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NEPA Compliance for Licensing a Small Modular Power Plant

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ABSTRACT

The National Environmental Policy Act (or NEPA), signed into law on January 1, 1970, requires that all federal agencies funding or permitting projects—including nuclear power plants—make those decisions in full consideration of the impact to the natural and human environment. NEPA further requires that the agencies disclose these environmental impacts to the public.

To comply with NEPA, an applicant seeking a license for a new nuclear power plant must submit an Environmental Report to the Nuclear Regulatory Commission. This document provides the agency with a comprehensive description of the environmental baseline conditions, the probable impacts of the proposed project along with potential mitigation measures, and monitoring efforts.

If a nuclear renaissance is to be successful, the potential environmental concerns associated with the construction and operation of a new nuclear plant must be identified, carefully evaluated, and dispositioned in the Environmental Report. This paper covers some of the key issues included in an Environmental Report as they relate to a new nuclear power plant—the evaluation of potential land use, water use, ecological and socioeconomic impacts. A comparison discussion paralleling the environmental impacts for the identified key environmental factors associated with a small modular reactor plant to those of a large conventional nuclear power plant is presented.

1. INTRODUCTION

The National Environmental Policy Act (NEPA) requires government agencies to undertake an assessment of the environmental effects of their proposed actions such as issuing permits, spending federal money, or taking actions on federal lands. In enacting NEPA, Congress recognized that nearly all Federal activities affect the environment in some way and mandated that before Federal agencies make decisions, they must consider the effects of their actions on the quality of the human environment. NEPA assigns the Council on Environmental Quality (CEQ) the task of ensuring that Federal agencies meet their obligations under NEPA. [1]

NEPA established federal policy, goals, and procedures to ensure:

- Federal agencies utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design in planning and in decision making which may have an impact on "man's environment; and
- Federal agencies make these impacts known to the public and involve the public in the decision making process. [1]

When an agency concludes that a proposed major federal action has the potential for causing significant environmental impacts, it is required to prepare a detailed statement, known as an Environmental Impact Statement (EIS), analyzing those potential environmental impacts. Licensing any nuclear facility is considered a "major Federal action" requiring an EIS. [2]

There are a number of small modular reactors (SMRs), light water and non-light water, being developed. These SMRs—typically fewer than 300 megawatts (MW)—coupled with modular construction principles will reduce the financing challenges facing conventional light water reactor (LWR) designs. These designs could replace inefficient fossil-fueled fired facilities, be used for generating electricity in remote areas or secured facilities such as military installations, or for producing high-temperature process heat for industrial purposes such as the petrochemical industry and desalination or water purification. The objective of these SMRs is to provide a flexible, cost-effective energy alternative for carbon-free nuclear energy. [3]

This paper looks at key environmental issues examined as part of the NEPA process for licensing new nuclear power plants and how the impacts relating to these key issues may differ between a conventional LWR and a SMR.

2. NRC LICENSING/PERMITTING STRUCTURE FOR NEW NUCLEAR POWER PLANTS

In order to operate a new nuclear power plant in the United States, several licenses/permits are required from various federal, state and local agencies, e.g., the United States Nuclear Regulatory Commission (NRC), the United States Environmental Protection Agency (EPA) and the United States Army Corps of Engineers (ACOE). The main licensing/permitting responsibilities for nuclear power plants lie with the NRC.

Recently, the NRC has developed a new licensing/permitting structure for new nuclear power plants. Prior to 1989, NRC licensed nuclear power plants under a two-step process, requiring both a construction permit and an operating license. In 1989, NRC finalized regulations establishing an alternative licensing process that combined a construction permit and an operating license into a combined license (COL). NRC also established two new licensing alternatives in 1989: Early Site Permit (ESP), which allows an applicant to obtain approval for a reactor site for future construction, and standard design certification (DCD) where NRC pre-approves a standard plant design. [4] The environmental report (ER) is an essential part of the COL or ESP application. It is estimated that a total of six years is expected for obtaining a COL.

The license application process for a SMR is similar to that of a conventional large LWR with the option for licensing either an individual reactor module or multiple reactor modules. Regardless, an ER is required for either option. The development of an ER for a SMR license application, whether an ESP, a COL, or a CP, would follow the same approach.

