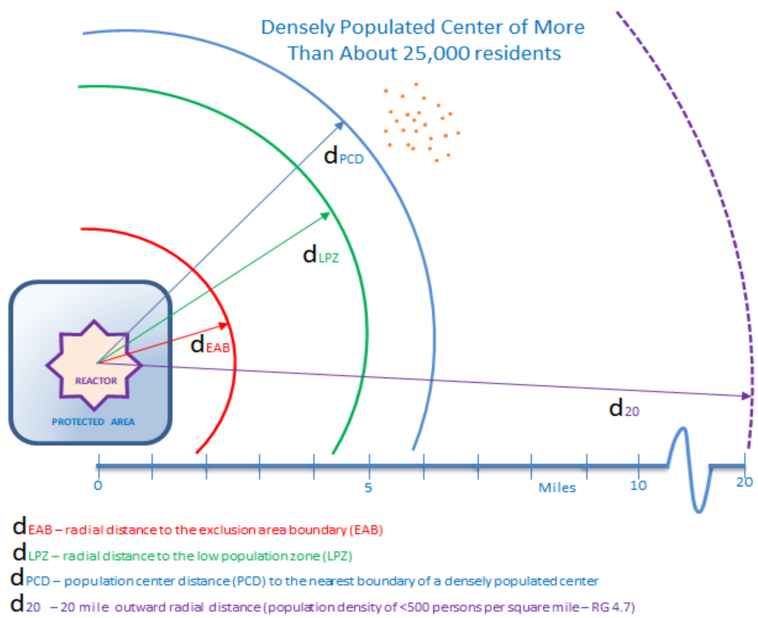

Figure 1 Limitations on populations near nuclear power plants

In addition to the above siting criteria related to possible radiation doses to hypothetical individuals, subsection (h) of 10 CFR 100.21, "Non-Seismic Site Criteria," states that reactor sites should be located away from very densely populated centers and that areas of low population density are generally preferred. RG 4.7 provides the following guidance related to compliance with 10 CFR 100.21(h):

> A reactor should be located so that, at the time of initial plant approval within about 5 years thereafter, the population density, including weighted transient population, averaged over any radial distance out to 20 [miles] (cumulative population at a distance divided by the circular area at that distance), does not exceed 500 persons per square mile. A reactor should not be located at a site where the population density is well in excess of this value.
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> If the population density of the proposed site exceeds but is not well in excess of the above preferred value, the analysis of alternative sites should pay particular attention to alternative sites with lower population density. However, consideration of other factors, such as safety, environmental, or economic concerns, may result in the site with the higher population density being found acceptable. Examples of such factors include, but are not limited to, the higher population density site having superior seismic characteristics, better rail or highway access, shorter transmission line requirements, or less environmental impact on undeveloped areas, wetlands, or endangered species.

The regulation in 10 CFR 100.21(h) and this provision of the guidance in RG 4.7 provide a framework for locating reactors away from population centers so as to limit societal consequences in the event of a severe accident.

The U.S. Department of Energy (DOE) and individual reactor developers have a goal to use the possible advantages of advanced reactor designs to offer a lower initial capital investment, greater scalability, and siting flexibility for locations that are unable to accommodate more traditional larger reactors. In particular, SMRs are discussed as a possible way to provide power for applications that do not require large plants or at sites that lack the infrastructure to support a large unit.[1] This would include smaller electrical markets, isolated areas, smaller grids, sites with limited water and acreage, or unique industrial applications. SMRs might also be used to replace or repower aging/retiring fossil plants or to provide an option for complementing existing industrial processes or power plants with an energy source that does not emit greenhouse gases. Some of these sites have attributes already recognized by the guidance in RG 4.7, including shorter transmission line requirements or less environmental impact on undeveloped areas.

The Commission has long recognized that improvements in reactor design could potentially affect siting decisions. In the Statements of Consideration for the last revision to 10 CFR Part 100, which the NRC published on December 11, 1996 (Volume 61 of the *Federal Register*, page 65157 (61 FR 65157)), the Commission acknowledged the expected safety improvements in future plants in the following passage:

> In summary, next-generation reactors are expected to have risk characteristics sufficiently low that the safety of the public is reasonably assured by the reactor and plant design and operation itself, resulting in a very low likelihood of occurrence of a severe accident. Such a plant can satisfy the QHOs [quantitative health objectives] of the Safety Goal with a very small exclusion area distance (as low as 0.1 miles). The consequences of design basis accidents, analyzed using revised source terms and with a realistic evaluation of engineered safety features, are likely to be found acceptable at distances of 0.25 miles or less. With regard to population density beyond the exclusion area, siting a reactor closer to a densely populated city than is current NRC practice would pose a very low risk to the populace.
>
> Nevertheless, the Commission concludes that defense-in-depth considerations and the additional enhancement in safety to be gained by siting reactors away from densely populated centers should be maintained.

