Contributing activities within the NRC's implementation action plan for improving its regulatory readiness for non-light water reactor (non-LWR) designs includes identifying and resolving policy issues (Strategy 5). An issue identified during interactions with stakeholders is possible changes to NRC guidance related to population-related siting considerations for advanced nuclear power plants. This draft Commission paper has been prepared and is being released to support ongoing public discussions – including a meeting with the Advisory Committee on Reactor Safeguards (tentatively scheduled for August 23, 2019).

This paper has not been subject to NRC management and legal reviews and approvals, and its contents should not be interpreted as official agency positions.

MEMORANDUM TO: The Commissioners

FROM: Margaret M. Doane
Executive Director for Operations

SUBJECT: POPULATION-RELATED SITING CONSIDERATIONS FOR ADVANCED REACTORS

PURPOSE:

The purpose of this paper is to provide options and a recommendation to the Commission on possible changes to guidance documents associated with population-related siting considerations for advanced reactors. The staff's recommendation is to pursue a revision to the population-related guidance to provide technology-inclusive, risk-informed, and performance-based criteria to assess population related issues in siting advanced reactors. This paper does not address any resource implications.

SUMMARY:

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. One of those factors relates to nearby populations and the NRC has implemented a policy of siting nuclear reactors away from very densely populated centers. The NRC's guidance and experience for siting nuclear power plants mostly relate to large light-water reactors (LWRs). The population-related siting considerations for large LWRs is based on an assumed severe accident with substantial melting of the core and the subsequent large release of radioactive material from the plant.

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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. Through its interactions with stakeholders, the NRC staff has identified the issue of population-related siting decisions for advanced reactors as a matter that warrants early engagement of the Commission.

In SECY-16-0012, "Accident Source Terms and Siting for Small Modular Reactors and Non-Light Water Reactors," dated February 7, 2016 (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 also 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 the Nuclear Energy Innovation and Modernization Act (NEIMA; Public Law No: 115-439), 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, including licensing basis event selection, source terms, containment performance, and emergency preparedness—all of which have a relationship with population-related siting considerations.

The staff has developed several options for consideration by the Commission regarding the revision of the population-related siting guidance in Regulatory Guide (RG) 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Revision 3, issued March 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12188A053), to address advanced reactors. The staff recommends an option that includes new criteria that are directly related to estimates of radiological consequences from a wide range of events for the subject design(s). The recommended approach considers Title 10 of the *Code of Federal Regulations* (10 CFR) Part 100, "Reactor Site Criteria," which requires licensees to establish exclusion areas (EAs) and low-population zones (LPZs), and to locate reactors some distance from population centers that have over 25,000 residents, and proposes a graded approach for sizing areas within which the population density would be assessed using revised guidance to be added to RG 4.7.

BACKGROUND:

The NRC has a longstanding policy of siting reactors away from densely populated centers.[1] The agency has implemented this policy through a combination of requirements such as 10 CFR Part 100 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 EA, as defined in 10 CFR 50.2, where the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the

[1] NRC regulations and guidance address many subjects related to the siting of nuclear power plants. Examples include the need to evaluate external hazards, such as seismicity, to ensure a plant is designed against possible natural or manmade hazards associated with a site, and the evaluation of the possible impacts of plant operations on local environments. This paper is limited to those siting considerations related to population density and proximity to population centers.

area. The EA 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

- an LPZ, as defined in 10 CFR 50.2, as the areas 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. 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

- a population center distance, as defined in 10 CFR 100.3 and 10 CFR 100.21, which is the distance from the reactor to the nearest boundary of a densely populated center of more than about 25,000 residents that is at least 1.33 times the distance from the reactor to the outer boundary of the LPZ

