Supplement Analysis for the National Environmental Policy Act Environmental Assessment

LINAC COHERENT LIGHT SOURCE-II (DOE/EA-1975-SA-02)

LCLS-II High Energy (LCLS-II-HE) Project

SLAC National Accelerator Laboratory
2575 Sand Hill Road
Menlo Park, California 94025

U.S. Department of Energy
Office of Science

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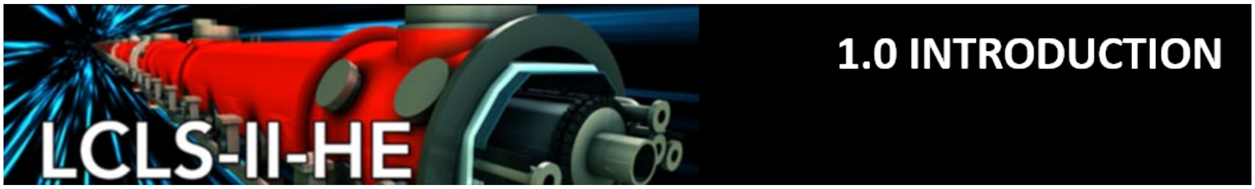
List of Acronyms and Abbreviations

AADT	annual average daily traffic
ALARA	as low as reasonably achievable
ALOHA	Areal Locations of Hazardous Atmospheres
BESAC	Basic Energy Sciences Advisory Committee
BTH	Beam Transport Hall
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
Ci	Curies
CRLF	California red-legged frog
DART	Days Away, Restricted, or Transferred
dB	decibel(s)
dBA	A-weighted decibel(s)
DREP	Dosimetry and Radiological Environmental Protection
DOE	U.S. Department of Energy
EA	Environmental Assessment
EBD	Electron Beam Dump
EPA	U.S. Environmental Protection Agency
FEH	Far Experimental Hall
FNAL	Fermi National Accelerator Laboratory
FONSI	Finding of No Significant Impact
GeV	gigaelectronvolts
GHG	greenhouse gas
HXR	hard X-ray
keV	kiloelectronvolts
kW	kilowatt
LCF	latent cancer fatalities
LCLS	Linac Coherent Light Source
L_{dn}	day-night averaged sound level
L_{eq}	equivalent continuous noise level
Linac	Linear Accelerator
MEI	maximally exposed individual
MHz	megahertz
mrem	millirems
MW	megawatt
NAAQS	National Ambient Air Quality Standards

NEH	Near Experimental Hall
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
ODH	Oxygen Deficiency Hazard
OSHA	Occupational Safety and Health Administration
pCi	picoCuries
PM_{10}	particulate matter with a diameter of 10 microns or less
$PM_{2.5}$	particulate matter with a diameter of 2.5 microns or less
SAAQS	State Ambient Air Quality Standards
SFBAAB	San Francisco Bay Area Air Basin
SLAC	SLAC National Accelerator Laboratory
SMOP	Synthetic Minor Operating Permit
SWPPP	Storm Water Pollution Prevention Plan
SXR	Soft X-ray
TJNAF	Thomas Jefferson National Accelerator Facility
TRC	Total Recordable Cases
UH	Undulator Hall
WSHP	Worker Safety and Health Program
XFEL	X-ray free electron laser



1.0 INTRODUCTION

In 2014, the U.S. Department of Energy (DOE) published an Environmental Assessment (EA) for the Linac Coherent Light Source-II (LCLS-II) project (DOE 2014). This document provides a Supplement Analysis of the SLAC National Accelerator Laboratory's (SLAC) proposed LCLS-II High Energy (LCLS-II-HE) upgrade, including additional cryomodules and a higher operating power.

1.1 SLAC National Accelerator Laboratory Overview

SLAC is operated by Stanford University under contract to DOE. SLAC's research campus is located on the San Francisco Peninsula in an unincorporated portion of San Mateo County, California (see **Figure 1-1** of the 2014 LCLS-II EA in Appendix A). SLAC was founded in 1962 to site and operate a particle collider and to conduct physics research, accelerator science, and particle physics. More recently, SLAC has been involved in photon science and astrophysics as well. SLAC is a multi-program national laboratory that uses electron and positron beams to explore frontier questions in accelerator research, particle physics, astrophysics, and the structure and function of matter. Its largest facility is the linear accelerator (Linac) which comprises an aboveground 2-mile-long klystron gallery and the belowground accelerator housing situated beneath the klystron gallery.

1.2 Existing LCLS Facilities and 2002 Environmental Assessment

One of SLAC and DOE's major scientific user facilities is the Linac Coherent Light Source (LCLS), the world's first hard X-ray free electron laser (XFEL). The brightness and other properties of the LCLS X-ray laser beam enable the simultaneous investigation of a material's electronic and structural properties on size (sub-nanometer) and time (femto-second) scales. LCLS investigations cover material sciences, catalytic sciences, structural molecular biology, and molecular environmental sciences. The potential environmental effects of the construction and operation of the LCLS were evaluated under the National Environmental Policy Act (NEPA) in an Environmental Assessment (EA) (DOE 2002). After public review, DOE published a Finding of No Significant Impact (FONSI) (DOE 2003).

Construction of the LCLS was completed in 2009, and experiments began during fall 2009. The LCLS uses SLAC's existing Linac (see **Figure 1-2** of the 2014 EA in Appendix A) to generate and accelerate the beam. However, the LCLS uses only the last third (eastern 0.6 mile—Sectors 20 through 30) of the 2-mile-long, 30-sector Linac, with an electron injector at Sector 20. The LCLS project included construction of a Beam Transport Hall (BTH), Undulator Hall (UH), Electron Beam Dump (EBD), Front End Enclosure, Near Experimental Hall (NEH), and Far Experimental Hall (FEH) (see **Figure 1-3** of the 2014 EA in Appendix A). LCLS users access the beam in the two experimental halls, which contain experimental stations with X-ray beam optics, diagnostic equipment, and control systems. The NEH is partially underground and contains approximately 25,000 square feet of research facilities. The UH and FEH are completely underground and together provide another 25,000 square feet of research facilities.

The commissioning and routine operation of the LCLS resulted in employment of approximately 100 additional regular SLAC employees. In addition, up to 40 visiting researchers work at the LCLS at a given time. The LCLS predominantly supports only one experiment at a time, which typically requires ten researchers; the additional researchers are on-site to prepare upcoming experiments and close out completed experiments.

1.3 LCLS-II and 2012 and 2014 Environmental Assessments

During 2011 and 2012, DOE and SLAC completed a NEPA EA (DOE 2012a) for SLAC’s proposed Linac Coherent Light Source-II project (LCLS-II). The LCLS-II originally was an expansion of the LCLS, with an additional beam, an additional experimental hall, and working stations to increase the number of experiments that could be completed. DOE determined that the additional facilities would not result in significant environmental effects and published a FONSI in March 2012.

In 2013, DOE’s Office of Science determined that in addition to increasing capacity and conducting more experiments, the LCLS-II also should be upgraded to enhance its experimental capabilities and perform new types of experiments. These upgrades required dismantling and removing existing equipment and utilities within Sectors 0 through 10 of the existing accelerator housing and klystron gallery and installing new superconducting accelerator equipment. To support this new superconducting accelerator, SLAC is constructing two cryogenic plants (cryoplants) to produce extremely cold liquid helium that would circulate through the accelerator, allowing production of a more powerful beam, thus enhancing experimental capabilities. The original plan included a primary 4 kilowatt (kW) cryogenic plant near Sector 4 of the existing klystron gallery and a smaller (approximately 1 kW) cryogenic plant near Sectors 0-1, to provide additional cryogen production capacity and backup capacity during maintenance shutdowns of the primary plant. The plan was later modified to provide more capacity (see Section 1.4). The LCLS-II project also requires upgrades to existing LCLS equipment and utilities, including those contained in the BTH, UH, NEH, and FEH. One of the upgrades is consistent with the original purpose of increasing capacity and includes a second beamline, but not the large new experimental hall described in the 2012 EA. SLAC completed a new NEPA review for the LCLS-II project with these enhanced capabilities and published the resulting EA (DOE 2014) and FONSI in 2014.

The LCLS-II is scheduled to begin operating in the early 2020s and will double the number of LCLS FEL sources and increase the number of experimental stations available to researchers. The LCLS-II will provide a next-generation microscope that will use the most advanced technologies of both X-ray and laser science to provide higher power, time resolution, and coherence. Specifically, it will provide access to an extended photon energy range, increased control over photon pulses, and two-color pump-probe experiments. The X-ray laser beams generated by the LCLS-II will allow the simultaneous investigation of a material’s electronic and structural properties, potentially leading to breakthrough discoveries across many areas of science including material sciences, catalytic sciences, structural molecular biology, and molecular environmental sciences. Two-color pump-probe experiments can expand our understanding of the transient, excited states that lie at the heart of chemical and biological reactivity and function.

1.4 2015 Supplement Analysis (SA)

After the 2014 EA and FONSI were published, DOE and SLAC completed a more detailed design of the superconducting Linac and determined that the project would benefit from more refrigeration capacity for cryogenic helium to cool the accelerator than was envisioned in the 2014 EA, and that the second cryogenic plant—originally planned to be smaller than the primary plant—would need to be approximately the same size (4 kW) as the primary plant. With the larger second cryogenic plant, the reconfigured cryoplants required a new cooling tower on the same site, rather than using the existing cooling tower as originally planned. These changes to the LCLS-II were addressed in a Supplement Analysis (SA) (DOE 2015). DOE determined that the modified LCLS-II project could proceed without further environmental review. SLAC is continuing construction of the LCLS-II with these upgrades.

1.5 Purpose of Current Supplement Analysis

This document analyzes whether the environmental impacts of the proposed changes to the LCLS-II project, referred to as the LCLS-II High Energy (LCLS-II-HE) project, would be within the original scope and impact envelope considered in the 2014 EA, such that there are no significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts. This proposed upgrade would fabricate and install an additional approximately 26 cryomodules in the Linac. LCLS-II-HE would also require additional electrical and cryogen distribution facilities and other equipment upgrades. The following sections describe the purpose of the additional upgrade, the added cryomodules and supporting facilities, the added construction and operation requirements, and potential environmental impacts. Because the upgrades would be within the same footprint as those described in the 2014 EA and 2015 SA, DOE has determined that this change should be analyzed in a second SA pursuant to 2019 DOE guidance titled "Recommendations for the Supplement Analysis Process" (DOE 2019). DOE will use the SA to determine whether the LCLS-II-HE project's impacts would be within the original scope and impact envelope considered in the 2014 EA. The SA must comply with NEPA of 1969 (P.L. 91-90, 42 United States Code 4321 et seq.), DOE NEPA Implementing Procedures (10 Code of Federal Regulations [CFR] Part 1021), and DOE Order 451.1B. If DOE determines that the impacts of LCLS-II-HE are within the original scope and impact envelope considered in the 2014 EA, then the project may proceed without further review. The SA will be made available to the public after the determination has been made. If DOE determines that the project is not within the original scope and impact envelope considered in the 2014 EA, then additional NEPA analysis and documentation will be required.

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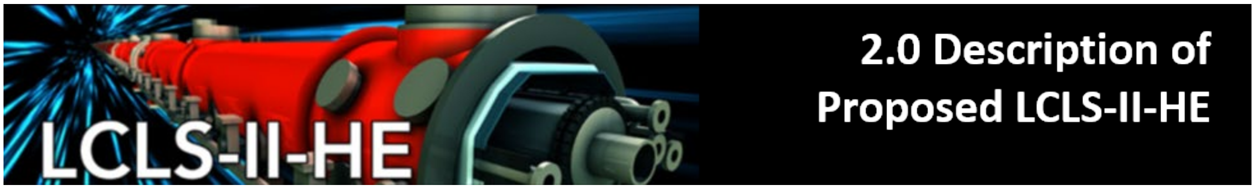


2.0 DESCRIPTION OF PROPOSED LCLS-II-HE

SLAC is proposing to upgrade the nearly completed LCLS-II research facility to operate at a higher power. The LCLS-II design allowed the opportunity to upgrade the Linac by installing additional cryomodules and increasing the acceleration gradient. The LCLS-II project is upgrading the LCLS by installing a superconducting Linac in the first 750 meters of SLAC's existing accelerator tunnel. This will consist of 37[1] 12-meter-long cryomodules, including 35 1.3-gigahertz (GHz) cryomodules and 2 3.9-GHz cryomodules. The tunnel was prepared by removing and disposing of outdated equipment and utilities in the first 1,000 meters (Sectors 0 through 10) of the tunnel. SLAC is proposing to add up to approximately 26 additional cryomodules in the Linac tunnel downgradient of the 37 cryomodules currently being installed. The total number of additional cryomodules would depend on how many are needed to achieve the project's performance targets for acceleration gradient. The cryomodules would be cooled by liquid helium from the two existing cryogenic plants (cryoplants) located at Linac Sector 4. This upgrade would approximately double the energy at the end of the Linac, which would provide the new experimental capabilities described above. Thus, the LCLS-II-HE would be installed within SLAC's existing accelerator housing and klystron gallery and would be cooled by the existing cryoplants with minimal changes to the cryogen distribution system as described below. However, this upgrade would require dismantling and removing existing equipment and utilities in Sector 11 of the accelerator housing and klystron gallery to clear additional space for the LCLS-II-HE cryomodules.