The NRC maintained the notion of siting as part of providing defense in depth against a reactor accident from previous requirements and practices. NUREG-0625, “Report of the Siting Policy Task Force,” issued August 1979 (ADAMS Accession No. ML12187A284), provides additional background information. The staff intended the recommendations in NUREG-0625 to “strengthen siting as a factor in defense in depth by establishing requirements for site approval

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[1] Under 10 CFR 170.3, “Definitions,” the NRC defines an SMR, for the purpose of calculating fees, as the “class of light-water power reactors having a licensed thermal power rating less than or equal to 1,000 MWt per module.” This paper uses the term SMR as a possible subset of advanced reactors in accordance with the more common definition used outside of the NRC as an advanced reactor, envisioned to vary in size from a couple megawatts up to hundreds of megawatts, that can employ light water as a coolant or other non-light-water coolants such as a gas, liquid metal, or molten salt.

that are independent of plant design consideration, take into consideration in siting the risk associated with accidents beyond the design basis (Class 9) by establishing population density and distribution criteria, and require that sites selected will minimize the risk from energy generation."

Although no changes in siting practices were recommended in 1996, the NRC has acknowledged that the specific source term and siting practices used for large LWRs may not be appropriate for the licensing and regulation of advanced reactor designs. The NRC first issued its Policy Statement on the Regulation of Advanced Reactors on July 8, 1986 (51 FR 24643), to provide all interested parties, including the public, with the Commission's views on the desired characteristics of advanced reactor designs. The NRC's policy statement identifies desirable attributes for these reactors, including highly reliable and less-complex heat removal systems, longer time constants before safety system challenges occur, the reduced potential for severe accidents and their consequences, and the use of the defense-in-depth philosophy to maintain multiple barriers against radiation release. Advanced reactor designs with such attributes are expected to have a reduced likelihood of accidents involving the release of radionuclides and to involve smaller and slower releases of radionuclides in the unlikely event of an accident.

In SECY-16-0012 the staff described potential issues with the NRC's siting policies in relation to the desired uses of advanced reactors. The staff noted that some industry organizations have expressed a desire to deploy SMRs to replace existing coal plants and acknowledged that to do so could involve siting SMRs closer to population centers than large LWRs typically have been. The staff described how advanced reactor designs and the use of mechanistic source term analyses could result in the calculation of smaller radiological releases to the environment following an accident, and these lower releases could, in turn, affect calculations of hypothetical doses to the public and decisions related to reactor siting.[2] SECY-16-0012 states that the use of mechanistic source terms could "…provide additional margin with respect to the dose-related portions of the current NRC siting requirements focused on radiological safety" and "…allow future COL applicants to consider reduced distances to EABs and LPZs, and potentially increased [SMR] proximity to population centers." Additional background information on this topic is provided in Oak Ridge National Laboratory (ORNL)/TM-2019/1197, "Advanced Reactor Siting Policy Considerations" (ADAMS Accession No. ML19192A102), prepared by ORNL for the NRC.

DISCUSSION

The staff has identified two primary issues related to the goals of DOE and developers for the possible deployment of advanced reactors and the NRC's current siting requirements and guidance represented in Figure 1. Both are related to the guidance in RG 4.7 that relates to 10 CFR 100.21(h). The first issue involves the current limitations in RG 4.7 on population density to not exceed 500 persons per square mile (ppsm) out to a distance of 20 miles from a reactor site. As described in the ORNL report, this provision in RG 4.7 might unnecessarily preclude many sites associated with retiring fossil plants or industrial sites with relatively large

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[2] As discussed in SECY-16-0012; Draft Regulatory Guide (DG) 1353, "Guidance for a Technology Inclusive, Risk-Informed, and Performance-Based Methodology To Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non Light Water Reactors," issued April 2019 (ADAMS Accession No. ML18312A242), and other papers related to the licensing of advanced reactors, the estimated offsite consequences from licensing basis events associated with advanced reactors are expected to be calculated using mechanistic source term models.

population centers closer than 20 miles. The second issue involves how the limitations in RG 4.7 (for population density to not exceed 500 ppsm) might prevent the potential use of SMRs for remote communities or smaller grids with relatively small but concentrated populations that would be near a reactor site. The NRC must decide whether it can revise the existing guidance related to 10 CFR 100.21(h) to reflect the potential for enhanced safety and reduced risks associated with radiological releases from advanced reactor designs. No other changes to population-related siting criteria are being proposed in this paper.