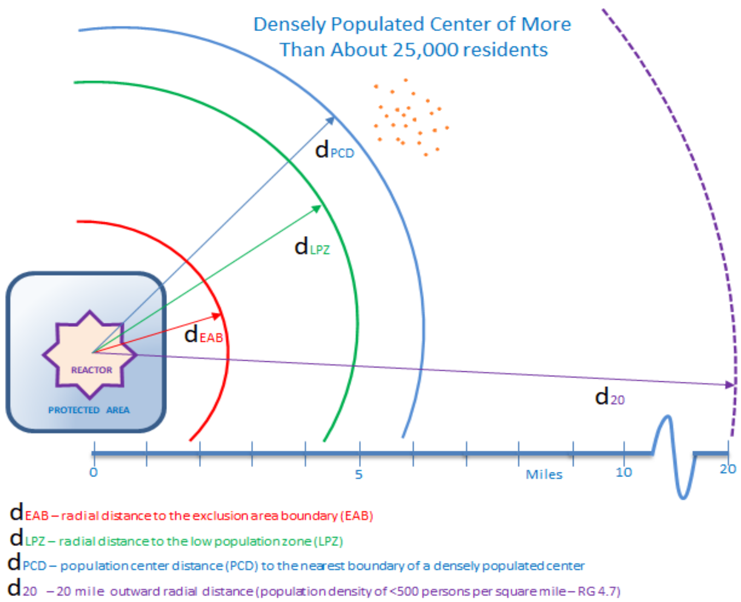

Figure 1 Limitations on populations near nuclear power plants

In addition to the above siting criteria related to possible radiation doses to hypothetical individuals, 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 on siting reactors relative to population densities:

> 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.

> 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 NRC's guidance and experience for siting nuclear power plants mostly relate to large LWRs. For example, the fission-product release assumed for determining EABs and LPZs is based on a major accident that is hypothesized to result in substantial meltdown of the core with the subsequent release of appreciable quantities of fission products into a large LWR-type containment structure. 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), also discusses the assumed accident source terms for large LWRs.

As stated in the supplementary information accompanying 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 staff's guidance in RG 4.7 is intended to provide a means of locating reactors away from population centers, including "major" population centers, depending on their size, that would limit societal consequences in the event of a severe accident.

The Commission acknowledged the expected safety improvements in future plants in the following passage from the 10 CFR Part 100 rulemaking in 1996:

> 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 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.[2]

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[2] 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 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."

While deciding to maintain siting and population considerations as an element of defense in depth for future reactors, the NRC has also recognized for many years 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 attributes that designers of advanced reactors should consider, 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. Compared to previous generations of reactor designs, 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.

The staff has identified the issue of siting decisions related to nearby populations as a matter that warrants early engagement with the Commission. 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, small modular reactors (SMRs)[3] 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. 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. In SECY-16-0012, the staff describes potential issues with the desired uses of advanced reactors in relation to the NRC's siting policies. Specifically, the staff stated that appropriate use of mechanistic source term analysis methods could "…allow future COL applicants to consider reduced distances to EABs and LPZs, and potentially increased [SMR] proximity to population centers." Oak Ridge National Laboratory (ORNL)/TM-2019/1197, "Advanced Reactor Siting Policy Considerations" (ADAMS Accession No. ML19192A102), prepared by ORNL for the NRC, provides additional background information on this topic.

DISCUSSION:

The staff has identified two primary issues with the goals stated above for the possible deployment of advanced reactors and the NRC's current siting requirements and guidance represented in Figure 1. 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 population centers closer than 20 miles. The second issue involves the potential use of SMRs

3 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 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.

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 on population density to reflect the potential for enhanced safety and reduced risks associated with radiological releases from advanced reactor designs.

The staff has interacted with stakeholders to develop several options for the Commission's consideration to address siting questions for advanced reactors. As mentioned in the supplemental information for the 1996 revision to 10 CFR Part 100, advanced reactor developers expect their designs to reduce the potential radiological releases resulting from reactor accidents. The lower estimated releases could justify shorter distances to the outer boundaries of EABs and LPZs, as compared to those associated with previously licensed plants.[4] 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. NRC regulations allow the determination of the size of the EABs and LPZs to be based on estimated consequences and do not establish minimum allowable distances. The regulations do restrict the siting of plants relative to a densely populated center containing more than about 25,000 residents. The staff's interactions with stakeholders have not involved near-term proposals to site reactors within a population center exceeding 25,000 residents. As a result of its interactions with stakeholders, the staff has not identified an immediate need to revise or process exemptions from the population-related restrictions defined by NRC regulations. Therefore, the staff has focused on developing options related to the guidance in RG 4.7 for assessing the population around possible advanced reactor sites using the criterion of the population density not exceeding 500 ppsm out to a distance of 20 miles.