The LCLS-II-HE project was recommended by the Basic Energy Sciences Advisory Committee (BESAC), which advises DOE on scientific direction and prioritization. The LCLS-II-HE would upgrade the LCLS-II superconducting Linac from 4 to at least 8 gigaelectronvolts (GeV) and would enable high-spectral brightness X-ray pulses with spectral range from 5 to 12.8 kiloelectronvolts (keV) or more at a pulse rate up to 1 megahertz (MHz). Although LCLS-II-HE would require an additional increment of cooling water and power, the existing cryoplants have sufficient capacity and would not require upgrades. The project would require several supporting equipment upgrades: the addition of four gaseous helium tanks outside the cryoplant building, a new cryogenic distribution box and transfer line between the cryoplants and the extended superconducting Linac, and the addition of a pulsed low-energy extraction point in the Linac to facilitate the delivery of soft- and hard-X-rays to the experimental halls. Relatedly, LCLS-II-HE would modify the FEH to accommodate additional X-ray endstations and revise the experimental optics and data systems.

[1] The LCLS-II superconducting linear accelerator will have a total of 37 cryomodules. The 2014 EA and 2015 SA, and the calculations therein, were based on 35 cryomodules. The two additional cryomodules were fabricated and installed to provide operational flexibility.

The proposed upgrade would require the fabrication (or purchase) and installation of the following components:

- Removal of existing equipment to clear space in Sector 11 and installation of an additional approximately 26 cryomodules to the existing LCLS-II superconducting Linac
- A new cryogenic distribution box and transfer line at Linac Sector 6 between the existing cryoplants and the extended superconducting Linac
- Klystron gallery modifications including a new cupola at Sector 6 for ventilation and Sector 4 for new penetrations or holes for installation of cryogen lines
- Four additional 110 cubic meter gaseous helium tanks near the cryoplant building, including additional floor space, foundations, and tie-in piping
- A pulsed low-energy 3.8 GeV extraction point in the superconducting Linac to allow quasi-independent operation of the soft X-ray and hard X-ray programs
- A bypass of the midsection of the Linac using an existing transport
- Installation of a hard X-ray self-seeding capability in the hard X-ray undulator capable of operating at high repetition rate
- Modification of the FEH to accommodate additional X-ray hutches or endstations to increase the number of researchers accessing the beam

The LCLS-II-HE would provide further expanded capabilities to research the technological developments needed for the energy sector and for biological and environmental sciences. In particular, the LCLS-II-HE would enable precision measurements of structural dynamics on atomic spatial scales and fundamental timescales. Measurements taken at atomic resolution and higher power are needed to understand the behavior of complex matter in real-world heterogeneous samples. Improving our understanding in these areas could lead to development of alternative sources of energy, methods to mitigate environmental impacts and climate change, new “green” technologies, and precision medical tools.

The LCLS-II-HE would be a natural extension of the LCLS-II in that it adds a well-established technology—a higher-power superconducting linear accelerator—to existing infrastructure, minimizing capital and operating costs and environmental consequences. It would intensify the existing high-repetition rate 5 keV beam into the critical “hard X-ray” regime by increasing the beam power to at least 13 keV and likely up to 20 keV, providing access to higher resolution than any other accelerator in the world—approximately one angstrom (Å) or 10^{-10} meters or one ten-billionth of a meter (0.1 nanometers).

2.1 Installation

The physical components of the LCLS-II-HE are described in more detail below, including how the LCLS was upgraded to the LCLS-II, and how the LCLS-II-HE would expand on the LCLS-II to achieve higher energy and additional experimental capabilities. With the addition of the LCLS-II-HE, SLAC would offer researchers access to the range of research capabilities offered by all three beamlines.

2.1.1 Equipment Dismantling and Removal

Existing utilities in the accelerator housing and klystron gallery in Sector 11—an area used by the Facility for Advanced Accelerator Experimental Tests or FACET—would be demolished, dismantled, and removed, including electrical equipment, hot and cool water system piping, air handling equipment, fire control equipment, and lighting. The work would be done by a crew of approximately 10 with oversight by industrial hygienists and radiation protection specialists. The construction contractor would manage the equipment removal process from a staging area adjacent to the Linac at the west end of SLAC, which is paved and would not require any clearing, grading, or resurfacing.

The decommissioning plan prepared for the LCLS-II for the removal of the existing infrastructure in Sectors 0 through 10 would be used to ensure that all demolition activities comply with applicable laws, regulations, and procedures reflecting established DOE and SLAC policies. Decommissioning procedures would include detailed radiological monitoring and surveys, hazardous material and waste identification and characterization, decontamination, disconnection of operating systems, drainage of liquid-filled systems, and hazardous and radiological waste disposition. The plan would also include salvaging and recycling the materials for reuse at SLAC, packaging components for shipment to other DOE sites, transport/shipment to approved waste disposal sites, or long-term storage at SLAC. The dismantling and removal process would generate approximately 1,500 additional cubic yards (cy) of equipment and utilities for recycling and approximately 80 cy of radioactive waste (e.g., copper and aluminum components).

2.1.2 Cryomodule Manufacture and Installation

The LCLS accelerates subatomic particles by subjecting the particles to electrical forces along the beamline. For the LCLS-II, SLAC added a superconducting accelerator system using cryogens (liquid helium) to reduce resistance and accelerate the electron beam at higher energies (4 GeV) and velocities and enhance experimental capabilities. The LCLS-II superconducting accelerator consists of 37 cryogenic modules (“cryomodules”) (**see photo**). To make room for the LCLS-II inside the klystron gallery and accelerator housing, SLAC removed and disposed of outdated equipment and utilities from Sectors 0 through 10. The LCLS-II cryomodules occupy Sectors 0 through 7.

Typical Cryomodule (yellow portion) of a Superconducting Linear Accelerator

For the proposed LCLS-II-HE, SLAC would install an additional approximately 26 cryomodules as required to achieve the targeted acceleration gradient. The cryomodules would be installed in the Linac, immediately downstream of the LCLS-II cryomodules. This upgrade would double the beam’s energy to 8 GeV and would make use of floor space cleared during 2016 for the LCLS-II. As described in the 2014 LCLS-II EA, Thomas Jefferson National Accelerator Facility (TJNAF) and Fermilab would design and fabricate the additional cryomodules. As was done for the LCLS-II cryomodules, the design and fabrication would be completed within existing buildings at those locations, using existing facilities (e.g., machine shops, clean rooms) and staff.

TJNAF and Fermilab would transport the cryomodules to SLAC by truck. Component delivery at SLAC would be the same as that described in the 2014 EA and would use the Alpine Road gate, the main entrance, and occasionally the west gate at Sand Hill Road and Whiskey Hill Road. The trucks would drive west on the haul road and enter the underground accelerator housing through an existing adit consisting of a vault and tunnel on the north side of the accelerator at Sector 10. SLAC would install the cryomodules employing the same procedure used to install the LCLS-II cryomodules. The cryomodules and supporting equipment (e.g., helium distribution hardware – see below) would be transported into the Linac tunnel. Their alignment and connection would follow the procedures developed for the LCLS-II and would include installing related power and control systems (e.g., cables) in the klystron gallery above the accelerator housing. (SLAC 2016)

2.1.3 Cryogen Storage and Distribution

The LCLS-II helium distribution system connects the two cryoplants to the cryomodules and includes surface cryogenic lines, two distribution boxes, and underground cryogenic lines. To accommodate the additional cryomodules, the system would require additional helium storage and SLAC would add four 110 cubic meter gaseous helium tanks, additional floor space, foundations, and tie-in piping. The LCLS-II-HE project would also require a modified interface box in the cryoplant building and a third distribution box in the klystron gallery at Sector 6. Here it would connect to distribution lines leading into the accelerator housing and cryomodules. The additional distribution lines would run parallel to the existing lines and would not require excavation in new areas. This system would balance the distribution of liquid helium evenly along the cryomodules. (SLAC 2016)

2.1.4 Pulsed Low-Energy Extraction Point

During construction of the LCLS-II, SLAC reconfigured accelerator equipment between Sectors 10 and 30, including a bypass line to transport the beam around an area used by other SLAC projects and east to the Beam Switchyard, east of Sector 30, and into a spreader that would transmit the beam to the LCLS UH and the soft X-ray (SXR) and hard X-ray (HXR) undulators.

The LCLS-II-HE would require additional modifications in this area, including an additional pulsed extraction line to transport the low-energy 3.6 GeV beam and reconfiguration of existing equipment and infrastructure. This extraction line would be installed by splitting the beam and the cryogenic helium supply along the (second) existing bypass line in a dogleg pattern using magnets. The beam would then be transported to the SXR undulator. (SLAC 2016)

2.1.5 Shielding

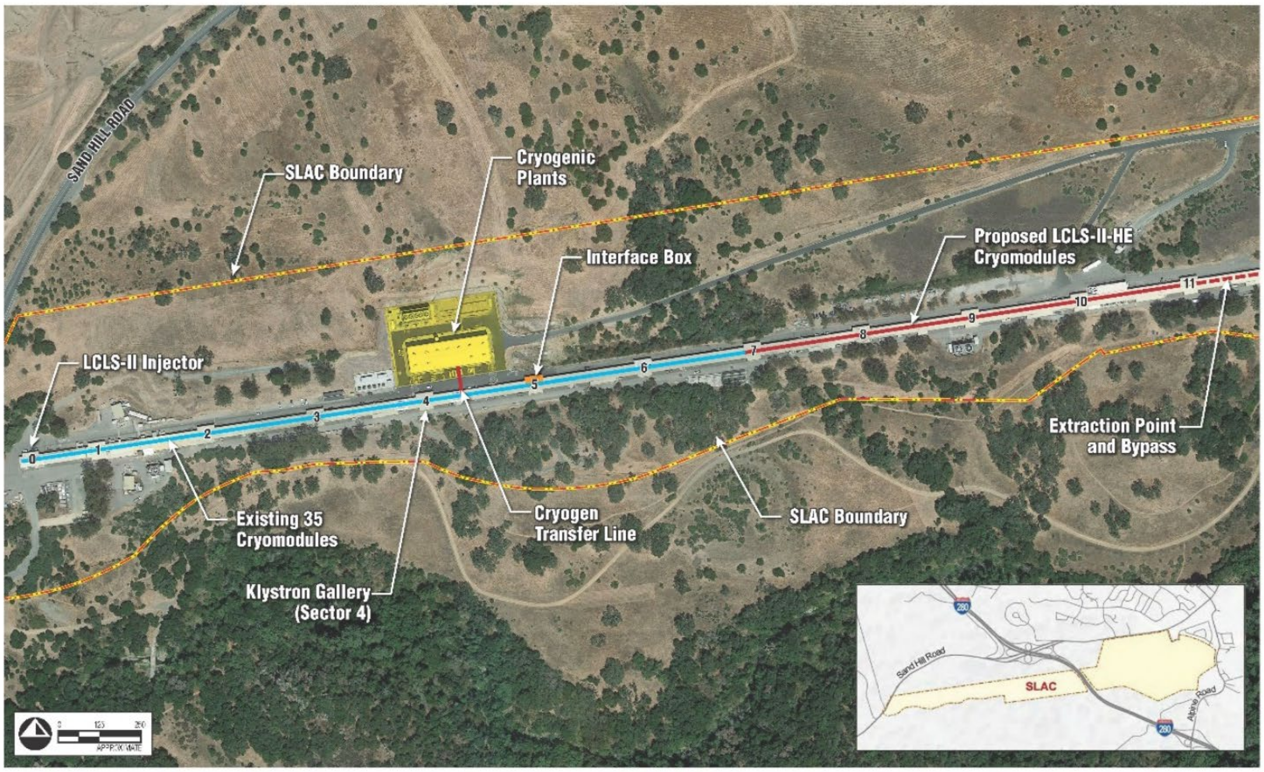
Because the Linac would operate at a higher power, the beam would generate an additional increment of ionizing radiation. Accordingly, SLAC would utilize shielding (preferred means) and safety interlocks to minimize worker and public exposure. The shielding would include concrete and local shielding, and/or personnel exclusion fencing.