Some estimations, including those for DOE's next generation nuclear plant project, have raised the possibility of the EAB and LPZ collapsing to the site boundary, which could be measured in hundreds of meters.[3] NRC regulations allow the determination of the size of the EABs and LPZs to be based on estimated offsite radiological consequences and do not establish minimum allowable distances. For this reason, the staff has determined that changes to regulations and guidance related to the determination of EABs and LPZs are not necessary. Furthermore, while NRC regulations do restrict the siting of plants relative to a population center containing more than about 25,000 residents, the staff's interactions with stakeholders have not identified any near-term proposals to site reactors within a population center exceeding 25,000 residents, and no changes to the relevant regulatory criteria and associated guidance are being proposed at this time.

The staff has interacted with stakeholders to develop several options for the Commission's consideration to address an alternative to the current guidance in RG 4.7 related to 10 CFR 100.21(h). This guidance currently provides for assessing the population around possible reactor sites using the criterion of the population density not exceeding 500 ppsm out to a distance of 20 miles.

Option 1

Option 1 is to maintain the status quo with no changes to the current population-related siting regulations or the existing guidance in RG 4.7 represented in Figure 2.

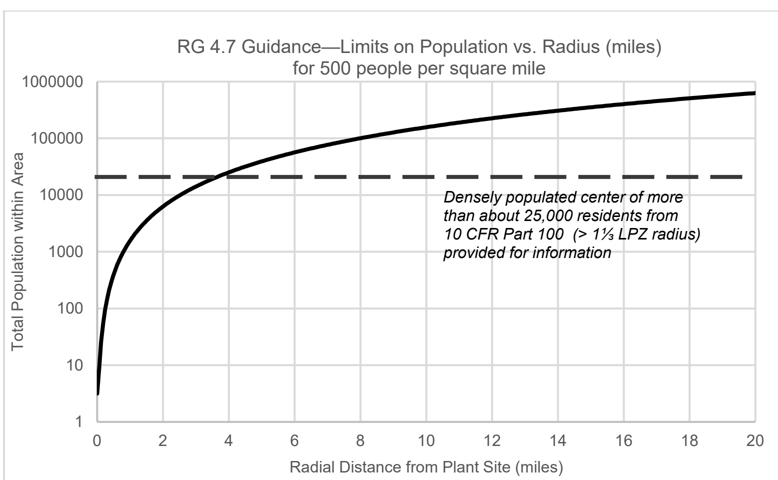

Figure 2 RG 4.7 limits on total population versus radius

3 See, for example, INL/EXT-11-23797, "NGNP: High-Temperature Gas-Cooled Reactor Key Definitions, Plant Capabilities, and Assumptions," February 2012, which is available from the website of DOE's Office of Scientific and Technical Information (www.osti.gov).

The guidance calls for the population to be less than about 1,600 people within a mile from the plant site. The guidance also calls for the total population within the first 10 miles to be less than about 157,000 people and to be less than about 628,000 people within 20 miles from the site. Applicants for either a remote site with a population greater than 1,600 people within a mile or a site with higher population densities within 20 miles from the plant could propose an alternative to the population-density guidance in RG 4.7. A possible proposed justification for an alternative to the guidance in RG 4.7 would cite the attributes of a particular advanced reactor design, which if demonstrated, could support a finding that the frequency of and consequences from accidents with radiological releases were both acceptably low. The staff would likely bring a siting-related proposal significantly different from RG 4.7 before the Commission as a specific policy issue or as an important aspect of a licensing decision because of the Commission's historical interest in siting as an element of defense in depth independent of plant design.