<u>Option 1</u>

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. The guidance effectively limits the close-in population to less than about 1,600 people within a mile from the plant site. The guidance restricts the total population within the first 10 miles to less than about 157,000 people and to 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 to deviate from the guidance in RG 4.7. A possible proposed justification for deviating from the guidance in RG 4.7 would cite the attributes of a particular advanced reactor design, which could support a finding that the frequency of and consequences from accidents with radiological releases were both acceptably low. The staff would likely bring the siting-related proposal 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.

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4 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.

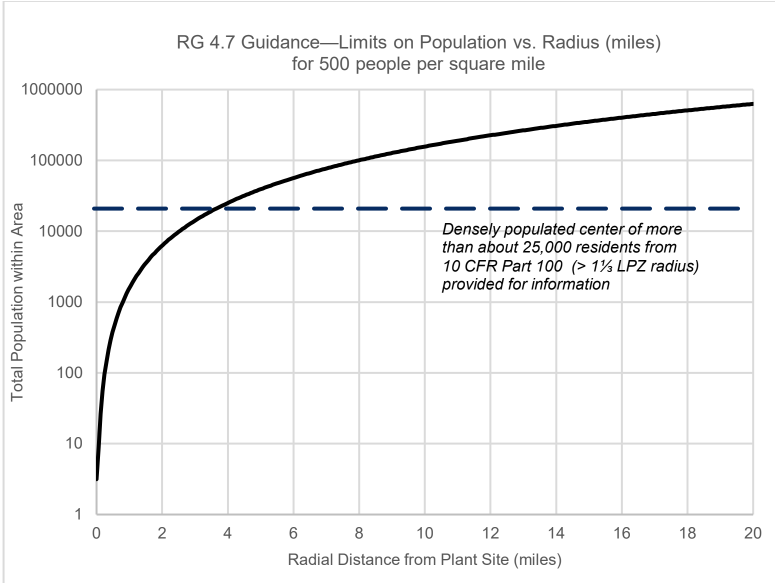

Figure 2 RG 4.7 limits on total population versus radius

Advantages: The agency would not spend its resources on developing the related guidance documents within the current planning horizon. The staff could take up the issue in the future on a case-by-case basis when there is increased certainty that advanced reactor applications will include proposed deviations from the population-related siting criteria in RG 4.7.

Disadvantages: Addressing population density for advanced reactors on a case-by-case basis does not reduce the regulatory uncertainties that the staff and some stakeholders identified to support the Commission's goal to minimize complexity and add stability and predictability in the licensing and regulation of advanced reactors. These uncertainties complicate the ability of reactor developers and potential applicants to make design and business decisions as they assess potential design features and possible sites for advanced reactors.

Some stakeholders favor Option 1 as discussed in a public meeting on June 27, 2019. While there was not a specific discussion from individuals or organizations favoring this option at that meeting, the staff is aware that some stakeholders advocate taking no action at this time and assessing proposed siting decisions for advanced reactors on a case-by-case basis.

Option 2

Option 2 does not involve changes to NRC regulations; however, the staff would revise the population-related guidance in RG 4.7 to include provisions for advanced reactor designs and more specifically for SMRs. 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 by the radiation dose to the larger population around nuclear power plants beyond the regulatory limits on possible doses to individuals. ORNL/TM-2019/1197 describes 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 (approximately 1,000 megawatts electric (MWe)) and combinations of a hypothetical reactor characterized by its source term, *D*; the siting factors of distance, *r*; and the population density, *ppsm*. Figure 3 shows the equivalent SRs for varying reactor source terms.