2.1 The Environmental Report as it relates to the National Environmental Policy Requirements and the Licensing of a Small Modular Reactor Plant

As described in the previous section, an EIS is required for any license issued by the NRC to site, construct, or operate a new nuclear power plant (10 CFR 51.20(b)), including a SMR. The scope of an EIS may be for a limited work authorization (LWA)/construction permit (CP), ESP, or COL. (An EIS for a COL could be prepared as a Supplemental EIS to a Final EIS for an ESP.) For an ESP, a CP, or a COL for either conventional LWR or SMR, the applicant submits an ER to the NRC. [5]

NEPA then requires the NRC to prepare an EIS, which is an analysis of the potential environmental impacts from the proposed project and from a full range of reasonable alternatives. The EPA provides review and comments on the EIS [5]. The regulations of CEQ require Federal agencies to make environmental review documents, comments, and responses as part of their administrative record. The NEPA process for development of an EIS for a new nuclear power plant is illustrated in Figure 1.

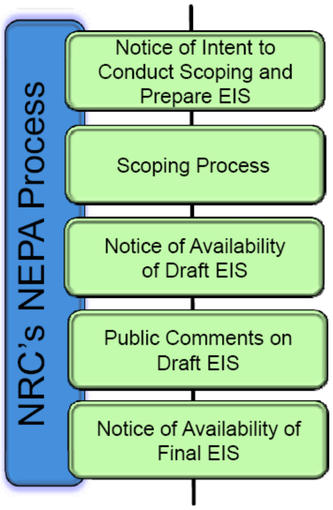


Figure 1 NRC's NEPA Process (Source U.S. NRC)

3. EVALUATION OF ENVIRONMENTAL IMPACTS IN THE ENVIRONMENTAL REPORT

The ERs currently being prepared closely follow the format and content requirements provided in NRC and other regulatory guidance documents which set out the expectations in terms of data and information needs, acceptance criteria and review procedures used. The NRC framework for implementing NEPA for licensing a SMR plant includes:

- 10 CFR Part 51
- Environmental Standard Review Plan (NUREG-1555)
- Supplemental ESRP Guidance

Table B-1 of 10 CFR Part 51, Subpart A, Appendix B defines three impact levels for evaluating environmental impacts during the NEPA process:

SMALL:	Effect is not detectable, or so minor it will neither destabilize nor noticeably alter any important attribute of the resource.
MODERATE:	Effect is sufficient to alter noticeably, but not destabilize important attributes of the resource.
LARGE:	Effect is clearly noticeable and sufficient to destabilize important attributes of the resource.

The ERs do not require adherence to a predetermined environmental outcome, but rather they require decision makers to account for environmental values in their decisions and to justify those decisions in light of detailed environmental studies and public comments on the potential environmental impacts of the proposed project. The ER contains a detailed analysis across several environmental and social science areas.

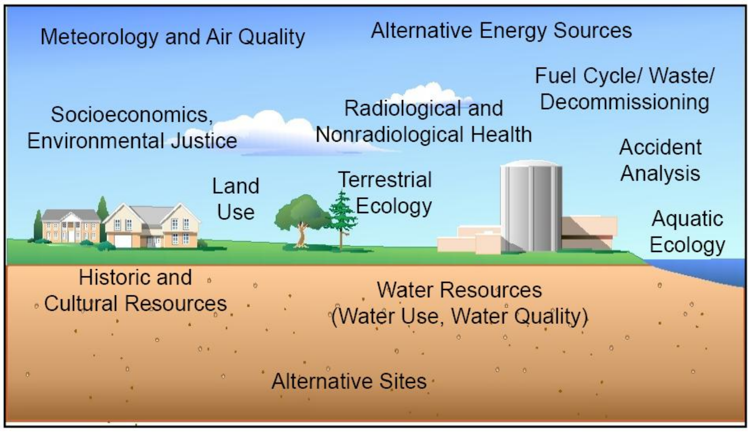
3.1 Organization of the Environmental Report

The ER must analyze the potential impacts of construction, operation and decommissioning of the proposed new nuclear power plant. The format of the ER is prescribed in NUREG-1555. Table 2 illustrates the various Chapters contained in an ER.

Table 2 Typical Layout of an ER [5]

Chapter	Title
1	Introduction
2	Environmental Description
3	Plant Description
4	Plant Construction Impacts
5	Plant Operating Impacts
6	Environmental Monitoring
7	Impacts of Postulated Accidents
8	Need for Power
9	Alternatives
10	Environmental Consequences

The ER Chapters logically fall into three groups. Chapters 1 through 3 are descriptive in nature and describe the vicinity and regional setting for the proposed action relating to its environment, and a detailed description the plant including those features of the plant that are most likely to affect the local environment (e.g., the cooling tower design). Chapters 4 through 7 relate to environmental impacts associated with construction and operation of the plant along with planned monitoring efforts and include the technical analyses used to derive the associated environmental impacts classification. Finally, Chapters 8 through 10 relate to the proposed action in terms of the need for power; an analysis of the applicants proposed action to no action, alternative sites, energy sources and system designs; and a summary of the conclusions relating to the proposed action Figure 2 illustrates the environmental resource areas typically analyzed in detail in the ER.