Option 2

Under Option 2, the staff would provide an alternative to the current guidance in RG 4.7 that relates to 10 CFR 100.21(h) to include provisions for advanced reactor designs and more specifically for SMRs and microreactors. The NRC's practice on restricting possible reactor sites based on population density was in large part intended to limit overall societal risks from severe reactor accidents. One way to characterize societal risk is in terms of the radiation dose to the larger population around nuclear power plants beyond the regulatory limits for calculated doses to individuals. ORNL/TM-2019/1197 describes a possible approach similar to this option, which is based on the general observation that radiological consequences from a reactor accident are related to the inventory of radionuclides and various factors that govern their retention within or possible release from a facility. An aggregate societal risk (SR) can be considered for advanced reactors as represented by the equation:

$$SR = \pi r^2 \times D \times ppsm$$

where:
r is the radial distance from a reactor site
D is a factor representing the source term or radioactive material released from a facility

This representation of societal risk allows one to develop rough equivalencies between the societal risks posed by a typical large LWR and combinations of a hypothetical reactor characterized by its source term factor, *D*; the radial distance from the reactor, *r*; and the population density, *ppsm*. Figure 3 is taken from ORNL/TM-2019/1197 and shows the equivalent SRs, in terms of population densities and distances, for several reactor source term factors.

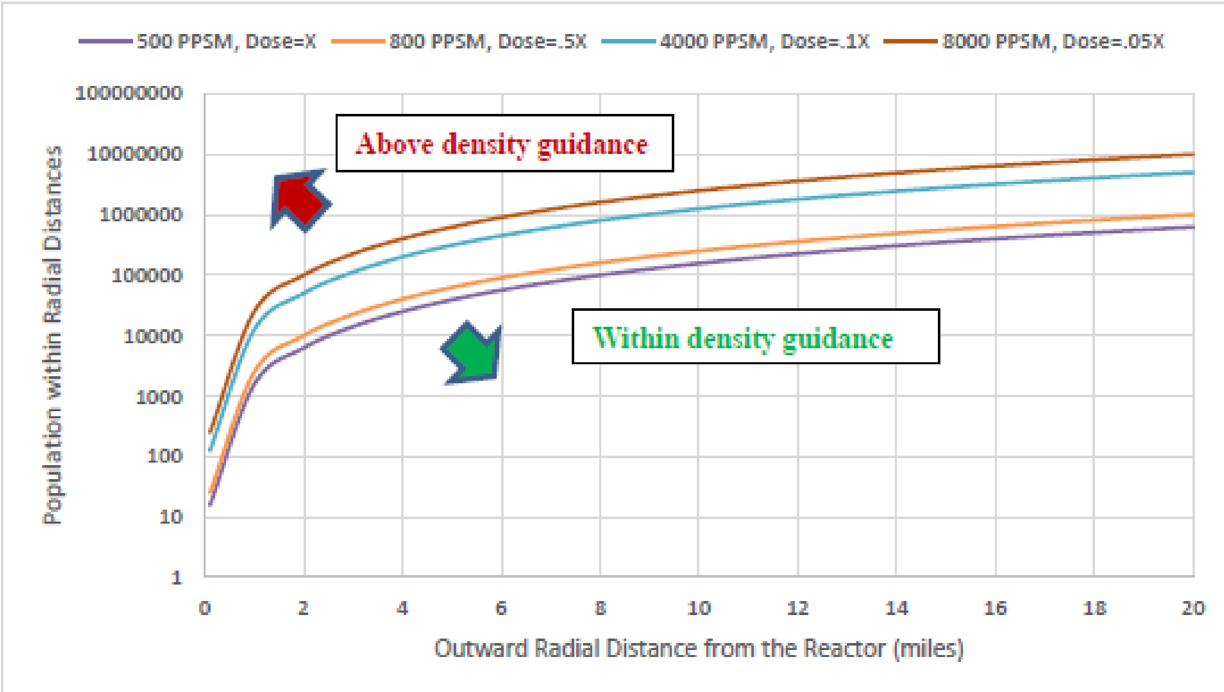

Figure 3 Population Density Comparison

For example, the top line in Figure 3 assumes a reactor with a source term factor of 5 percent or less of the source term for a current-generation, large LWR (e.g., an SMR producing about 50 megawatts electric). An accident at a smaller reactor can reasonably be assumed to result in a smaller area of contamination, relative to the 1,256 square miles associated with the current guidance for large LWRs ($\pi \bullet 20^2$ square miles). If a direct correlation between the source term and the affected area is assumed as a reasonable approximation, the equivalent area is 5 percent of 1,256 square miles or approximately 63 square miles, which corresponds to a radius of 4.5 miles. The proposed approach includes a margin of 25 percent to address the approximation and uncertainties associated with the potential for dissimilar radiological mixtures in the source terms for various advanced reactor designs; this results in an equivalent SR radius of 5 miles for a reactor represented by a source term factor of 5 percent. Similarly, the potentially affected population within the 20 miles defined in RG 4.7 is 628,000 people at the allowed population density of 500 ppsm. An equivalent SR for the example reactor, with a source term factor of 5 percent and an uncertainty margin of 25 percent yielding an equivalent radius of 5 miles, is achieved with a population density of 8,000 ppsm. In this example, the siting of a reactor might not be determined by population-density considerations but would instead be governed by the regulatory requirement in 10 CFR 100.21(b) for reactors to be located distant from densely populated centers with more than about 25,000 residents. If needed to address estimated offsite consequences, additional population-related siting considerations could be associated with an applicant's determination of the EAB and LPZ in accordance with 10 CFR Part 100, 10 CFR Part 50 and 10 CFR Part 52.