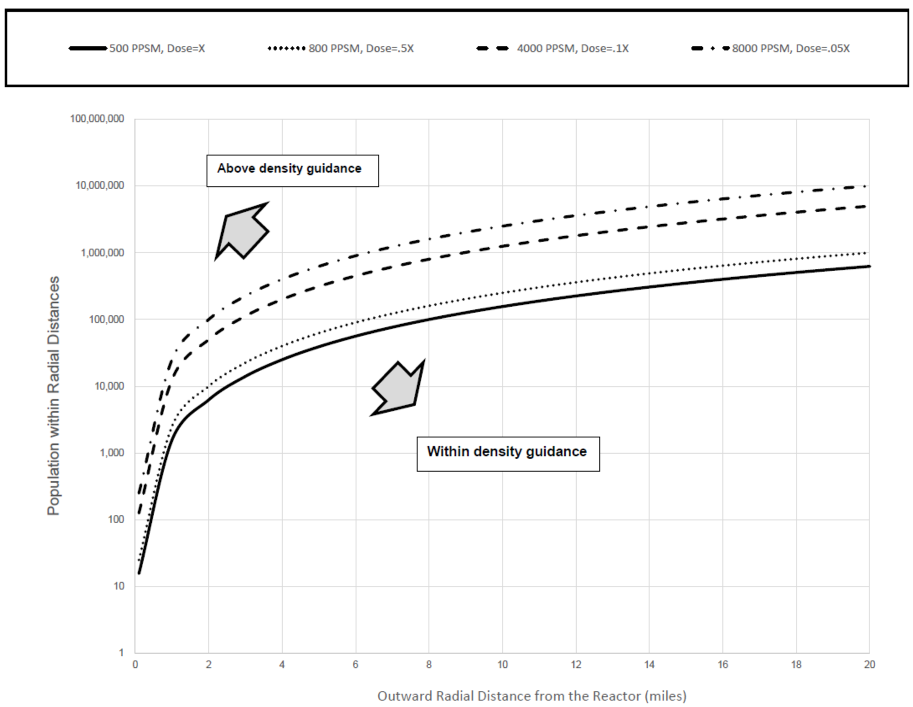

Figure 3 Population Density Comparison

For example, one can assume 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 MWe). A reduced area of contamination can be assumed from the 1,256 square miles associated with the current guidance ($\pi \bullet 20^2$ 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. 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 equivalent radius of 5 miles is achieved with a population density of 8,000 ppsm. In this example, the close-in control of population becomes governed by the regulatory requirement for reactors to be located outside of densely populated centers with more than 25,000 residents. If needed to address estimated offsite consequences, additional close-in controls on population 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.

Advantages: This option uses a combination of the regulatory requirements related to population and revisions to the population density criterion in RG 4.7 to support the policy on siting plants away from population centers and introduces a variable criterion based on source term or power level. The variable criterion is based on a general relationship between possible radiological releases and the inventory of radionuclides (e.g., power level) while otherwise maintaining the independence between siting and design. A revision to RG 4.7 would (1) promote regulatory stability, predictability, and clarity, (2) eliminate the need for future applicants to propose alternatives to the existing criteria in RG 4.7, (3) recognize technology advancements and design features associated with the NRC-recommended attributes of advanced reactors, and (4) replace a single prescriptive criterion on population density with technology-inclusive, risk-informed, and performance-based guidance based on the general relationships between accident consequences and the inventory of radionuclides available for release. The population values shown in Figure 3 maintain the general approach to societal risk provided in the current guidance for large LWRs. The approach also provides a relatively simple and flexible way to address the expected lower source terms for advanced reactors in comparison to the traditional LWR severe or "Class 9" accident on which current policy is based. This option would increase the number of allowable sites, including retiring fossil stations and isolated communities with populations below 25,000 residents.

Disadvantages: This option requires a revision to longstanding guidance related to population-related siting criteria to address potentially lower source terms for advanced reactors; therefore, it would require resource expenditures. The resource issue is largely addressed by current and expected future dedicated budget appropriations for the NRC to develop infrastructure for licensing and regulating advanced reactors. This option somewhat reduces the practice of site approvals being independent of plant design considerations in that a correlation of accident consequences to radionuclide inventory is introduced into the decisionmaking. Some stakeholders may view efforts to revise guidance related to matters such as siting and populations as controversial.

Both positive and negative views about Option 2 were received from stakeholders during a public meeting on June 27, 2019. Some stakeholders at the meeting observed that this option would recognize advanced reactor attributes and provide flexibility for siting decisions. Other stakeholders, namely the Union of Concerned Scientists (UCS), expressed the view that Option 2 was overly simplistic in that it considers only a source term factor (e.g., power level).