2.1.6 Far Experimental Hall Modification

For the LCLS-II, SLAC made changes to the instrumentation in the experimental halls to ensure compatibility with the superconducting Linac and X-ray sources, including X-ray transport equipment, optics, and diagnostics. The LCLS-II-HE would intensify the beam into the hard X-ray range (5-20 keV); thus SLAC would need to revise its existing instruments, including 1) updating optics and data systems to be consistent with the higher energy beam and repetition rate, 2) relocating equipment to maximize the number of experimental stations and operational efficiency, and 3) installing new instruments consistent with increased capabilities. These changes would all occur within the FEH and would include modifying the FEH to accommodate an additional X-ray hutch.

The currently proposed LCLS-II-HE would not require new civil construction or capacity upgrades of the existing cryoplants or cooling tower. The existing cryoplants provide sufficient cooling capacity for the additional cryomodules and would not require upgrades. The existing cryomodules were designed using conservative assumptions and successful research and development has improved their efficiency such that no additional cryoplant capacity is needed. The existing cooling tower—installed for the LSLS-II—would have sufficient cooling capacity to accommodate LCLS-II-HE and no new cooling equipment or upgrades would be needed. **Figure 2-1** shows a conceptual layout of the LCLS-II-HE, including the location of the additional cryomodules, and the extraction point and bypass in the Linac. The FEH upgrades would all be located inside the existing FEH building (not shown).

Figure 2-1 Proposed LCLS-II-HE Layout



2.2 Operations

Operation of the LCLS-II-HE would not change substantially from existing LCLS operations and would be a continuation of the LCLS-II, which will begin operation in the early 2020s. SLAC would operate and maintain the superconducting Linac and cryogenic plants as described in the 2014 LCLS-II EA and 2015 SA. Whereas the LCLS-II adds 46 SLAC staff to operate the injector system, cryogenic plants, and beam delivery systems, the LCLS-II-HE would require only three additional staff but would substantially increase experimental capacity. Whereas the LCLS-II allows an additional 15 researchers, LCLS-II-HE's operational flexibility and additional FEH hutches would accommodate an additional six researchers. Fermilab and TJNAF involvement would continue through commissioning and operation, and as needed for cryomodule maintenance and repair.

LCLS-II startup will require 3 to 10 liquid helium deliveries for the startup volume of 6,800 gallons (approximately 4 tons), followed by 1 to 3 deliveries per year during operations. The LCLS-II-HE would operate with approximately 10,200 gallons (6 tons) of liquid helium. It would not require more deliveries for startup, but it would require one additional helium delivery per year for makeup volume. LCLS-II startup will require initial liquid nitrogen deliveries of 40,000 gallons (120 tons) for startup and 4 to 5 liquid nitrogen deliveries per week to deliver 10 tons per day for makeup volume. The liquid nitrogen inventory for the LCLS-II-HE would be unchanged, but the additional increment of cooling required of the cryoplants would consume an additional 10 tons per day. It therefore would require an additional 4 to 5 nitrogen deliveries per week for a total of 8 to 10 weekly deliveries for makeup volume for the combined LCLS-II and LCLS-II-HE projects.

SLAC would continue to operate and use hazardous materials as authorized by the state of California (California Health and Safety Code Section 25201.6), including such materials as solvents and fuels during construction, and cryogens and compressed gases, and disposal of radioactive components during operations. As applicable, SLAC would update its hazardous materials business plan and spill control plan as required under the California Accidental Release Prevention Program. The LCLS-II-HE would comply with federal environmental laws including the Occupational Safety and Health Act of 1970 and the Hazardous Materials Transportation Act. Furthermore, the LCLS-II-HE would comply with the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations and SLAC would continue to monitor and report (in its Annual Site Environmental Report) its releases of radionuclides to the ambient air. Emissions of radionuclides to the ambient air from SLAC would not result in effective dose equivalent to any member of the public in any year that would exceed the regulatory limit of 10 millirem/year (40 CFR Part 61).

LCLS-II-HE would not add substantially to risks related to air exposures. Further information regarding the on- and off-site doses and risks from radionuclides in air and other media is presented in Section 3.4, Health and Safety. Moreover, operation of LCLS-II-HE would comply with all the site's plans and environmental measures, as described in the 2014 EA, including the site-wide Storm Water Pollution Prevention Plan (SWPPP) (SLAC 2017b), SLAC's Site Sustainability Plan (SLAC 2018a), SLAC discharge permits, and SLAC's procedures for spill prevention, traffic control, health and safety, radiological safety, fire prevention, and waste management. It would also comply with Executive Order 13834, Efficient Federal Operations, which was signed in 2018 and affirms that federal agencies will operate in a manner that increases efficiency, optimizes performance, eliminates unnecessary use of resources, and protects the environment.

2.2.1 Power Usage

SLAC's power is generated and delivered by commercial power suppliers. SLAC also receives some power from the Bureau of Reclamation's Central Valley Project. The Western Area Power Administration serves as the purchasing agent for SLAC's power needs. SLAC currently has approximately 60 megawatts (MW) of power available from these sources and currently draws approximately 35-40 MW.

Whereas the LCLS typically uses 12 MW, the LCLS-II will draw an additional 13 MW to operate the superconducting Linac and cryogenic plant compressors. The LCLS-II-HE would draw an additional increment of 7 MW to operate the additional cryomodules and an additional increment of refrigeration and cooling.

2.2.2 Water Usage

Although the LCLS-II-HE would not require additional cooling capacity, dissipating the heat created by the additional cryomodules and the incremental increase in helium volume would require additional cooling. This would result in more water lost to evaporation from the existing cooling tower and would add to SLAC's daily water use. The LCLS-II superconducting Linac, with 37 additional cryomodules, will add approximately 120,000 gallons to SLAC's pre-LCLS-II daily water usage of 200,000 gallons per day. The LCLS-II-HE would add approximately 70,000 gallons to SLAC's daily water use. In addition, the LCLS-II-HE would add a small incremental volume to the cooling tower blowdown, which is discharged to the sewer system.

As for the LCLS-II, SLAC would continue to offset this additional water consumption to the extent practicable by designing and operating this and all SLAC facilities in a manner consistent with the SLAC Site Sustainability Plan. The plan is required by prior Executive and DOE Orders and contains goals to continually improve efficiency and reduce potable water consumption.

2.2.3 Staffing

The number of construction workers required for the LCLS-II-HE would be low compared to the LCLS-II, which required 40 workers to assemble the cryoplants and clear floor space in Sectors 0 through 10 of the Linac, which included extensive radiological surveys and demolition, dismantling, and removal of electrical equipment, water pipes, air handling equipment, fire control equipment, and lighting. Clearing Sector 11 would require a crew of approximately 10. Installation of LCLS-II-HE would require approximately 3 to 4 workers to unload and install the cryomodules and supporting equipment and to complete the installation of the additional hutches and replacement instruments in the experimental halls.

The proposed additional cryomodules and supporting facilities would require three additional SLAC operation and maintenance workers. However, the additional beamline capabilities and the additional experimental hutches in the FEH would accommodate approximately six additional researchers.

2.2.4 Schedule

Given that the LCLS-II-HE is primarily an extension of the superconducting Linac that is now being installed, the schedule is dominated by the procurement, design, fabrication, testing, installation, and commissioning of the additional cryomodules. The procurement and installation of the supporting components (e.g., cryogen distribution equipment, experimental hall instruments) would occur concurrently. The schedule would benefit from using the same supply chain used for the LCLS-II cryomodules, including early purchase of long lead-time specialized components, such as niobium sheet.

The design and fabrication of the cryomodules at TJNAF and Fermilab would occur from 2021 through 2023. Once the cryomodules arrive at SLAC, the installation would require approximately 4.5 to 6 months, or one week per cryomodule. Construction would be completed during weekday shifts of 10 hours per day. The work required at SLAC would be scheduled to minimize any impacts on the LCLS-II operational schedule, leading to a projected completion during 2025. The equipment would require a two-year commissioning process, followed by the first experiments in 2027.

2.2.5 Decommissioning

Decommissioning would not occur for decades into the future and would be completed pursuant to a decommissioning plan prepared to outline the SLAC and DOE policies and procedures in effect at the time. The additional cryomodules and supporting equipment would add to the volume of equipment that would require detailed radiological surveys and appropriate future disposal, which could require on-site storage, reuse, or final disposal. SLAC would continue to update and implement its ESH Manual and Radiological Control Manual to govern such decommissioning activities as monitoring by radiation safety professionals, disconnecting of the cryomodules, initial decontamination, storing components within Radioactive Material Areas, and/or packaging components for transport and disposal.

2.2.6 Cost

The cost of the approved LCLS-II project is $1045 million. The preliminary cost estimate for the LCLS-II-HE is $368 million (FY17 dollars) including design, equipment capital costs, installation, commissioning, and project management. The operating budget would account for additional power costs, maintenance of the additional cryomodules, consumables, replacement equipment parts, and staff to support additional researchers. The incremental operational cost represents a minor (5 percent) budget increase over the LCLS-II because the LCLS-II-HE would use many of the same staff.

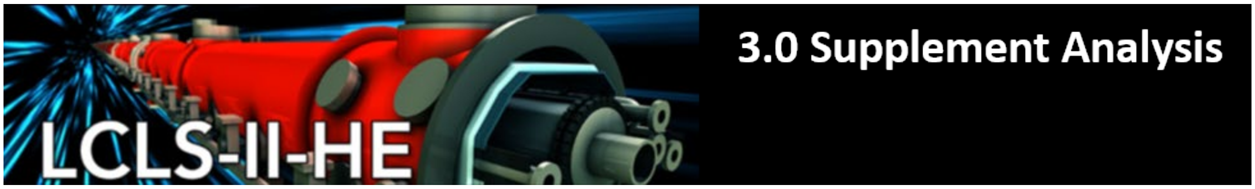
The following table summarizes the features of the LCLS, LCLS-II with and without the revised cryoplant design (evaluated in the 2015 SA), and LCLS-II-HE, and how the LCLS upgrades provide higher beam energy, particle acceleration, brightness, and coherence.

Table 2-1 Operational Parameters of LCLS, LCLS-II, and LCLS-II-HE

Operational Parameter	LCLS	LCLS-II	LCLS-II (revised cryoplant design)	LCLS-II-HE
Beam Energy gigaelectronvolts (GeV)	15 (Warm Cu)	3.3 to 4	3.3 to 4	8
Cryomodules	NA	37	37	63
Acceleration gradient (Megavolt/meter)	120	16	16	18.8
Repetition rate (temporal coherence)	120 Hz	Up to 1 MHz	Up to 1 MHz	Up to 1 MHz
Spectral range (brightness) (kiloelectronvolts [keV])	0.25 to 12.8	0.25 to 5	0.25 to 5	0.25 to 12.8-20
Helium inventory (gallons) *	NA	4,200	6,800	10,200
Helium deliveries (per year) *	NA	1 to 3	1 to 3	2 to 4
Nitrogen inventory (gallons) *	NA	20,000	40,000	40,000
Nitrogen deliveries (per week) *	NA	3 to 4	4 to 5	8 to 10
Undulator sources	1	2	2	2
Water use (gallons per day) *	117,000	193,500	237,000	307,000
Power use (megawatts [MW]) *	12	13	25	32
Project staff and research population	60 staff 40 researchers	100 staff 40 researchers	106 staff 55 researchers	109 staff 61 researchers
Hutch space	7 hutches	9 hutches	9 hutches	11 hutches
Opening date	2009	2020 (planned)	2020 (planned)	2026 (proposed)

Notes: Values for each parameter or component with an * are cumulative totals.
Total numbers of cryomodules include 37 for the LCLS-II and up to approximately 26 additional for the LCLS-II-HE to achieve the planned acceleration gradient.

Sources: DOE 2014; SLAC 2016



3.0 SUPPLEMENT ANALYSIS

This section describes the potential environmental impacts of the proposed LCLS-II-HE, including the removal of equipment in Sector 11 and the installation of an additional approximately 26 cryomodules to the Linac. It describes the potential incremental effects of the upgrade in view of the environmental analysis conducted in the 2014 EA and 2015 Supplement Analysis (SA). It then determines, per DOE's recommendations for conducting the Supplement Analysis (DOE 2019), whether the project's impacts are within the original scope and impact envelope considered in the 2014 EA, and whether further NEPA review is required. As described in the DOE guidance, the SA is not a substitute for any further NEPA review that might be required.

LCLS-II-HE would not require ground disturbance, such as grading or excavation. Construction would use existing entrances and access roads and would occur primarily within Sectors 7 through 11 of the klystron gallery and accelerator housing (Linac tunnel), and within the FEH located 2 miles to the east, closer to SLAC's main campus. Furthermore, construction would not require site preparation, paving, or landscaping. Therefore, the planned upgrade also would not create additional impervious surfaces and would not require additional stormwater drainage facilities.