Option 3

Under Option 3, the staff would revise the guidance in RG 4.7 that relates to 10 CFR 100.21(h) to include provisions for advanced reactor designs. This option is similar to Option 2 except that the criteria are directly related to estimates of radiological consequences from design-specific events rather than a general correlation of offsite doses to radionuclide inventories or power level. The approach retains the regulatory requirements in 10 CFR Part 100 that call for licensees to establish EABs and LPZs, and locate reactors some distance from densely populated centers with more than 25,000 residents, and does not make changes to regulations or guidance related to these topics. However, a new graded approach is used to size areas within which the population density would be assessed using the current criterion of density no greater than 500 ppsm.

The performance criteria in Option 3 for determining the size of the area within which the population density would be assessed relates to the estimated dose to an individual from postulated accidents. Option 3 allows for the evaluation of estimated doses to be performed for licensing-basis events as described in DG-1353, "Guidance for a Technology Inclusive, Risk-Informed, and Performance-Based Methodology To Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors," issued April 2019 (ADAMS Accession No. ML18312A242), or in accordance with current LWR practices with a hypothetical major accident and guidance such as RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," issued July 2000 (ADAMS Accession No. ML003716792).

The proposed criterion is that the population density would be assessed out to a distance equal to twice the distance at which a hypothetical individual could receive a calculated dose of 1 rem over a period of 1 month from the release of radionuclides following postulated accidents. Similar consequence-based criteria have been proposed to resolve other advanced reactor policy issues. For example, if the proposed rule for emergency planning for small modular reactors and other new technologies (RIN 3150-AJ68) is finalized, emergency planning zones are expected to be determined by calculating doses and applying similar criteria (i.e., the distance for 1 rem over a period of 96 hours from the same event categories).[4] The staff is proposing to use the estimated doses accumulated over 30 days as part of the performance criteria specifically because that would conform with the models and calculations expected to be part of the licensing process described in DG-1353. The methodology described in DG-1353 includes using estimates of hypothetical doses over 30 days at the EAB for evaluating licensing basis events; classification of structures, systems, and components; and assessing defense in depth. In addition, considering the possible estimated doses accumulated over a longer time

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[4] See SECY-18-0103, "Proposed Rule, 'Emergency Preparedness for Small Modular Reactors and Other New Technologies'," dated October 12, 2018 (ADAMS Accession No. ML18134A076), and related SRM dated December 17, 2019 (ADAMS Accession No. ML19351C729). The proposed use of similar dose criteria will generally result in the radius of the area in which population density is assessed being greater than twice the radius of the consequence-based plume-exposure emergency planning zone described in SECY-18-0103. The criterion of 1 rem over the first 96 hours from the release from a spectrum of credible accidents is described in DG-1350, "Emergency Preparedness for Small Modular Reactors and Other New Technologies" (ADAMS Accession No. ML 18082A044), as being consistent with the U.S. Environmental Protection Agency (EPA), "PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents," EPA-400/R-17/001, issued January 2017. Option 3 proposes a similar criterion of 1 rem over a period of 1 month as a more general representation of societal risk and to be consistent with the analysis approach described in DG-1353.

period such as 30 days can serve to limit societal risks from postulated accidents beyond assessing the appropriate planning for immediate protective actions.

The staff acknowledges that alternative criteria could be selected for addressing the broader societal risks from postulated accidents. For example, the staff considered referring to the EPA Protective Action Guide (PAG) Manual guidelines for the relocation of the public following a potential nuclear accident (2-rem projected dose in the first year, 0.5 rem per year projected dose in the second and subsequent years). The general relationships between the various immediate (e.g., evacuation) and intermediate (e.g., relocation) protective actions and related areas around a nuclear power plant are represented in Figure 4. The staff elected to define a criterion using the current population density of not exceeding 500 ppsm and an assessment area out to twice the radius at which 1 rem over a period of 1 month from the release of radionuclides following postulated accidents. This criterion maintains the general NRC policy of limiting societal risks beyond the measures provided by regulatory limits on calculated doses to individuals and thereby limits the population potentially affected by longer-term protective actions such as being relocated.