Source U.S. NRC

Figure 2 Resource Areas Addressed in the ER (Source U.S. NRC)

4. DERIVING ENVIRONMENTAL IMPACTS ASSOCIATED WITH THE CONSTRUCTION AND OPERATION OF A SMR

4.1 Site Characterization (baseline conditions) and Plant Description

4.1.1 Site Characterization

Prior to developing environmental impacts, the existing environment must be described in sufficient detail in the ER to form a basis for evaluating the potential for direct, indirect, and cumulative impacts. A brief description is provided regarding the collection of baseline data that is compiled and/or collected for site characterization requirements to provide an understanding of the comparative analysis involved in deriving environmental impacts. Baseline data collection needs include: meteorological; geological; geophysical; surface water; groundwater; biological; and radiological data. Site- and station-specific factors and the degree of detail should be modified according to the anticipated magnitude of the potential impacts.

Often collection of baseline data is found to be inadequate in its spatial and temporal extents for site characterization. Deficiency in the collected data affects the accuracy of the impact assessment directly. Therefore, a systematic process for gathering baseline data is required. Baseline data should be of sufficient sample size to conduct hypothesis testing against post-commissioning monitoring data and collected under auditable quality assurance programs.

The site characterization requirements that would be needed for a conventional LWR versus a SMR would be dependent on the number of units selected for the SMR design. A design with a smaller footprint (i.e., a small number of SMR units) is expected to require less temporal and spatial data collection to establish baseline conditions.

4.1.2 Plant Description

A detailed description the plant including those features of the plant that are most likely to affect the local environment are included in the ER in order to develop the environmental impacts associated with the selected design element. Some of the necessary plant descriptive elements included in an ER are as follows:

- A description of the planning, layout, and appearance of the proposed plant and existing station structures and any related offsite structures;
- A description of the reactor and electric generating equipment;
- A description of plant water use (e.g.,circulating water system, sanitary waste system, radwaste and chemical waste systems, and service water systems) to include a description of the treatment needed for the plant water streams;
- A description of the proposed plant cooling system and its operational modes;
- A description of the proposed intake, discharge, and heat dissipation system design and performance characteristics.[5]

Plant description requirements and inputs would be similar for both the conventional LWR and SMR design i.e., the technology dependent level of detail is commensurate with both.

4.2 Key Environmental Impacts Associated With the Construction and Operation of a SMR

4.2.1 Land Use

Land requirements for a new nuclear power plant, including a small modular reactor plant, can be significant, depending on the selected design, the number of modules or units proposed, whether a cooling pond or reservoir will be required, and the length of new transmission lines that are proposed. Changes in existing land use and zoning laws may present challenges and are potential concerns in terms of cumulative impacts (for example, prime farmland, protected lands, sensitive resources/critical habitat, coastal zone). Land ownership (private, public, protected lands) may also be a concern where extensive public land crossings (such as national forests or parks or other public lands) are required to provide site access, to access cooling water, or for utility and transmission corridors. [2]

The primary basis in evaluating land use impacts includes the identification of the total acreage and current land uses that will be affected by the construction and operation of the new nuclear power plant. Locating a new nuclear power plant at a site would include clearing, dredging, grading, excavation, spoil deposition, and dewatering activities. The total impacted area onsite could include up to several hundred acres (or more if a new reservoir is constructed), although the majority of acreage should be affected only temporarily and be able to be restored following plant construction. The area permanently disturbed varies with the design and number of units. [2, 5]

In recent ER submittals, the amount of permanent land disturbance has proved to be highly dependent on the required cooling water system as other land disturbance activities are not as variable. For example, a conventional LWR COL applicant utilizing an intake structure estimates a total permanent disturbed area of 320 acres—of which 5 acres of disturbance results from the intake structure. [6] While, a second conventional LWR ESP applicant utilizing a cooling basin design estimates a total permanent disturbed area of 6354 acres—of which 5785 acres results from construction of the cooling basin. [7] And, a third conventional LWR COL applicant utilizing a combination of reclaimed water and wells estimates a permanent disturbed acreage of 930 acres—of which 6 acres are attributed to the wells (permanent) and an additional 56 acres of temporary disturbance would be attributed to the pipeline corridors. [8] Cooling water system design applications can also affect the amount of salt deposition from cooling tower drift on vegetation. Therefore, conventional LWR reactors have the potential to significantly affect the land use in the vicinity and region of the proposed plant.