Construction would be subject to the same standard environmental protection measures and minimization and avoidance measures described in the 2014 EA to reduce or eliminate potential minor adverse construction and operational impacts from dust, potential minor spills, noise, and waste disposal. Examples relevant to LCLS-II-HE include radiological protection programs and spill prevention and control, and compliance with site sustainable design policies, including selecting equipment that minimizes water use and maximizes energy efficiency.

As with the 2014 EA, this document does not describe potential implications for land use because the LCLS-II-HE would be within the boundaries of lands leased by DOE and would not require construction of off-site power, stormwater, wastewater, or other utilities. In addition, because the LCLS-II-HE would not require ground disturbance for grading or excavation, this SA also does not identify impacts on geology or soils.

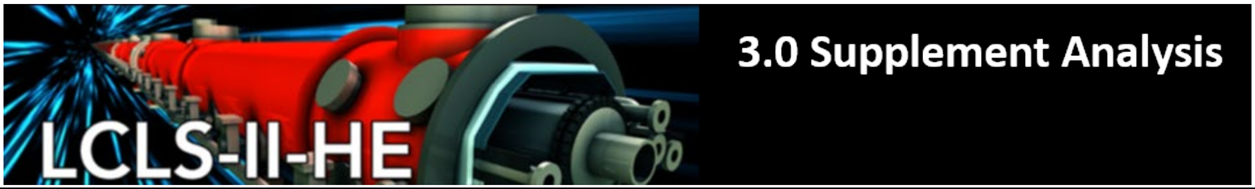
The following summarizes the areas examined for potential environmental impacts resulting from the removal of existing equipment in Sector 11, the addition of cryomodules and supporting equipment, and operating the LCLS-II at a higher energy. This will provide DOE with the information needed to determine whether the effects of the LCLS-II-HE project are within the original scope and impact envelope considered in the 2014 EA. This SA for the LCLS-II-HE identifies potential impacts on the following resources:

- Air Quality – increased air emissions, including greenhouse gases, from additional construction, radioactive air effluent, and higher energy use for operations.

- Biological Resources – potential impacts on wildlife adjacent to access roads and work areas.
- Cultural Resources – potential impacts of equipment installation on historic structures.
- Geology – potential impacts of the installation process on geology and soils.
- Health and Safety – added worker safety hazards from additional equipment removal and construction, increased worker radiation exposure from higher operational energy, and increased delivery and operating volumes of liquid helium and nitrogen.
- Hydrology and Water Quality – added water consumption from cooling tower evaporation and potential effects of increased radiation on groundwater quality.
- Noise and Vibration – extended construction noise impacts and higher equipment and delivery noise levels from operating at higher power.
- Socioeconomics and Environmental Justice – additional construction and operational workers, increased project expenditures for cryomodule fabrication and installation, and increased annual operating costs.
- Transportation – extended construction period for equipment removal and transport and installation of additional cryomodules, and transportation effects of additional SLAC workers, deliveries, and researchers.
- Visual Resources – visual effects of added equipment, including the cryogenic distribution box and transfer line.
- Waste Management – additional construction waste generation.

This SA also describes the potential cumulative impacts of the LCLS-II-HE when considered together with the recently completed construction and start-up operation of the LCLS-II, other SLAC facilities and activities, and other projects in the area.

This SA was completed without conducting additional air emissions, noise, or other modeling. Because the LCLS-II-HE primarily adds new equipment within existing buildings and the installation activities would be very similar to the LCLS-II, this SA relies on the results of calculations and modeling completed for the LCLS-II, which included very similar installation and will involve very similar operations. In some cases, the LCLS-II-HE involves identical activities over a longer time period. Rather than completing new modeling, this SA uses those data to describe the potential effects of the LCLS-II-HE by extrapolating from prior analyses. By using the results of prior modeling completed for the LCLS-II project, the impact description presented in this SA consistently overestimates environmental effects and is conservative.



The following subsections (3.1 through 3.12) present the impact evaluations for air quality, biological resources, cultural resources, geology and soils, health and safety, hydrology and water quality, noise and vibration, socioeconomics and environmental justice, transportation, visual resources, waste management, and cumulative effects.

3.1 Air Quality

The LCLS-II-HE, with installation of an additional approximately 26 cryomodules and supporting equipment, would have an incremental impact on air emissions. These components would require fabrication and installation and would require an increase in electrical power during operation. This section describes potential incremental impacts on air quality from emissions of criteria air pollutants during installation and operation. Because greenhouse gas (GHG) emissions would only have impacts when considered together with other emissions sources, GHGs are addressed in Section 3.12, “Cumulative Effects.”

Criteria pollutant emissions from the added LCLS-II-HE components were estimated based on the calculations completed for the 2014 EA. Emissions were evaluated for criteria pollutants for which the region does not comply with National Ambient Air Quality Standards (NAAQS) and State Ambient Air Quality Standards (SAAQS), where applicable (BAAQMD 2019). Area air quality is classified by the U.S. Environmental Protection Agency (EPA) as a nonattainment/marginal area for the 8-hour ozone standard and 24-hour fine particulates (particulate matter with a diameter of 2.5 microns or less [$PM_{2.5}$]) standard. For all other federal standards, the San Francisco Bay Area Air Basin (SFBAAB) is in attainment or unclassified. Based on the SAAQS, the SFBAAB currently is in nonattainment for both the 1-hour and 8-hour standards for ozone, particles with a diameter of 10 microns or less (PM_{10}), and $PM_{2.5}$. The EA also evaluated air pollutants for which SLAC has permit limits. Therefore, consistent with the 2014 EA and 2015 SA, the paragraphs below evaluate emissions of precursor organics (volatile organic compounds [VOC]), nitrous oxides (NOx), and particulate matter (PM_{10} and $PM_{2.5}$).

Installation - The 2014 EA used CalEEMod to calculate emissions, including installing cryomodules in the accelerator housing (see Section 3.4, Table 3-3, and Appendix A of the 2014 EA). **Table 3-1** shows the LCLS-II 2016–2018 construction emissions, as calculated in the 2014 EA and 2015 SA, and the estimated incremental emissions of the LCLS-II-HE from installing the additional cryomodules and supporting equipment. This SA assumes that for LCLS-II-HE cryomodule installation in 2025, emissions would be proportional to the installation work done for the LCLS-II. Because the LCLS-II-HE would install an additional approximately 26 cryomodules versus the 35 cryomodules evaluated in the 2014 EA for the LCLS-II, the upgrade would have approximately 74 percent[2] of the emissions of installing the 35 LCLS-II cryomodules (Table 3-4 of the 2014 EA, included in Appendix B, page B-1). During 2018 and into 2019, SLAC is installing 35 cryomodules and completing related work. The estimated emissions for

[2] Percentage based on the proportional relationship of 26 LCLS-II-HE cryomodules proposed for installation in 2025 to 35 LCLS-II cryomodules installed in 2018/2019.

installation were VOCs – 0.25 tons/year, NOx- 2.28 tons/year, PM_{10}-0.84 tons/year, and $PM_{2.5}$-0.48 tons/year. Each of these values was multiplied by 0.74 to estimate the incremental emissions for installing the LCLS-II-HE cryomodules. The results for projected 2025 emissions are presented below and compared with 1) general conformity *de minimis* levels for compliance with EPA's General Conformity Rule and for achieving federal standards, 2) overall SLAC emissions for 2017, and 3) SLAC's Synthetic Minor Operating Permit (SMOP) limits (BAAQMD 2018). Table 3-1 shows that emissions for the LCLS-II and LCLS-II-HE, and site-wide emissions, would be well below conformity levels and SMOP limits.

Table 3-1 LCLS-II and Incremental LCLS-II-HE Emissions from Installation of Additional Cryomodules and Supporting Equipment

Construction Activity/Year	Annual Emissions (tons per year)			
	VOCs	NO_x	PM_{10}	$PM_{2.5}$
LCLS-II				
Cryoplant construction (2016-2017)	1.31	16.26	2.14	1.38
Installation of 35 cryomodules (2018)	0.25	2.28	0.84	0.48
Reconfigured cryoplants (2016-2018)	0.44	5.29	0.85	0.53
Total LCLS-II Construction Emissions†	2.00	23.83	3.83	2.39
LCLS-II-HE				
Installation of 26 Additional Cryomodules (2025)[1]	0.18	1.68	0.62	0.36
Comparative Values				
de minimis Levels[2]	100	100	100	100
Overall 2017 SLAC Emissions[3]	3.84	3.23	<1	<1
SLAC's SMOP Limits[4]	35	35	95	95
Exceed *de minimis* Levels or SMOP Limits?	No	No	No	No

Notes:

† 2016 to 2018 total emissions include the original LCLS-II proposed action and cryogen plant reconfiguration. The total emissions values are from Table 3-1 of the 2015 Supplement Analysis. See Appendix B, page B-2.

1 2025 emissions include installation of additional cryomodules, supporting equipment, and FEH hutch and instruments. These emissions were estimated to be approximately 74 percent of LCLS-II 2018 emissions (see Appendix B, page B-1), which evaluated the impacts of installing 35 cryomodules in Sectors 1-7 of the accelerator housing.

2 EPA adopted the General Conformity Rule in November 1993 to implement the conformity provision of Title I, Section 176 (c)(1) of the federal Clean Air Act. EPA requires each state to prepare a State Implementation Plan (SIP). The *de minimis* levels for conformity of each criteria pollutant in nonattainment are 100 tons per year.

3 Overall 2017 SLAC emissions – these values do not include LCLS-II-HE emissions.

4 SLAC SMOP emission limits include 35 tons per year (tpy) for precursor organic compounds (POC), 35 tpy for NOx, an overall limit of 95 tpy for each of the other criteria air pollutants (carbon monoxide (CO), PM_{10}, and SO_2). Hazardous air pollutants (HAP) are limited to 9 tpy for an individual and 23 tpy for total HAPs.

Sources: DOE 2014, DOE 2015, and BAAQMD 2018

Fabrication of components at TJNAF and Fermilab would be consistent with prior fabrication work for the LCLS-II and ongoing operations at those facilities. The work would be conducted within existing buildings, laboratories, and machine shops that are routinely used to fabricate, clean, and test prototype equipment as well as manufacture components for use at DOE national laboratories and research facilities. Therefore, fabrication of components at these sites would not result in a substantial incremental increase in emissions beyond those already generated by those facilities.

Operations - The 2014 EA (see Section 3.4, Table 3-4, and Appendix A of the 2014 EA) and 2015 SA also estimated operational emissions, including from energy consumption, water use, and vehicle trips for additional employees. **Table 3-2** presents the current estimated annual operations emissions for the LCLS-II and the estimated incremental increase in emissions from LCLS-II-HE. The incremental increase was estimated using a conservative method similar to that described above for construction and assumed that the added emissions would be derived from the incremental increase in energy consumption required to operate the additional cryomodules and to cool an incrementally larger operational volume of helium. The installation of an additional approximately 26 cryomodules would increase LCLS energy demand by 9.6 MW, an approximate 74 percent increase over the 13 MW increase for the LCLS-II. Therefore, for future operations, this SA assumed that energy production emissions would increase by 74 percent above the additional 13 MW for the LCLS-II (see Table 3-5 in the 2014 EA). This SA also assumes that emissions from additional SLAC employee commutes, researcher commutes, and helium/nitrogen deliveries, would be the same as the LCLS-II. In this way, it assumes an increase equal to the larger LCLS-II and therefore this estimate is conservative and would account for the very small emissions related to installing other equipment. **Table 3-2** shows that with the increase in energy demand and operational vehicle trips, SLAC's operational emissions still would be well below its SMOP limits and conformity levels for each pollutant.

This information shows that the small incremental increases in criteria pollutant emissions from installation of the LCLS-II-HE would be within the original scope and impact envelope considered in the 2014 EA. As described in the EA and 2015 SA, SLAC is taking a number of steps to reduce emissions, as outlined in detail in the Site Sustainability Plan. These include encouraging employees to use public transportation, upgrading site lighting systems, completing energy audits on existing buildings and implementing upgrades, and employing energy efficiency measures across the operation, including installing a "power saving mode" in energy-intensive equipment, including the site's accelerators.