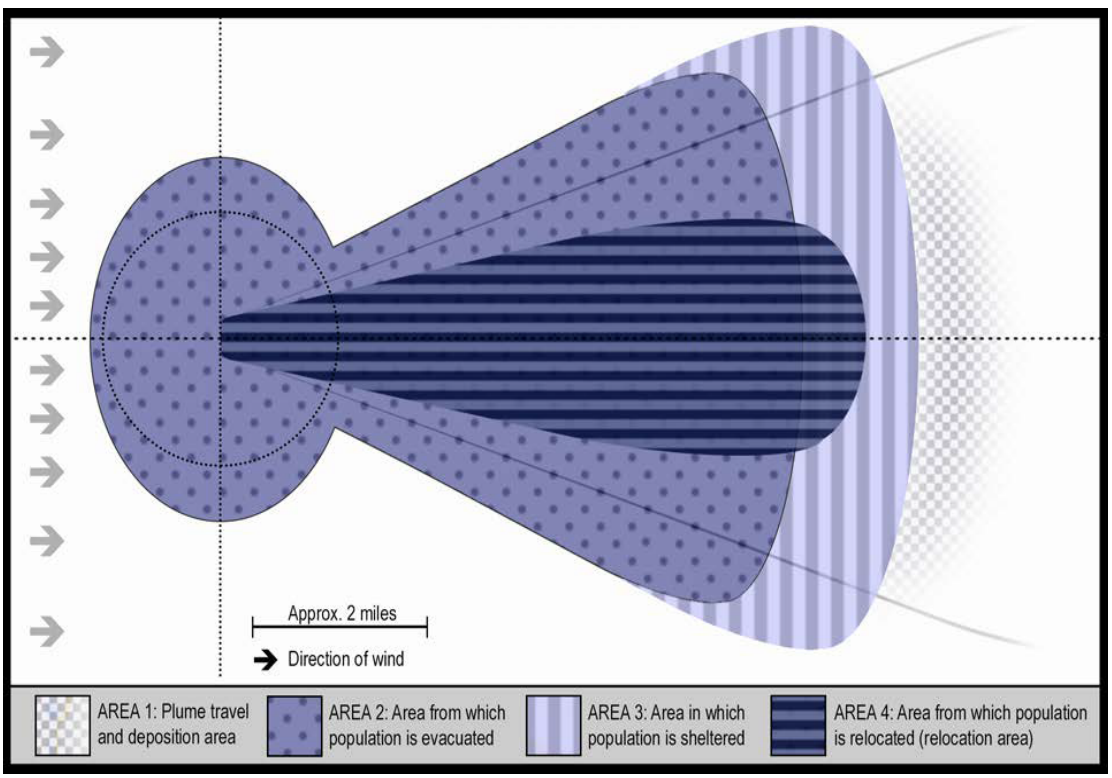

Figure 4 EPA PAG Manual Protective Action Areas
(Figure 4-1. Generalized Protective Action Areas for Nuclear Power Plant Incident in PAG Manual)

The following three hypothetical cases involving possible offsite consequences from design-basis events and beyond-design-basis events as described in DG-1353 illustrate the proposed limitations on populations near an advanced reactor under Option 3:

(1) In the first case for possible advanced reactor designs, the potential offsite consequences of some design-basis accidents are calculated to approach 25 rem over the course of the event. As specified in 10 CFR Part 100, the distance out to which 25 rem is estimated over the course of the event defines the radius of the LPZ, and the distance out to which 25 rem is estimated for the worst 2-hour duration defines the radius of the EAB. In this case, the EAB could lie either within or beyond the site boundary but the LPZ outer boundary would be at a distance beyond the site boundary. In addition, under 10 CFR Part 100, the allowable distance from the reactor to a densely populated center of approximately 25,000 residents would be no closer than 1.33 times the radius of the LPZ. The revised guidance would also assess the total population near the plant site by calling for the population density to be no greater than 500 ppsm out to a distance equal to twice the distance at which an individual would be estimated to receive 1 rem over the month following any design-basis or beyond-design-basis event. As shown in Figure 5, the population density will be evaluated within an area that encompasses and extends beyond the LPZ.