Option 3

Option 3 does not involve changes to NRC regulations; however, the staff would revise the population-related guidance in RG 4.7 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. Option 3 builds upon the evaluation of licensing-basis events as described in DG-1353 which includes the evaluation of offsite consequences for both design-basis and beyond-design-basis events.[5] The approach considers 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 implements a graded approach to sizing areas within which the population density would be assessed using the criterion of density less 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 either design-basis events or beyond-design-basis events.[6] 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 resulting from the subject event categories. 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).[7] The staff is proposing to use these performance criteria specifically because it expects the models and calculations to be part of the licensing process described in DG-1353.[8]

The following three 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:

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5 An applicant using a licensing approach different from that discussed in DG-1353 could propose to use Option 3 by evaluating the potential offsite consequences for a wide range of possible plant transients and accidents, including beyond-design-basis events.

6 DG-1353 describes licensing-basis event categories for advanced reactors. Design-basis events are event sequences with frequencies between 1×10^{-2} and 1×10^{-4} per plant year. Beyond-design-basis events are generally those event sequences between 1×10^{-4} and 5×10^{-7} per plant year.

7 See SECY-18-0103, "Proposed Rule, 'Emergency Preparedness for Small Modular Reactors and Other New Technologies'," dated October 12, 2018 (ADAMS Accession No. ML18134A076). 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 draft regulatory guide (DG) 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.

8 The staff acknowledges that alternative criteria could be selected. For example, the staff considered using EPA PAG Manual guidelines for relocation of the public (2-rem projected dose in the first year, 0.5 rem per year projected dose in the second and subsequent years). Using the relocation PAG could correlate better to economical elements of societal risks. The staff instead selected to simply double the distance associated with a calculation (distance for 1 rem over a month) that was already expected to be performed as part of the licensing process for advanced reactors.

(1) In the first case for possible advanced reactor designs, the potential offsite consequences of some beyond-design-basis events are calculated to approach 25 rem over the course of the event. As defined 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 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. In addition to these requirements, the revised guidance would also assess the total population near the plant site by calling for the population density to be less 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. The population density will be evaluated within an area that encompasses and extends beyond the LPZ.

(2) The second case involves an advanced reactor design for which all design-basis events and beyond-design-basis events are calculated to result in doses to an individual at the site boundary of less than 25 rem over the duration of the event. However, for this case, 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 less 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 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.

(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. An advanced reactor with estimated doses below 1 rem at the site boundary over the month following the assumed design-basis or beyond-design-basis event could hypothetically be allowed within towns with populations of no more than approximately 25,000 residents.

Advantages: This option allows consideration of the design- and site-specific accident consequences and specific features of an advanced reactor design beyond the likely lesser power levels that may limit the release of radionuclides. The approach uses a combination of the regulatory requirements related to population and revisions to population density criteria in RG 4.7 to support a more performance-based approach to the policy on siting away from population centers as a means to help control societal risks. This option would increase the number of allowable sites for advanced reactors in comparison to current guidance, including sites at retiring fossil stations and isolated communities with populations below 25,000 residents. The staff would pursue a revision to RG 4.7 that would provide the same benefits as Option 2 while allowing a more design-specific assessment of risks.

Disadvantages: This option requires a revision to longstanding guidance related to population-related siting limitations to address potentially lower source terms for advanced reactors; therefore, it would require resource expenditures. The resource issue is largely addressed by current and expected future dedicated appropriations for the NRC to develop infrastructure for licensing and regulating advanced reactors. Option 3 is a somewhat more significant change to the regulatory framework in that siting policy would no longer be independent of plant design. Some stakeholders may view efforts to revise guidance related to matters such as siting and populations as controversial.

During interactions with the NRC staff, the Nuclear Energy Institute (NEI), the Nuclear Industry Council (NIC), and individual developers identified Option 3 as their preferred option. The stakeholders favoring this option cite the goal of reducing regulatory uncertainties and providing a process by which advanced reactor attributes—characterized in this case by estimations of offsite radiological consequences from licensing basis events— are credited to provide operational flexibility, including revisions to population-related siting guidance. NEI and some developers favoring Option 3 have proposed for the NRC to proceed with revisions to RG 4.7 but to also consider changing the limitations for locating reactors within population centers of approximately 25,000 residents as part of a future rulemaking activity (e.g., the rulemaking mandated by NEIMA to provide a technology-inclusive regulatory framework for advanced reactors).