The proposed LCLS-II-HE would also be required to comply with NESHAP regulations, which include standards for radioactivity emissions. Operations would not increase halogenated cleaning solvent use. As described in SLAC's Annual Site Environmental Report (SLAC 2017a), SLAC operations result in releases of airborne radionuclides to air. Beam operation would result in the formation of radioisotopes in the air within the accelerator housing. These would include radionuclides of carbon, nitrogen, oxygen, and argon, all of which have short half-lives. To minimize releases into the ambient air, and consistent with existing accelerator operations, SLAC would use the existing air control system to regulate ventilation. The housing would be sealed as much as practicable to reduce air exchange rates and allows for radioactive decay inside the accelerator housing prior to air release. It also minimizes worker exposure by preventing air flow to work areas and requiring ventilation before workers enter the accelerator housing.

Table 3-2 LCLS-II and Incremental LCLS-II-HE Emissions from Operation of Additional Cryomodules and Supporting Equipment

Operational Emissions Source	Annual Emissions (tons per year)			
	VOCs	NO_x	PM_{10}	$PM_{2.5}$
LCLS-II				
Area	0.305	0.000	0.000	0.000
Energy consumption	0.004	0.034	0.003	0.003
Motor vehicles	0.005	0.010	0.009	0.003
Increased energy consumption from reconfigured power plants	0.0064	0.0544	0.0048	0.0048
Emissions from increased motor vehicle trips (2015 SA)	0.005	0.01	0.009	0.003
Total LCLS-II Operational Emissions (2015 SA) †	0.33	0.11	0.03	0.01
LCLS-II-HE				
Increased emissions from energy consumption (74 percent)[1]	0.003	0.025	0.002	0.002
Increased emissions from increased vehicle trips)[2]	0.005	0.01	0.009	0.003
Comparative Values				
de minimis Levels[3]	100	100	100	100
Overall 2017 SLAC Emissions[4]	3.84	3.23	<1	<1
SLAC's SMOP Limits[5]	35	35	95	95
Exceed *de minimis* Levels or SMOP Limits?	No	No	No	No

Notes:

† Proposed action emissions including reconfigured cryogenic plants (2014 EA and 2015 SA). See Table 3-2 of the 2015 Supplement Analysis in Appendix B, Page B-3.

1 Incremental increase in annual operational emissions from energy consumption for the LCLS-II-HE. See Table 3-5 of the 2014 EA.

2 Emissions from transportation. See Table 3-2 of the 2015 Supplement Analysis in Appendix B, Page B-3.

3 EPA adopted the General Conformity Rule in November 1993 to implement the conformity provision of Title I, Section 176 (c)(1) of the federal Clean Air Act. EPA requires each state to prepare a State Implementation Plan (SIP). The *de minimis* levels for conformity of each criteria pollutant in nonattainment are 100 tons per year.

4 Overall 2017 SLAC emissions – these values do not include LCLS-II-HE emissions.

5 SLAC SMOP emission limits include 35 tons per year (tpy) for precursor organic compounds (POC), 35 tpy for NOx, an overall limit of 95 tpy for each of the other criteria air pollutants (carbon monoxide (CO), PM_{10}, and SO_2). Hazardous air pollutants (HAP) are limited to 9 tpy for an individual and 23 tpy for total HAPs.

Sources: DOE 2014, DOE 2015, BAAQMD 2018

The public dose from the estimated radioactivity releases in a year to the ambient air from SLAC is well below the regulatory limit of 10 mrem/year (40 CFR Part 61) (see Section 3.4). The dose from each air release point at SLAC is also lower than the EPA's limit of 0.1 mrem/year, above which a continuous air monitoring system is required for the release point. The higher operating energy of the Linac would have the potential to emit higher skyshine radiation (ionizing radiation scattered in the atmosphere above an accelerator facility). However, as described above, SLAC would use shielding to limit skyshine radiation, which would remain well below regulatory and SLAC limits. Further information regarding the on- and off-site doses and risks from radionuclides in air and other media is presented in Section 3.4, Health and Safety.

3.2 Biological Resources

The potential biological effects of the LCLS-II project were evaluated in the 2014 EA (see Section 3.5 of the 2014 EA), including vegetation and special-status species in downgradient aquatic habitat. In contrast, the LCLS-II-HE would not require ground disturbance such as grading or excavation and therefore would not directly affect wildlife habitat in the adjacent grasslands or in San Francisquito Creek. Installation would use existing access roads and the work would primarily occur within existing structures, such as the accelerator housing and klystron gallery. Equipment would be installed in the paved area between the cryogen plants and the Linac and equipment delivery trucks would use the existing entrance and access roads. Wildlife species in these areas include birds, bats, snakes, lizards, and small mammals that are adapted to human activity. During construction of the LCLS-II, nesting birds have been observed in some areas which required monitoring and in one case, establishment of a temporary buffer zone, which is in accordance with the requirements outlined in the 2014 EA. To minimize impacts, SLAC would continue to implement these avoidance measures during LCLS-II-HE construction. Therefore, any biological effects of the LCLS-II-HE are within the original scope and impact envelope considered in the 2014 EA.

Fabrication of LCLS-II-HE components at TJNAF and Fermilab would be conducted within existing buildings currently used to fabricate research equipment and would not require excavation or grading for new buildings or access roads that could disturb biological resources. Therefore, any incremental effects from fabrication of components for the LCLS-II-HE on biological resources at those locations would be within the original scope and impact envelope considered in the 2014 EA.

3.3 Cultural Resources

The LCLS-II-HE would not require ground disturbance and there would be no impacts on archaeological or paleontological resources. However, the LCLS-II-HE would require making several changes within the accelerator housing and klystron gallery. The accelerator housing is a concrete tunnel and the klystron gallery walls consist of metal cladding. The 2014 EA (see Section 3.6 and Appendix B of the 2014 EA) showed that the minor changes to the accelerator housing and the klystron gallery needed for the LCLS-II were consistent with the designed use of those buildings (Page and Turnbull 2014) and the State Historic Preservation Officer concurred that the LCLS-II would not adversely affect historic properties.

The proposed LCLS-II-HE would involve making more of the same types of changes. Beyond the changes to the accelerator equipment within the buildings (i.e., adding cryomodules, removing existing ductwork and shielding), the LCLS-II-HE would require a new cryogen transfer line, adding a third cryogenic distribution box to the cryogenic distribution system at Sector 6, and the addition of a third cupola on the klystron gallery building. These changes would require new utility connections to the new cryomodules that would be constructed in existing underground areas and would not affect the surrounding structures. However, the new cryogen line and installing a new cupola to provide additional ventilation would require new penetrations (i.e., cutting openings) into the klystron gallery. Therefore, SLAC and DOE have consulted with the Site Office regarding the previous Section 106 consultation and have determined that no additional consultation is required and that the proposed changes are within the original scope and impact envelope considered in the 2014 EA.

Fabrication of LCLS-II components at TJNAF and Fermilab would be conducted within existing buildings currently used to fabricate research equipment and would not require excavation or grading for new buildings or access roads that could disturb buried cultural or historical resources, or demolition or alteration of historic structures. Therefore, any incremental effects from fabrication of LCLS-II components on cultural resources at those locations would be within the original scope and impact envelope considered in the 2014 EA.

3.4 Geology and Soils

The potential effects of the LCLS-II project on geology and soils were evaluated in the 2014 EA (see Section 3.7 of the 2014 EA), including the impacts of foundation excavation and seismic activity. In contrast, the LCLS-II-HE would not require grading, excavation, trenching, or other ground disturbance because the footprint of the project would be unchanged. Therefore, the LCLS-II-HE is within the original scope and impact envelope considered in the 2014 EA.

3.5 Health and Safety

The environmental impacts of the LCLS-II were evaluated in the 2014 EA (see Section 3.8 of the 2014 EA). This section describes how the proposed LCLS-II-HE project could result in increased human health risks and safety hazards. Construction, including fabrication and installation of the additional cryomodules and supporting equipment, would result in additional occupational safety hazards, potentially resulting in industrial injuries. Operating at the higher energy levels provided by LCLS-II-HE would result in higher levels of ionizing radiation, potentially resulting in incrementally higher radiation doses and risks for workers and off-site receptors. In addition, the increased operational cryogen volume and helium and nitrogen deliveries could increase the risk of spills.

The proposed LCLS-II-HE components would be similar to those installed for the LCLS-II and would not introduce any new types of work hazards. The added work would be evaluated under SLAC's Work Planning and Control program, which is a formal process for identifying and mitigating risks to workers, the public, and the environment. The program addresses both construction and operations and would evaluate LCLS-II-HE's higher energy and needed controls (see Radiological Risk below).

The LCLS-II-HE would benefit from detailed health and safety evaluations completed by SLAC for the LCLS-II and documented in the LCLS-II Hazards Analysis Report prepared during construction, installation, testing, and routine operation of the cryogenic plants and cryogenic modules (SLAC 2015). The report would serve as a checklist during design, installation, and operation of the higher-energy Linac to ensure incorporation of safe procedures and "lessons learned."

This section identifies the incremental safety hazards and health risks of the LCLS-II-HE and highlights how these hazards and risks would be minimized by existing engineering controls, and existing safety and environmental health management programs at SLAC, TJNAF, and Fermilab.

3.5.1 Occupational Safety

The proposed LCLS-II-HE installation would involve the fabrication and installation of cryomodules and supporting equipment. These types of activities and related hazards are well known at SLAC and across the DOE complex. The occupational hazards would be nearly identical to those encountered for the LCLS-II, as described in Section 3.8 of the 2014 EA, and would include heavy equipment, high voltage, dust, fumes, and equipment noise. For example, some workers would remove existing hardware (magnets and vacuum chambers). Other workers would use heavy equipment in the accelerator housing to unload and install the additional cryomodules. Other crews would install the cryogenic distribution system and would work in the accelerator housing to install the extraction point and magnets. These activities would pose a risk of injury from moving heavy equipment and would produce low quantities of waste.

As for industrial work in general, work at SLAC results in some occupational injuries. Workplace injuries and illnesses are tracked by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), which requires employers to report recordable injuries. The Bureau of Labor Statistics maintains injury and illness statistics for the construction industry. Under OSHA regulations (29 CFR 1904), a work-related injury is "recordable" if it results in death; days away from work, restricted work, or transfer to another job; medical treatment beyond first aid; or loss of consciousness. Injuries or illnesses that require a hospital visit or prescription medication are tracked as Total Recordable Cases (TRCs). The rate is based on 100 employees working full-time for 1 year and is "normalized" for different size employers by taking the number of recordable cases divided by the hours worked and then multiplying the result by 200,000 (100 employees working 40 hours per week for 50 weeks). If an injury prevents an employee from performing any or all of his or her duties and the employee must be assigned "light duty" or cannot work at all, the injury is classified as a Days Away, Restricted, or Transferred (DART) case. DART cases are a subset of the TRCs.

Construction injuries resulting from the LCLS-II-HE would not be substantially different in nature or occurrence than from the LCLS-II. The 2014 EA estimated the potential workplace injuries from construction of the LCLS-II. Given a construction workforce of 20 over 3 years (120,000 worker hours) and SLAC's TRC and DART rates for 2013 (1.4 and 0.7, respectively), the EA predicted the LCLS-II would result in 0.84 recordable injuries and 0.4 DART cases. For the LCLS-II-HE, with an average construction workforce of 4 over 3 additional years and 60,000 additional worker hours and considering SLAC's most recent TRC and DART rates for 2018 (1.21 and 0.89, respectively; Weibel 2019), there could be an additional 0.15 recordable injuries and 0.11 DART cases. SLAC's injury rates are substantially lower than the injury rates for the U.S. as a whole, which were 2.8 and 1.5 for TRC and DART for 2017, respectively (Bureau of Labor Statistics 2018).

Operation of the accelerator with the LCLS-II-HE would be nearly identical to the LCLS-II and would result in the same types of operational hazards including fire, electric shock, hazardous materials exposure, and other routine workplace hazards. LCLS-II operations, before and after the LCLS-II-HE, involve cryogenic hazards, including "burns" from inadvertent contact, pressure hazards from over-pressurized systems, and the potential for oxygen-deficient atmospheres in the event of an indoor leak from the cryogenic systems.

Occupational injuries resulting from LCLS-II-HE operations would not be substantially different in nature or occurrence than the LCLS-II. The 2014 EA and 2015 SA estimated the potential workplace injuries from construction of the LCLS-II. Given an operational workforce of six over 20 years (240,000 worker hours), plus the additional operational labor to operate the cryoplants and a new cooling tower (DOE 2015), and considering SLAC's TRC and DART rates for 2013 (1.4 and 0.7, respectively), the prior analyses predicted the LCLS-II would result in 2.4 recordable injuries and 1.2 DART cases. Table 3.3 summarizes prior workplace injury predictions for the LCLS-II and the potential incremental injuries for the LCLS-II-HE. With an average workforce of 3 over 20 years and 120,000 additional operational worker hours, the LCLS-II-HE would result in an additional predicted 0.7 recordable injuries and 0.5 DART cases. As for construction, LCLS-II-HE values are based on SLAC's 2018 TRC and DART rates (Weibel 2019), which are substantially lower than the U.S. as a whole. The incremental increase in injuries—on the order of a single event—are within the original scope and impact envelope considered in the 2014 EA.