The SMR reactor designs, can offer a significant savings regarding land use disturbance depending on the number of units constructed or whether the SMRs are built at grade or below grade. The SMR reactors have a much smaller footprint when built at grade and thus can be utilized in areas where there is not an abundance of land with the appropriate land use designation or in areas where environmentally sensitive areas are prevalent. Additionally, it is anticipated the construction period required to build a SMR will be less than that of a conventional LWR, limiting the time period of possible significant but temporary impacts during construction. Further, with regard to land disturbance as a result of water supply/use, SMR designs use less water and therefore land disturbance as a result of the creation of cooling water reservoirs and well fields would not be required—at least one SMR design is looking at the possibility of an air cooled system. [9]

However, a few of the SMR designs are considering below ground containment in which the excavation may require a much larger footprint due to the structural soil sloping and generate a significant quantity of spoils which could have large impact land use. [3] The construction period would be much longer due to the deep excavation—estimated at 3 years for a below ground SMR designs in comparison with 5 years for a large conventional LWR [8] [9].

In summary, SMR designs can offer significant advantages regarding land use impacts, but these advantages would be highly dependent on the number of units constructed, required excavation, current land use designations and spoils generation.

4.2.2 Water Resources

One of the primary impact areas from new nuclear power plant development, both construction and operation, is water—specifically water supply and use, water quality, and hydrology. Water resource impacts during construction can result from: dewatering activities; cooling water system installation (cooling pond or reservoir); constructing cofferdams and storm sewers; dredging operations; constructing intake and outfall structures; constructing roads and bridges; constructing activities contributing to sediment runoff, such as road construction, clearing and grading. Additionally, water use impacts regarding dust abatement, and concrete batch plant operations must be accounted for in the development of the ER. [3, 5]

Cooling system operations will probably cause the most significant hydrological alterations over the course of plant operation. There are three main types of water based cooling systems, each with substantially different effects: (1) once-through; (2) closed-cycle system that utilizes cooling towers; and (3) cooling ponds/reservoirs. [3] For example conventional LWR applicants estimate water supply requirements at approximately 50,000 gpm for mechanical draft cooling tower sites and approximately 500 gpm for sites utilizing a cooling water reservoir [6, 7, 8]. It is anticipated that in light of new regulatory requirements, once-through systems are not expected to be an option with new applicants [3]. Potential issues surrounding water uses associated with a conventional LWR include: water use conflicts; altered patterns at intake and discharge structures; altered salinity gradients; temperature effects on sediment transport capacity; and scouring due to discharged cooling water. Additionally, depending on the design and location of the proposed facility, construction of the foundation of the reactor and various other buildings, the installation of dewatering systems may be required. Dewatering systems would depress the water table in the local vicinity and possibly change the direction of groundwater flow and the available capacity of local wells. [3, 5]

In general, while conventional LWR can result in significant hydrologic changes, studies and monitoring at existing LWR plants has shown that the impacts appear to be largely controlled through existing permitting processes (e.g., intake and discharge effects are regulated through the National Pollutant Discharge Elimination System (NPDES) permit). However, consumptive water uses may be more difficult to mitigate in areas experiencing water availability problems and loss through consumption and evaporation can represent a substantial proportion of the flows in small rivers. Therefore, depending upon the design and location of the proposed facility, in particular the design of the cooling system structure, conventional LWR reactors can have a significant impact on water resources.

The non-light water SMR designs would offer inherent significant savings regarding water resource impacts especially during operation if a dewatering system is not required. The light water SMR designs can still offer a significant savings regarding water resource impacts. Again this savings depends in large part on the number of units selected. The water consumption requirements for SMRs are much less at a per unit basis. Therefore, the scalability of the SMRs can play an important role in achieving balance in areas where water availability problems exist. However, one potential note of concern for some SMR designs exists. At least two SMR designs are considering below ground containment and, thus, a large amount of excavation/dewatering work would be required at the construction phase and a dewatering system may be required at the operation phase. The impacts of the dewatering system may offset some of the benefits of a much lower water consumptive use; however, it would be expected, as with the conventional LWR designs, that many of the potential dewatering impacts during operation would be controlled through existing permits—with the exception of some of the hydrological impacts, e.g., groundwater flow patterns.