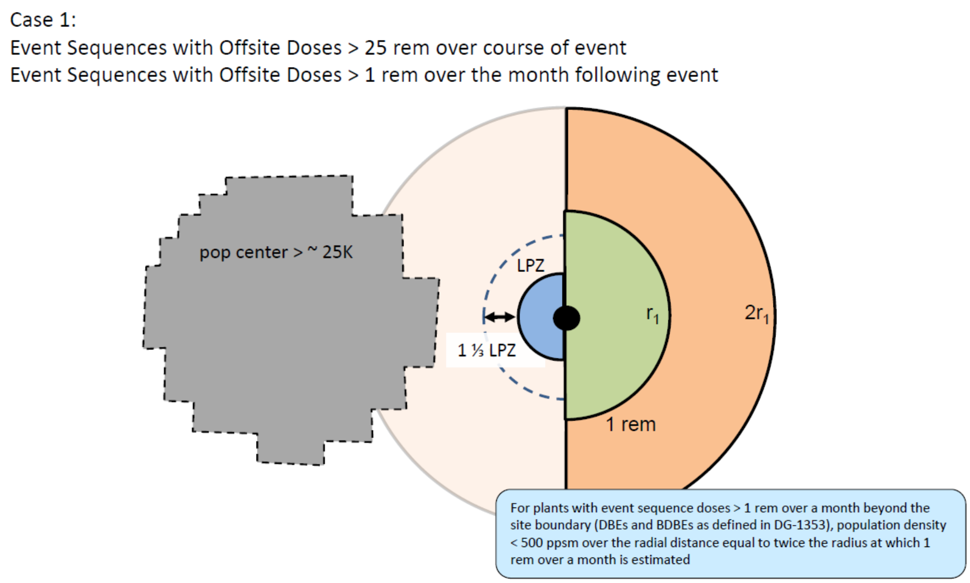

Figure 5 Option 3, Case 1 – LPZ beyond the site boundary

(2) The second case involves an advanced reactor design for which all design-basis accidents are calculated to result in doses to an individual at the site boundary of less than 25 rem over the duration of the event. In such a case, the EAB and LPZ could hypothetically be defined to be at the site boundary. However, for this example, the calculation of some design-basis events or beyond-design-basis events results in offsite doses exceeding 1 rem over the month following the event. The population density would be assessed against a criterion in the guidance that the population density is expected to be no greater than 500 ppsm out to twice the distance at which the 1 rem dose was calculated. The criteria for the total population for this case can be seen in Figure 2 with the distance being considered limited to twice the distance at which the 1 rem dose over 30 days is calculated. The requirements of 10 CFR Part 100 provide an additional limitation that precludes a reactor from being within a population center of greater than approximately 25,000 residents. Figure 6 provides a graphical depiction of this case.

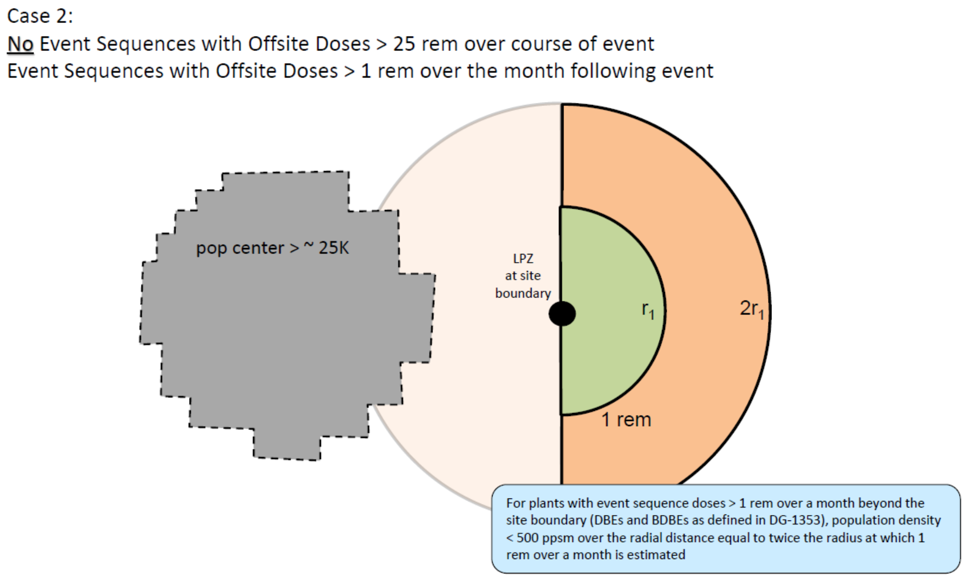

Figure 6 Option 3, Case 2 – Events exceeding 1 rem beyond the site boundary

(3) In the third case, the potential consequences from all design-basis and beyond-design-basis events are estimated to be below 1 rem for the month following the event for an individual at the site boundary. In this case, the requirements of 10 CFR Part 100, which preclude a reactor from being within a population center of greater than approximately 25,000 residents, become the controlling factor on population-related siting considerations. As shown in Figure 7, an advanced reactor with estimated doses below 1 rem at the site boundary over the month following the assumed postulated accident could hypothetically be allowed within towns with populations of no more than approximately 25,000 residents.