Table 3-3 Proposed Action Potential Workplace Injuries for Operation of the LCLS-II and the Incremental Cases for LCLS-II-HE

Health and Safety Evaluation	Added Full-time Operational Staff	Worker Hours over 20 Years of Operation	Total Recordable	DART cases
LCLS-II*	9	360,000	2.4	1.2
LCLS-II-HE**	3	120,000	0.7	0.5

* LCLS-II Total Recordable Cases (TRC) and Days Away, Restricted, or Transferred (DART) were based on SLAC data for 2013

** LCLS-II-HE TRC and DART cases based on SLAC data for 2018 (Weibel 2019)

To minimize occupational hazards, SLAC has a well-developed safety program to protect workers and the public. SLAC has integrated safety into its management and work practices at all levels, including for construction contractors, by developing and implementing an Integrated Safety and Environmental Management System. SLAC (and all DOE sites, including partner labs) is required to establish a Worker Safety and Health Program (WSHP) in accordance with 10 CFR 851 to reduce or prevent the potential for injuries, illnesses, and accidents. The SLAC WSHP manual (SLAC 2018b) applies to all non-radiological safety and health issues associated with design, construction, operation, maintenance, decontamination and decommissioning, research and development, and restoration activities at SLAC.

The LCLS-II-HE would be evaluated and planned so that control processes can be implemented to identify and address hazards before work is authorized. SLAC obtains input from on-site experts (e.g., construction safety, industrial hygiene, accelerator operations) and safety officers (e.g., electrical) to ensure that designs comply with applicable code and hazards are mitigated. Health and safety programs are overseen by SLAC's Security and Emergency Management Department, Fire Marshal, Emergency Response Team, and Site Security. Occupational safety at TJNAF and Fermilab would be addressed by existing programs at those sites, including procedures for machining of parts, laboratory operations, clean rooms, and fire protection.

3.5.2 Radiation Risks

Radiation risks to the public and environment for an accelerator facility include: 1) potential doses to the public from direct radiation and radioactive air effluent, and 2) potential radioactivity introduced to the groundwater outside the accelerator housing, and 3) potential radioactivity added to the cooling water that is discharged as wastewater to the sanitary sewer. The risk levels depend on the electron beam energy and average power and the shielding around beam loss points.

The LCLS-II beam has higher energy than the LCLS beam, and the LCLS-II-HE beam energy would be approximately twice that of the LCLS-II baseline. The beams have similar energy at GeV levels, thus the unmitigated risk would mainly depend on average beam power. The average beam power of LCLS-II is near 100 kW, which is much higher than the average power of the LCLS. Therefore, to reduce the LCLS-II radiation risk to be comparable with LCLS and to stay below regulatory and SLAC limits, the LCLS-II facility requires more significant shielding and other beam loss controls (mainly through intensive concrete housing, local shielding, and beam/radiation interlocks). The average beam power of LCLS-II-HE will be twice that of LCLS-II; however, with shielding and other controls, the incremental radiation risk would only be slightly higher than the LCLS-II, which will be managed using existing mitigation techniques.

3.5.2.1 Overview of SLAC Radiation Safety Programs

In addition to the extensive engineering controls outlined above, radiation generated by the beam, including from the LCLS-II and LCLS-II-HE, would be managed under SLAC's robust radiation safety programs, as described in the following paragraphs.

Radiation exposure is managed under SLAC's Radiological Protection Program (SLAC 2018c) to keep worker and public doses as measured in a common unit of rem. For smaller doses, such as those that occur at SLAC, the unit millirem (mrem) is used. The biological effects of radiation depend on radiation type and energy level, the portion of the body exposed, and the duration of exposure. Dose limits for radiation workers are established by the DOE in 10 CFR 835, "Occupational Radiation Protection" (DOE 2011). Although the limits vary depending on the affected part of the body, the annual dose limit for the whole body is 5,000 mrem (5 rem) for occupational workers (10 CFR 835.202).

The SLAC Radiation Protection Department (RPD) is responsible for the radiation safety and radiological programs that protect the workers, the general public, and the environment. The RPD includes five technical groups: Radiation Physics Group, Dosimetry and Radiological Environmental Protection (DREP) Group, Field Operations Group, Radioactive Waste Management Group, and Laser Safety Group. The Radiation Physics Group provides support for safety analysis and control, which includes shielding calculations, radiation safety system design, and oversight for the safe operation of the accelerator. The DREP Group provides dosimetry services and radiological monitoring. The Field Operations Group oversees radiological workplace monitoring, management of radioactive materials and sources, training, radiological control, and work support. The Radioactive Waste Management Group is responsible for radioactive waste management at SLAC such as low-level radioactive waste disposal. The Laser Safety Group develops and implements SLAC's Laser Safety Program.

Radiological hazards are also addressed through SLAC's Radiological Control Manual (SLAC 2018d), which complies with DOE regulations for occupational radiation protection (10 CFR 835). Radiation safety systems are based on the protocol described in the Radiation Safety System – Technical Basis Document (RSS-TBD) (SLAC 2010). Radiation protection for the existing facilities, such as the LCLS, is provided primarily by concrete shielding walls. Design criteria for radiation shielding at SLAC are based on controlling individual doses from external radiation sources to no more than 1,000 mrem total effective dose per year for radiological workers (or 100 mrem/y for users) and kept "as low as reasonably achievable" (ALARA) (SLAC 2010). The existing concrete walls of the LCLS BTH are approximately 6 feet thick. The existing EBD hall is equipped with a specially designed radiation shielding maze. Special beam loss locations are equipped with local shielding that conforms to the SLAC's Radiological Control Manual (SLAC 2018d) and RSS-TBD (SLAC 2010) guidelines and requirements.

SLAC assesses and submits annual reports on airborne radioactivity as required by its policies and by state or federal regulations. SLAC uses EPA-approved software (CAP88-PC) to estimate dose to public based on conservative estimates of radioactive isotopes in air (e.g., argon [^{41}Ar], nitrogen [^{13}N], oxygen [^{15}O], and carbon [^{11}C]). EPA regulations (40 CFR 61, Subpart H) enacted under the Clean Air Act and DOE Order 458.1 "Radiation Protection of the Public and the Environment" require SLAC to demonstrate that airborne radionuclide emissions do not result in annual doses to the public greater than 10 mrem. For SLAC operations over the last several years, the public dose from radioactive air emission was well below the limit. For example, in 2017, the maximally exposed individual (MEI) dose was 1.4 x10^{-3} mrem (SLAC 2017a).

Radiation that escapes to the environment is minimized by facility design (i.e., underground construction, beam containment, shielding); however, photons and neutrons that escape the accelerator and strike soil or water may create radionuclides in soil or water. Most of these isotopes have short half-lives (minutes or hours) and would decay quickly when the operation stops; however, a few radionuclides have long half-lives and are of interest for environmental protection. For example, the ^{3}H (tritium) with a half-life of 12.3 years is of main interest for groundwater impact analysis and protection.

SLAC also monitors radioactivity in industrial wastewater, stormwater, and groundwater. Federal (10 CFR 20.2003) and state (17 CCR 30253) regulations set limits on radioactivity discharged to industrial wastewater. The annual limit for discharge to the sanitary sewer is 5 Ci for tritium. For SLAC operations over the last few years, the activity released to the sewer was no more than 5 x 10^{-4} Ci (0.0005 Ci) of tritium or 0.01 percent of the applicable annual limit (SLAC 2017a). No radioactivity other than naturally occurring background was detected in stormwater or sediment samples (SLAC 2017a).

Based on the results of groundwater monitoring of more than 100 groundwater wells under SLAC's Groundwater Self-Monitoring Program, low levels of tritium from historical operations were detected in wells near the Beam Dump East and Plating Shop. For the past few years, tritium values ranged from nondetectable (i.e., below SLAC detection limits of 500 picoCuries per liter [pCi/L]) to a maximum quarterly average tritium value of less than 4,000 pCi/L (SLAC 2019b). However, this maximum radioactivity (tritium) was still well below the federal and state drinking water standards of 20,000 pCi/L (40 CFR 141.66 and 22 CCR 64443). In addition, groundwater is not used at SLAC as a source of drinking water because of insufficient quantity and naturally high concentrations of total dissolved solids; thus, no personnel exposure pathway occurs.

Federal regulations and DOE orders require SLAC to demonstrate that the public does not receive an annual radiation dose of greater than 100 mrem from all exposure pathways. DOE standards limiting radiological doses to members of the public (not occupational workers) are addressed in 10 CFR 835 and DOE Order 458.1 (DOE 2013). Public doses at SLAC from skyshine radiation are estimated by measuring site boundary radiation doses at more than 40 locations using sensitive photon and neutron environmental dosimeters. As in several past years, the dose received by the public from SLAC operations is well below regulatory limits of 100 mrem/y. For the past few years, the annual skyshine doses have been well below the SLAC shielding design limit of 10 mrem/y. For instance, in 2017, the maximum dose that could be received off-site from skyshine radiation (see discussion regarding MEI below) was 0.03 mrem (0.03 percent of the 100 mrem regulatory limit) (SLAC 2017a).

Worker (and public) exposures can also occur from radiation doses from naturally occurring and man-made sources. The average member of the U.S. population receives a total dose of ionizing radiation of about 0.624 rem (624 mrem) per year (NCRP 2009) from sources such as terrestrial and cosmic radiation and from medical, commercial, and industrial activity. About half of the total annual average U.S. individual's radiation exposure comes from natural sources. For example, in 2017, the maximum public dose of 0.031 mrem from SLAC operations is well below background exposures (SLAC 2017a).

Exposures to low levels of ionizing radiation may result in an increase in latent cancer fatalities (LCFs) in the exposed population. Because the primary health concern with radiation is latent cancers, DOE uses a dose-to-risk conversion factor to estimate potential radiation impacts. The number of radiation-induced LCFs is estimated by multiplying the dose (person-rem) by health risk conversion factors (DOE 2004). These factors relate the radiation dose to the potential number of expected LCFs based on comprehensive studies of people historically exposed to large doses of radiation, such as survivors of atomic weapon detonations during World War II. The factor most commonly used in recent assessments is 0.0004 LCF per person-rem of exposure for workers and for members of the public (NCRP 2009). Based on a dose-to-risk conversion factor of 0.0004 fatal cancers per person-rem and the collective dose (0.025 person-rem in CY2017) for the population of 5 million within approximately 50 miles of SLAC, the estimated probability of an additional fatal cancer induced by SLAC radiation is 1×10^{-5} per year (about 1 in 100,000 or 50 in 5 million people). For comparison, an individual's natural lifetime risk of fatal cancer in the U.S. population is about 0.2 (two in 10 or 1.06 million in 5 million people) (American Cancer Society 2013).

Existing exposures of biological resources to ionizing radiation are below exposure standards. DOE risk assessment methods state that exposure of plants and animals should not exceed 1 rad[3] per day for aquatic receptors and terrestrial plants and 0.1 rad (absorbed dose) per day for terrestrial animals (DOE 2002). Monitoring conducted for 12 months in 2017 at 600 on-site locations found average doses of less than 0.0005 rad per day (SLAC 2017a). Because many of the monitoring locations were inside shielding facilities (i.e., concrete walls), SLAC found that any exposure of plants and animals outside the shielding would be well below DOE standards.

SLAC prepared conservative radiation dose estimates and risks to the MEI and the surrounding population within 50 miles (approximately 5 million persons) for 2017 operations. The estimates are based on exposure to direct radiation (or skyshine) and radioactive air releases. **Table 3-4** presents the results.

[3] Absorbed ionizing radiation dose equivalent to an energy absorption per unit mass of 0.01 joule per kilogram of irradiated material.

Table 3-4 SLAC Radiation Dose Estimates and Associated Risks Based on CY2017 Estimates

Pathway	MEI Dose (rem per year)	Population Dose (person-rem per year)	MEI Lifetime Risk for 30 years of Operation	Population Dose Lifetime Risk for 30 years of Operation
Direct	0.00003 (3.0E-05)	0.023 (2.3E-02)	0.36/1,000,000 (3.6E-07)	240/1,000,000 (2.4E-04)
Air	0.00000135 (1.35E-06)	0.002 (2.0E-03)	0.016/1,000,000 (1.6E-08)	24/1,000,000 (2.4E-05)
Total	**0.000031 (3.1E-05)**	**0.025 (2.5E-02)**	**0.37/1,000,000 (3.7E-07)**	**300/1,000,000 (3.0E-04)**

Notes:
Dose values are presented as decimal values (e.g., 0.03) and in scientific notation (e.g., 3.0E-02)
Source: SLAC 2017a. The average risk for the U.S. population of 4×10^{-4} per rem (NCRP 2009) was used in these calculations.