4.2.3 Radiological and Nonradiological Health

4.2.3.1 Radiological Waste Disposal

Operation of either a conventional LWR or SMR will result in the generation of radioactive waste streams. NEPA provides a framework to regulate these waste streams during all phases including generation, management, handling, treatment, storage, transportation, and disposal. However, a SMR is not expected to generate a large volume of radioactive waste during its operation due to its inherent design. The radioactive waste resulted from SMR operation includes liquid and solid waste.

In most cases, SMRs require no or little water for reactor cooling. Therefore, a SMR would generate at most the volume of radioactive liquid waste roughly proportional to the volume that would generate by a conventional large LWR by the ratio of their megawatt output.

For radioactive solid waste, a SMR would generate smaller quantities than a conventional large LWR. These radioactive solid wastes could include dry active waste, low level contaminated equipment, and medium level contaminated materials.

However, when there is more than one unit of SMRs present in a plant site, their total megawatt output may equal or more than a conventional large LWR (in the range of

1,000 megawatts). Therefore, it is possible that the volume of radioactive solid waste generated by the combined SMR group could exceed the waste volume of a conventional light water reactor.

The environmental impacts of generating, managing, handling, storing, and disposing of radioactive liquid waste generated in a conventional large LWR are determined to be low. Therefore, the environmental impacts of generating, managing, handling, storing, and disposing of radioactive liquid waste generated in a SMR plant would be very low.

The environmental impacts of generating, managing, handling, storing, and disposing of radioactive solid wastes generated in a conventional LWR reactor plant are determined to be low. Therefore, the environmental impacts of generating, managing, handling, storing, and disposing of radioactive solid wastes generated in a SMR plant would be low.

4.2.3.2 Transportation of Nuclear Fuel and Radioactive Solid Waste

In addition to lower number of fuel assemblies designed for the reactor core, SMR designs require longer refueling cycles, varying from NuScale’s cycle of every 24 months to Toshiba’s 4S cycle of 30 years. [9, 10, 11] Longer refueling cycles provides significant advantages as compared to conventional LWRs, which require on the average 18 months refueling cycle. Therefore, the quantities of fresh fuel and used fuel required to be transported to and from the plant are substantially lower than a conventional LWR plant. Consequently, the number of fuel transportation trips for a SMR plant is also lower than that of a conventional LWR plant.

As discussed in Section 4.2.3.1 above, the volume of radioactive solid waste generated in a SMR plant is lower than a conventional LWR plant. The number of waste transportation trips for a SMR plant is also lower than that of a conventional LWR plant.
Consequently, the radiological and non-radiological impacts of transportation for a SMR plant are comparatively smaller than the impacts of a conventional LWR plant. These impacts are considered to be very low.

4.2.4 Socioeconomic impacts

Socioeconomic impacts on the nearby community (e.g., from noise, odors, air pollution, dust, vibration and visual intrusion), and local municipalities and the region (e.g. from minority population, public infrastructure and services, employment) during plant construction and operation are required to be evaluated to ensure negative impacts and mitigation measures are identified. [5]

In general, the community impacts can be mitigated to an acceptable level through good engineering design and best management practices. The significance of local population impacts depend on the number of individuals who will migrate into the area to work at the plant or off-site as a result of indirect job creation. Effects from worker influx (and their families) and out-flux, especially on small towns and communities, can be significant if a large percentage of the workers in-migrate or leave following construction activities. The capacity of communities to absorb an increase in population depends on the availability of sufficient resources, such as adequate housing and community services (including schools, hospitals, police, transportation systems, utilities, and fire protection) to support the influx without straining existing services.

For a conventional LWR, construction activities are typically last up to 5 years and need up to 5000 workers for two units (ranging from 700 – 1100 MW each. The number of operations workers required will be small (about 700 – 800 workers for two units) relative to original construction work force size, and the operations workers are generally introduced gradually to the site so that housing demand will also increase gradually. [6, 7, 8] This large influx of workers and jobs would also create large benefits to the area in terms of increased revenues and taxes

In looking at the SMR designs, one could see that a significant reduction in the number of influx and out-flux of nuclear power plant workers would be required for construction and operation. This would reduce the significant impacts in local housing, schools, community, and social services as compared with the conventional LWR. In addition, some SMRs are looking at below ground containment, and along with their smaller footprint, would lessen any potential visual impacts.