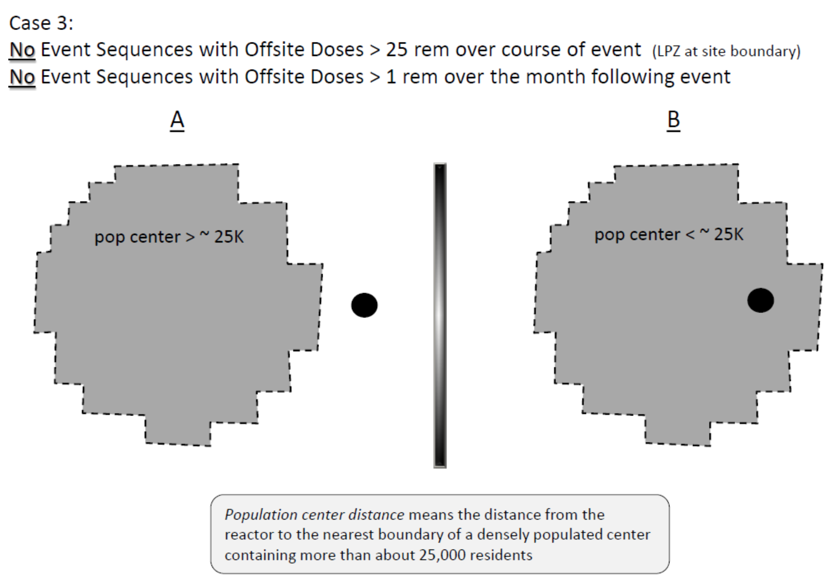

Figure 7 Option 3, Case 3 – No events exceeding 1 rem beyond the site boundary

Option 4

Option 4 calls for the NRC staff to develop societal risk measures for assessing specific advanced reactor designs at specific sites. This option could be pursued without changes to NRC regulations by including the assessment of societal risks in RG 4.7 as an alternative to the current criterion on population density. The assessment of the potential impact of a reactor design at a site would consider factors beyond the potential dose to individuals and populations, including matters such as adverse effects on economies, land availability, population displacement, and decontamination costs. The unit of measure for Option 4 would likely be in monetary units (e.g., dollars) with consideration of the event frequencies leading to offsite releases. The staff previously discussed possible performance measures to address societal risks in papers such as SECY-12-0110, "Consideration of Economic Consequences within the U.S. Nuclear Regulatory Commission's Regulatory Framework," dated August 14, 2012 (ADAMS Accession No. ML12173A478 (package)), and SECY-15-0085, "Evaluation of the Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors Rulemaking Activities (10 CFR Part 50)," dated June 18, 2015 (ADAMS Accession No. ML15022A218). The Commission's SRMs on these papers are dated March 20, 2013 (ADAMS Accession No. ML13079A055), and August 19, 2015 (ADAMS Accession No. ML15231A471). SECY-20-0008, "Draft Final NUREG/BR-0058, 'Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission,'" dated January 28, 2020 (ADAMS Accession No. ML19261A277 (package)), also addresses the consideration of various societal impacts. In addition, academic, international, and other papers have been written on the potential benefits and possible development of societal risk measures for nuclear power plants.

An issue related to the possible development of more in-depth assessments of societal risks for the licensing of advanced reactors is how to use such assessments in the decisionmaking process. Many of the discussions within the NRC associated with considering societal measures have been in the context of evaluating proposed changes to be imposed on licensed facilities. In these cases, the results from an assessment of possible changes in societal risks resulting from a new requirement can be compared to the costs of imposing the requirement on existing facilities. The use of societal measures for the initial licensing of advanced reactors would require an assessment of societal risks and costs for comparison to another type of performance measure. Some proposed approaches for using societal measures involve comparing the assessment of the risks from a proposed reactor design and site to other risks to public health and property (e.g., natural disasters) in a manner similar to that used within the NRC's safety goals.