Based on 2017 operations, the potential doses are well below the DOE and SLAC limits. The lifetime dose risk to the MEI from 30 years of SLAC operation would be about 0.37 in 1 million (3.7×10^{-07}). The lifetime dose risk to the MEI from LCLS-II-HE operation would be managed to be the same level. For comparison, the natural lifetime risk of fatal cancer in the U.S. population is about 0.2 (2 in 10). All of the risk values in the above table are significantly lower than this reference value by many orders of magnitude.

3.5.2.2 LCLS-II-HE Radiological Risk

The objective of the LCLS-II-HE is to produce a beam with higher energy and beam power, which would inherently result in ionizing radiation and risks to workers and the public. These risks are managed across the SLAC campus, where high-energy research facilities have been operated since the 1960s. These risks are greatly reduced by engineering controls implemented for each experimental facility, including building enclosures (e.g., accelerator housing), dense shielding, radiation protection procedures, and the distance of the experimental facilities from the public and the SLAC main campus. Any radiation risks from the LCLS-II-HE would result in incremental impacts beyond those already present from the existing LCLS-II facilities.

During installation, workers would enter the accelerator housing and klystron gallery and would be exposed to induced radiation from beamline components. As workers dismantle and remove components, SLAC health physicists would minimize radiological exposures through monitoring and preventative measures such as dust control. Similarly, as workers place and align the cryomodules and supporting equipment, SLAC health physicists would minimize radiological exposures through monitoring and preventative measures following ALARA principles. In addition, SLAC RPD would support the LCLS-II-HE by conducting surveys and ensuring that activated material is surveyed, labeled, and moved to an appropriate on-site storage location or prepared for off-site disposal. Radiological wastes would be managed in compliance with DOE Order 435.1 (DOE 1999) and the SLAC RPD radioactive waste program.

Prior to operation, the LCLS-II-HE would be required to comply with DOE-Order 420.2.c – Safety of Accelerator Facilities. SLAC would be required to perform an Accelerator Readiness Review and Equipment Readiness Review to ensure that the higher power Linac is adequately prepared for safe commissioning and operations. The order establishes accelerator-specific safety requirements and approval authorities which, when supplemented by other applicable safety and health requirements, promote safe operations to ensure DOE that protection of workers, the public, and the environment is adequately addressed.

As described in the 2014 EA, the LCLS-II superconducting accelerator will produce a substantial increase in beam power and incremental radiation risks beyond what was present for the LCLS, which has been operating since 2009. However, DOE determined that these risks would be mitigated by more engineering controls and SLAC's radiological safety programs. The LCLS-II-HE would potentially increase radiation exposure for workers exposed to beam radiation within the accelerator housing and the potential for radiation from the more powerful beam to penetrate the accelerator shielding.

To minimize radiation exposure from LCLS-II-HE's increased beam power, SLAC would primarily rely on local shielding on various expected chronic loss points, such as some halo collimators and some Linac penetrations, which is similar to the LCLS-II. The existing concrete walls of the LCLS BTH are approximately 6 feet thick, which would be augmented for the LCLS-II by a personnel exclusion zone. In addition, local shielding at potential beam loss points, and/or interlocked beam loss monitors are used for the LCLS-II. Similar mitigation and controls would be used for the LCLS-II-HE. The added experimental hutch in the FEH would have a Hutch Protection System; an access control system that would prevent personnel from entering the hutch when prompt radiation could be present.

To achieve the increased beam energy, more cryomodules operated at a higher acceleration gradient are needed for the LCLS-II-HE, which would lead to an increase in radiation. Air activation would increase as would activation of the cryomodules and nearby components. Depending on the magnitude of the increase, these components would require longer cool-down times and other radiation protection measures before workers access the Linac.

Other safety systems are integrated into the overall radiation safety system, such as burn-through monitors and interlocked radiation detectors, called beam shutoff ion chambers. This is a well-established program that can effectively accommodate the proposed cryomodule additions and has been utilized for the present LCLS-II design. Exposure to beam radiation would also be minimized by the SLAC beam containment system. For the LCLS-II-HE, the existing beam containment system would be augmented as needed with additional collimators in some new beamline segments and the existing beam dumps to steer and contain the beam to limit losses that result in radiation exposure. These engineering controls would be similar to SLAC's current operations and would be consistent with the requirements specified in 10 CFR 835 and the accelerator-specific safety requirements as set by DOE Order 420.2C, Safety of Accelerator Facilities.

SLAC would shield the LCLS-II and LCLS-II-HE electron beam enclosures to maintain the annual dose below 1 rem/y (0.5 mrem/h for 2,000 hours occupancy) in accessible areas of the accelerator and research yard and less than 0.1 rem/y (0.05 mrem/h for 2,000 hours occupancy) for other areas of SLAC where users or the public may access. Personnel would not be expected to incur radiation exposure above the SLAC limits. The effective dose for personnel, including users working inside and around the experimental halls, would not exceed 100 mrem per year. The maximum exposure to a radiological worker from LCLS-II-HE operations would be well below the SLAC administrative control level of 0.5 rem in 1 year and the SLAC dose-management “ALARA Level” of 360 mrem/year. The average annual dose to an individual worker would not exceed 0.1 rem. Thus, the radiation exposure from LCLS-II-HE would adhere to the same limits as the LCLS-II. For reference, between 2008 and 2018, the average dose (mrem/y per individual) to the approximately 40 SLAC radiological workers who have received doses from work was less than 0.04 rem per year, much lower than the DOE dose limit of 5 rem for radiological workers. The number of radiation-induced fatal cancers in the potentially exposed SLAC population (conservatively assumed to be 50 individuals and that each worker would receive 0.1 rem per year) over an operating period of 30 years[4] is approximately 0.06 (using a cancer risk of 0.0004 per rem), with a 90 percent confidence interval ranging from 0.02 to 0.14. In comparison, the cumulative number of naturally occurring cancer deaths expected in the same population (50) would be about 10.

SLAC closely limits and monitors public exposure to radiation including direct prompt radiation dose and exposure to airborne radioisotopes. SLAC also monitors groundwater and wastewater discharges. Because LCLS-II-HE would produce a higher energy beam, these exposure pathways could result in incrementally higher risks. However, during LCLS-II-HE operations, public exposures would be maintained ALARA by continued radiological safety protocols and compliance with DOE Order 458.1, which imposes an annual dose limit for members of the public to the MEI of 100 mrem/year from all exposure pathways.

The LCLS-II-HE could increase skyshine radiation, which may emanate from the accelerator housing and klystron gallery. However, SLAC would continue to comply with its shielding design guideline for skyshine radiation of 10 mrem/y to the MEI from all facilities and 5 mrem/y from any single facility. Because existing LCLS facilities are heavily shielded, the maximum dose to the MEI is several orders of magnitude below these regulatory limits. For instance, in 2017, the maximum dose to the public was 0.031 mrem/y (SLAC 2017a). To reduce skyshine, SLAC would design the LCLS-II-HE with additional shielding and would relocate components to areas with lower beam losses. In addition, SLAC would continue to monitor skyshine using passive environmental dosimeters and the active site boundary Perimeter Monitoring Stations.

4 The LCLS-II would have a planned operational lifetime of 20 years. The risk assessment assumed 30 years of operation as a conservative assumption.

The higher beam power of the LCLS-II-HE would also result in a slightly higher increment of radioactive air that would be released through ventilation, due to the cryomodule operation at Sectors 0-10. The annual regulatory dose limit for the MEI from air exposure is 10 mrem/y, and a continuous air effluent monitoring system is required for each single release point that would exceed 0.1 mrem/y. SLAC uses the EPA-approved code CAP88-PC to calculate the MEI and collective annual doses to the population up to 80 km from SLAC. For CY2017, the maximum calculated off-site public dose from airborne radioactivity associated with SLAC was 1.35×10^{-3} mrem, or 0.01 percent of the 10 mrem regulatory limit (SLAC 2017a). The CY2017 MEI dose primarily resulted from LCLS operation and is 7,400 times lower than the 10 mrem/y limit and 75 times lower than the 0.1 mrem/y threshold. Because the LCLS-II-HE would be outfitted with additional local shielding as needed, SLAC expects that the maximum off-site public dose would be similar to current conditions.

The LCLS-II-HE would be designed to minimize wastewater and stormwater discharges. Potential wastewater discharges include cooling water replacement and discharge as well as water originating within the accelerator housing. Wastewater is collected at sumps and pumped to holding tanks outside the accelerator housing. SLAC would continue to manage storage, radiological monitoring and analysis, and discharge of wastewater with radioisotopes into the sanitary sewer to meet the discharge limits of the site’s Silicon Valley Clean Water wastewater permit.

Normal beam loss has the potential to activate soil and groundwater near beam loss points, and the LCLS-II-HE would have an incrementally higher potential to expose these media to radiation. The primary radioisotope of concern is tritium ^{3}H (12.3-year half-life) because it readily leaches from soil to water. Therefore, SLAC would design the beam dumps with adequate shielding to minimize groundwater activations. Existing monitoring wells and new wells required for the LCLS-II’s higher-power operation would be used to monitor the LCLS-II-HE.

Fabrication of LCLS-II-HE components at TJNAF and Fermilab would not generate radiation; however, both of these locations have test facilities that would be used to test and condition the cryomodules and this process would produce radiation. Both TJNAF and Fermilab have well-established radiological protection programs that would maintain exposure at below DOE limits.

In summary, radiation exposure from LCLS-II-HE would be very similar to the exposure from the LCLS-II, as described in Section 3.8 of the 2014 EA. SLAC would continue to reduce exposure through existing management systems, work planning and control processes, and compliance with regulatory requirements. The SLAC Radiological Control Manual specifies an administrative control level of 500 mrem total effective dose per year and a dose-management “ALARA Level” of a maximum of 360 mrem total effective dose per year above natural background levels for radiological workers. The actual dose received by most SLAC personnel is well below these levels. For several past years, no SLAC employee received more than 40 mrem/y (SLAC 2019a). This would continue for LCLS-II-HE operations based on the use of radiation safety systems (including physical shielding) and existing radiological safety programs. For these reasons, the incremental radiation risks from the higher power LCLS-II-HE beam would be within the original scope and impact envelope considered in the 2014 EA.

3.5.2.3 LCLS-II Cryogenic Hazards

The LCLS-II-HE would add to the overall cryogen volume and the frequency of deliveries of liquid helium and nitrogen. The new cryomodules would add to the inventory of liquid helium, and in turn, the increased cooling required to create cryogenic helium would require an increase in liquid nitrogen deliveries.

Potential hazards to workers in indoor working areas could include an oxygen deficiency hazard (ODH). This condition would result from an indoor (e.g., within the klystron gallery) spill of liquid helium that could displace enough air to cause injury or death. SLAC's preliminary ODH analysis indicated that the accelerator housing and klystron gallery should be assigned an ODH Level 1 classification, which would require engineering and administrative controls. The LCLS-II-HE would require an additional operational review and evaluation of the need for enhanced monitoring, refuge areas for workers, and ventilation. In addition, the oxygen deficiency monitoring system planned for the LCLS-II may be expanded to accommodate the extended Linac.

An outdoor cryogen spill scenario could occur during a liquid helium or nitrogen delivery and could affect workers and visitors. For the LCLS-II, SLAC evaluated the potential effects of a spill during delivery or the mechanical failure of a valve resulting in a release from a tank or pipeline. Liquid helium has a liquid-to-gas expansion ratio of 780 and is far lighter than air with a specific density of 0.14 (air has a density of 1). Liquid nitrogen has a liquid-to-gas expansion ratio of 696 but a much higher specific density of 0.97. Because its density is similar to air, liquid nitrogen would not disperse as quickly as helium and would cause a more persistent ODH.

To evaluate potential impacts of an outdoor release, SLAC and DOE's 2014 EA used the Areal Locations of Hazardous Atmospheres (ALOHA) air dispersion model (EPA and National Atmospheric Administration 2007). The resulting air concentrations were compared with air concentration criteria from DOE's Protective Action Criteria database (DOE 2012b). For liquid helium, the model assumed a reasonable worst-case release of 100 percent of the 4,200-gallon helium inventory within 2 minutes and stable atmospheric conditions (low wind). For liquid nitrogen, the modeled scenario was a spill at the delivery dock by a truck using a 4-inch diameter hose and a spill rate of 120 gpm.