4.2.5 Cumulative Impacts

Several key areas of information should be considered in determining the cumulative impacts assessment in a NEPA/ER document [12]. These areas include the following:

- Resources and Ecosystem Components
- Geographic Boundaries and Time Period
- Past, Present, and Reasonably Foreseeable Future Actions
- Describing the condition of the Environment
- Using Thresholds to Assess Resource Degradation

Particular attention should be paid to the following impact areas when addressing cumulative impacts for a SMR plant:

- The co-location of plants could contribute to potential cumulative impacts of new plant construction on existing plant operation, and combined impacts when both plants are operating. Combined impacts of operation include traffic/congestion, noise, and socioeconomic effects (beneficial and adverse).
- The impacts from pre-construction, authorized construction activities, and the activities of the proposed project and alternatives must be considered together to provide an adequate assessment of cumulative impacts.
- Cumulative impacts from other nuclear power plant-related construction, such as constructing a reservoir for water storage or constructing an onsite treatment facility if cooling water needs to be treated before input to the plant, should be addressed.
- Radiological or other health effects may occur in populations affected by cumulative or multiple exposures to environmental hazards.
- Other currently planned industrial, commercial or public installations that would consume water within the general vicinity should be considered.

The assessment for a conventional LWR versus a SMR would be dependent on the number of units selected for the SMR design and the site and regional characteristics.

4.2.6 Alternative Sites

The objective of the alternative site evaluation is to verify that there are no “obviously superior sites” for the eventual construction and operation of a new nuclear plant. The decision for a proposed power plant site is fundamentally a business decision, yet one that still must satisfy energy demands of the nation while meeting the requirements of NEPA. Therefore, licensing/permit applicants should ensure sufficient information and an adequate demonstration that the alternative sites are not environmentally preferable to the proposed site under consideration.

SMR designs could prove more difficult to differentiate whether an alternative site is environmentally preferable. With its smaller design and the concept of scalability (the option of placing one or several units at a site), there potentially would be more sites available for siting an SMR. For example, while consumptive water use is a major consideration in choosing a site for conventional LWRs, if one where to consider, SMRs, a greater number of sites could fulfill the SMR water consumption requirements.

4.3 Comparison Results

A summary of the comparison discussion paralleling the environmental impacts for the identified key environmental factors associated with a SMR plant to those of a large conventional LWR are presented in Table 3.

Table 3 Comparison Summary of Key Environmental Impact Issues

Environmental Impacts	Conventional Light Water Reactors	Small Modular Reactors
Land Use	Impacts would be largely dependent on cooling system design (e.g., cooling water reservoir versus intake structure).	Impacts are generally less than those of a conventional LWR but impact is very dependent on the number of units built. Spoils disposal may also be an issue due to deep excavation for below grade containment.
Water Resources	Consumptive water use can have a significant impact on water resources. Other water quality issues would be mitigated through permitting.	Impacts are generally much less regarding water consumptive impacts—again this may be dependent on the number of units analyzed. Dewatering requirements for underground containment during construction and operation may also be a potential impact.
Radiological Waste Disposal	Impacts of generating, managing, handling, storing, and disposing of radioactive liquid or solid waste generated are generally low.	Impacts are generally much less regarding liquid radioactive waste—radioactive solid wastes are more dependent on the number of units considered.
Transportation of Nuclear Fuel and Radioactive Solid Waste	Impacts from the transport of nuclear fuel and radioactive solid waste are generally low.	Impacts are generally less for the transport of nuclear fuel and radioactive solid waste due to the longer fuel cycle (24 months to 30 years for SMRs versus 18 months for conventional LWRs).
Socioeconomics	Influx of workers (construction and operation) could create a strain on local resources. However, there are associated revenue and tax benefits.	Impacts would generally be less during construction (fewer workers required). Visual impacts would also be less. But associated revenue and tax benefits would be smaller.

5. SUMMARY

To operate a small modular reactor plant in the United States, applicants must obtain a license from the NRC. Part of the applicant's responsibilities during the application process is the development of an ER for submittal to the NRC as part of the ESP or COL application. The ER will be used as the basis for the NRC to prepare an EIS to fulfill NEPA requirements. SMRs may offer unique advantages over a LWR in deriving environmental impacts and determining the associated mitigation measures. For instance, the scalability, or ability to site one or more of the SMRs at a site, may provide needed flexibility to lessen the environmental impacts analyzed during the NEPA process. It should be noted that overall the comparative analysis shows that most of the advantages of the SMR are dependent on the site characteristics, containment placement (below or above grade) and number of SMRs considered for a site.

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