The NRC staff recommends Option 3 because it best meets the goals for the timely resolution of policy issues as described in "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness," issued December 2016 (ADAMS Accession No. ML16356A670). Option 3 also promotes (1) consideration of safety in the early stages of design and siting as recommended in the agency's policies related to advanced reactors, (2) risk-informed and performance-based regulations commensurate with the risks posed by advanced reactor designs, and (3) efficiency and clarity as described in the NRC's Principles of Good Regulation. A revision to the guidance in RG 4.7 would allow for a technology-inclusive, risk-informed, and performance-based approach to address population-related issues for siting advanced reactors.

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 criteria 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). SECY-18-0042, "Draft Final NUREG/BR-0058, Revision 5, 'Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission,'" dated March 28, 2018

(ADAMS Accession No. ML17221A000 (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 societal risks and costs can be compared to the costs of imposing a 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 baseline. 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. In a less comprehensive example, the Atomic Energy Commission and the NRC have used siting criteria and other factors associated with societal risk measures to support the moving of proposed reactor sites to alternative sites.

Advantages: This option would provide an assessment of the societal risks associated with a specific reactor design located on a specific site for comparison to other societal risks or performance measures. Such an approach could supplement the current NRC practice of basing most consequence-based assessments on the estimated doses to individuals.

Disadvantages: This option would require significant resources and would be unlikely to support some current reactor developers with their design and siting decisions. Option 4 is a significant change from considering siting as an independent element of defense in depth; instead, it would include the specific combinations of reactor designs and sites to assess societal risks. Some approaches to assessing societal risks and using them in decisionmaking would require the NRC to characterize nonnuclear risks (e.g., natural disasters and other energy supplies) for use as part of comparisons and findings that the societal risks associated with a reactor and site were acceptably low.

Both positive and negative views about Option 4 were received from stakeholders during a public meeting on June 27, 2019. For example, NIC expressed the opinion that the NRC should not consider developing broader societal measures. However, Option 4 was the stated preference of UCS if the NRC were to pursue any option other than the status quo.

<u>Stakeholder Interactions</u>

The NRC staff discussed population-related siting considerations during several public meetings. The staff prepared and made publicly available white papers on the topic (ADAMS Accession Nos. ML17354B219 and ML19163A168) to support the public interactions. Time was made available during the public meeting on June 27, 2019 (ADAMS Accession No. ML19xxxAyyy), for stakeholders to provide feedback or other insights on siting considerations related to population and the development of this paper.

A draft of this paper was made publicly available (ADAMS Accession No. MLxxxAyyy) to support a meeting with the Future Plants Subcommittee of the Advisory Committee on Reactor Safeguards (ACRS) scheduled for August 23, 2019.

Relationship to other Advanced Reactor Priorities

Uncertainties associated with the possible regulatory approach for siting advanced reactors are limiting the ability of designers to complete their assessments of plant designs and sites. The staff is currently interacting with light-water SMR and non-LWR stakeholders (e.g., DOE, designers) on a variety of policy and regulatory issues. An integrated approach is needed for resolving issues and developing a regulatory framework for advanced reactors. This integrated approach is being developed as part of the activities underway to provide the needed infrastructure for the design, siting, licensing, deployment, and operation of advanced reactors. The guidance to inform the design and siting processes and the related content of applications for licenses, certifications, and approvals for advanced reactors depends on resolving the siting issues addressed in this paper.

COMMITMENT:

If the Commission approves an option involving changing regulatory guidance related to population-related siting considerations, the staff will undertake the process of revising RG 4.7 using the established agency processes described in Management Directive 6.6, “Regulatory Guides” (ADAMS Accession No. ML16083A122).

RECOMMENDATION:

The staff recommends that the Commission approve Option 3, which consists of revising guidance to provide technology-inclusive, risk-informed, and performance-based criteria to assess population-related issues in siting advanced reactors.

COORDINATION:

The staff will consider its interactions with the ACRS in finalizing this paper.

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for Operations