The modeling results showed that the spills would dissipate within a short distance of the source of the spill. The 2014 EA demonstrated that the low density of helium and the transient nature of a plume of either helium or nitrogen would greatly reduce the effects of a spill. The ALOHA modeling showed that either material would dissipate in the air almost as quickly as it was released in the accident scenarios evaluated in the 2014 EA—via a broken pipe or faulty valve—and would affect only a small area potentially occupied by workers and would have no effect on off-site areas. A liquid helium spill would only present life-threatening conditions within approximately 33 feet and would have no serious adverse health effects beyond 154 feet, and a liquid nitrogen spill would have no serious adverse health effects beyond 36 feet. SLAC completed additional modeling for the 2015 SA when the helium inventory was increased to approximately 6,800 gallons. The distances at which harmful effects could occur were not substantially different (33 to 137 feet) and demonstrated that the impact area of a helium spill would not be sensitive to the released volume. These results are consistent with the properties of helium, which has a very low molecular weight, rises very quickly, and is quickly diluted in the atmosphere.

Because the LCLS-II-HE would only increase the helium inventory by 3,400 gallons and would not require substantial changes in the pressure in the system or pipe sizes, it would not substantially change the characteristics of a release, including the size of the affected area.

For liquid nitrogen, the LCLS-II-HE would not increase the nitrogen inventory and there would be no changes in the equipment or methods used to deliver the material. Therefore, in the event of an accidental release, the rate of release would be the same and the size of the affected area would not change substantially. The only incremental change would be that nitrogen deliveries would be required more often to maintain the liquid nitrogen supply for the two larger plants. However, as described above for liquid helium, each delivery would be covered by SLAC’s cryogen-related standard operating procedure, facility designs, and building codes.

As was completed for the LCLS-II, SLAC would complete a review of cryogenic hazards through the hazard analysis process defined in SLAC’s ESH Manual chapter titled *Cryogenic and Oxygen Deficiency Hazard Safety* (2018b). This process would evaluate any additional protective measures required for an ODH and any additional engineering controls needed for piping, valves, and other devices. The LCLS-II-HE project would not generate new hazards that have not already been identified and addressed at SLAC or across the DOE complex. The potential hazards of cryogen handling would be mitigated by established policies and procedures. Furthermore, the cryoplants are in a remote location and the number of operational workers at any given time would be small. Moreover, SLAC workers have extensive experience with cryogens and manage SLAC’s existing inventories of liquid nitrogen, helium, and carbon dioxide, and no further protective measures are required beyond SLAC’s existing engineering and facility designs, applicable codes and standards, and cryogen-related standard operating procedure. Thus, the cryogen hazards from the LCLS-II-HE are within the original scope and impact envelope considered in the 2014 EA.

3.5.3 Accidents and Intentional Destructive Acts

Construction and operation of the LCLS-II-HE would be very similar to the construction and operation of the existing LCLS/LCLS-II and would not increase the probability of an accident or make the area more prone to damage from an intentional act. The existing LCLS-II could potentially result in hazards such as non-routine accidents, fires, hazardous materials releases, and natural disasters such as earthquakes. These types of events are addressed by the safety and response programs and plans currently in place at SLAC. With continued compliance with design guidelines and implementation of the existing SLAC safety programs, no major reasonably foreseeable accident scenario is likely to result from the installation of additional cryomodules, such as a major fire. Installation would not require the use or transport of large volumes of hazardous or radioactive materials; therefore, there would be minimal incremental risk of intentional destructive acts associated with these types of materials.

The LCLS-II-HE would increase power and would incrementally increase potential exposure to higher radiation doses from irradiated components. However, as with the LCLS-II, any irradiated components would be within the accelerator housing and klystron gallery. Any intentional destructive act would be deterred by site security and would have little effect on surrounding residential areas because any fuel and material storage would be located away from nearby roads and neighborhoods. Therefore, intentional destructive acts would carry a low but uncertain probability and limited consequences because of the isolated nature of the construction activity.

By increasing beam power from existing LCLS capabilities to those proposed for the LCLS II, beam operation could result in an increase in the consequences of an incident, with greater damage to equipment and induced radiation. Such an event would only occur in the event the beam is not properly aligned. Although improbable, this could result in component heating and damage, and in a maximum reasonably foreseeable accident the equipment would be destroyed and removing the equipment would result in higher radiation exposure of workers involved in isolating and replacing the damaged equipment. Many of the components are very heavy and handling them would result in additional risk of injury. Component replacement would be a source of exposure to activated components; however, this would be managed under the SLAC Radiation Work Permit (RWP) Process.

However, the LCLS-II-HE's higher beam power would not increase the potential for a beam-steering accident. A range of steps are built into the process to minimize beam loss and component activation and damage. The LCLS-II-HE would be designed to avoid beam misdirection. Abnormal beam conditions would be evaluated in the design of radiation safety systems, including active monitoring systems that would shield and detect a beam that is misdirected by incorrectly powered magnets. Furthermore, monitors would protect against beams of excessive power. For added radiation protection, SLAC would design the LCLS-II-HE such that the effective dose for the maximum credible incident would not exceed 25 rem/h, and such that the integrated effective dose would not exceed 3 rem. The maximum credible incident considers the unlikely scenario of failure of safety systems and is defined as the highest beam power that the accelerator can deliver to a point, limited by hardware or credited beam power controls. Therefore, the risk of damage from an intentionally destructive act would be reduced using the same measures used for the LCLS-II and the risk is within the original scope and impact envelope considered in the 2014 EA.

3.5.4 Wildfire Risk

The LCLS-II project increased the risk of a potential wildfire and Section 3.8 of 2014 EA outlined several avoidance measures. In contrast, the LCLS-II-HE would not substantially increase the risk of wildfire. Whereas the previous upgrade of reconfiguring the cryoplants involved outdoor work in the grassy area north of the Linac, the LCLS-II-HE would transport the new components directly to indoor working spaces inside the accelerator housing. Outdoor work would be limited and would include only the installation of additional cryogen distribution equipment. In this case, SLAC would use established procedures to minimize the chance of a wildfire, including established procedures regarding parking on dry vegetation. For any exterior work during the wildfire season (typically beginning in April and continuing through about October), grass fire risk would be minimized by requiring that any grass near work areas be cut to ground level. In addition, contractors would be required to follow all construction fire safety precautions contained in OSHA, the California Fire Code, and the National Fire Protection Act 241, "Standard for Safeguarding Construction, Alteration and Demolition Operations." Furthermore, any ignition sources would be controlled. Smoking would be limited to designated areas, and any hot work would be conducted in compliance with the SLAC hot work permit program. Exterior hot work would be prohibited on hot, dry, windy days, designated by the state of California as red flag days. For these reasons, the incremental risk of wildfire would be within the original scope and impact envelope considered in the 2014 EA.

3.6 Hydrology and Water Quality

Potential environmental impacts on hydrology and water quality would be nearly identical to those described in the 2014 EA (see Section 3.9 of the 2014 EA). The LCLS-II-HE would be installed within the footprint of the Linac, cryogenic plants, and cooling tower. Therefore, the volume of runoff and the peak rate of runoff from the site would be the same as that described in the 2014 EA and 2015 SA, and no incremental effect on San Francisquito Creek, Bear Creek, or their tributaries would occur.

For the same reasons, potential impacts on water quality would not change substantially from those described in the 2014 EA. Stormwater runoff during construction would be addressed by a project-specific Erosion and Sedimentation Control Plan with associated stormwater best management practices, and SLAC would comply with its site-wide Industrial Stormwater Permit and SWPPP. Because construction would not require ground disturbance, SLAC would not be required to obtain a separate Stormwater Construction Permit. Truck deliveries and workers would continue to use site roadways to access the work site; however, those impacts would continue to be addressed by stormwater best management practices and would not contribute substantially to impacts on downstream water quality.

The increased cooling water flow and subsequent additional cooling tower blowdown water would be discharged to the sewer system, as is cooling water from all other SLAC facilities. The extended superconducting Linac would require additional cooling and an additional increment of cooling water would be lost to evaporation. The additional flow and evaporation would add 70,000 gallons per day to SLAC's daily water use of 320,000 gallons per day (with LCLS-II). SLAC would continue to offset this additional water consumption to the extent practicable by designing and operating LCLS-II-HE in a manner consistent with the SLAC Site Sustainability Plan (SLAC 2018a). SLAC has also reduced landscape irrigation, repaired plumbing leaks, and converted lawns to water-efficient landscaping. One current project is the reconstruction of low-conductivity water facilities that provide process cooling water with more efficient heat exchangers. In the coming years, SLAC is planning to upgrade its underground cooling water laterals. This project will reduce potential leaks in piping along the Linac that could increase makeup water usage. In addition, SLAC plans to replace older cooling towers with modular towers that will reduce water use.

The objective of LCLS-II-HE would be a higher operating power, which would have the potential for an incremental increase in beam loss from the Linac and impacts on water quality, including formation of tritium in soil and water. However, as described above, SLAC would evaluate the Linac and beam dumps for potential beam loss and install additional heavy concrete, lead, and steel shielding to reduce the potential for residual activity in the soil and groundwater below the dump enclosure. The potential for soil activation would be minimal and limited to a localized area immediately around the beam dump shielding. SLAC would evaluate potential activation of groundwater and would design a monitoring well network and shielding to ensure that impacts on soil would be ALARA and that tritium concentrations in groundwater would be below detection limits.

By employing the same avoidance and minimization measures as the LCLS-II, including stormwater controls, water-saving measures, and shielding and monitoring to protect groundwater, any incremental effects of the LCLS-II-HE on water quality would be within the original scope and impact envelope considered in the 2014 EA.

3.7 Noise and Vibration

The LCLS-II-HE would have the potential to increase noise in 2025 when the cryomodules are installed by increasing truck deliveries and worker traffic. The added installation work would be nearly identical to the installation work described in the 2014 EA and would not result in increased noise (see Section 3.10 of the 2014 EA). It could also result in a small incremental increase in operational noise from added equipment. The added cryogenic equipment might result in a minor noise increase near Sectors 7 through 11 that would only be audible to workers in the immediate area. These changes would not result in any appreciable incremental increase in noise above the existing cryoplants and no noise increase would be detectable at the site boundary.

As described in the 2014 EA, Sector 4 is located in an isolated area on the western end of the SLAC campus, and the previous noise evaluation (see Section 3.10 of the 2014 EA) showed that any receptors at SLAC (more than a mile to the east) or in residential or commercial areas to the north, east, or south of SLAC would not be affected. Furthermore, any noise receptors at the west end of SLAC near Sand Hill Road and Whiskey Hill Road are exposed to substantial ambient noise from traffic, which were measured in the field for the 2014 EA and ranged from 46.2 to 67.5 dBA L_{eq} (DOE 2015). Moreover, SLAC would design the LCLS-II-HE and its operating procedure to minimize noise, such as selecting quieter equipment or adding enclosures. As described in the 2014 EA, any increase in equipment vibration from the LCLS-II would not be perceptible. Because the LCLS-II-HE would add the same types of static equipment (cryomodules, waveguides, solid state amplifiers etc.) and because of the substantial distance to sensitive receptors, there would be no vibration effects. For these reasons, any incremental noise and vibration effects from the LCLS-II-HE would be within the original scope and impact envelope considered in the 2014 EA.

3.8 Socioeconomics and Environmental Justice

The 2014 EA described the existing population, ethnicity, employment, income, housing, and the local economy near SLAC and evaluated the potential socioeconomic and environmental justice impacts of the proposed action, including the potential for adverse human health or environmental impacts that could disproportionately affect a minority or low-income population (see Section 3.11 of the 2014 EA). The analysis showed that the area around SLAC is less diverse than the surrounding area, and that the area is relatively affluent in terms of income, home prices, and employment opportunities, with no identified low-income populations in the area.

In this setting, the small increment of additional workers and expenditures required to install the additional cryomodules and supporting equipment would have no impact on employment and would not require in-migration of workers that would affect the population or housing market. Any changes in operational impacts and the total increased operating budget would be inconsequential and would be related only to a small increase in employment for meeting maintenance requirements and from a marginally higher expenditure for the added increment of liquid helium and nitrogen to supply the superconducting accelerator with cryogen.

Therefore, any socioeconomic or environmental justice impacts of the installation and operation of the LCLS-II-HE would be within the original scope and impact envelope considered in the 2014 EA.

3.9 Transportation

The LCLS-II-HE would result in an increase in truck and worker traffic on local roads near SLAC; however, as described in the 2014 EA (see Section 3.12 of the 2014 EA), traffic on local roads (i.e., Sand Hill Road and Alpine Road) ranges from approximately 14,000 to 19,000 trips per day. The previous project change (reconfiguration of the cryoplants) required a minor increase in daily truck traffic from 20 to 25 trucks, with no increase in construction workers. The LCLS-II-HE would require a brief peak in worker vehicles (10) and truck trips (20) during removal of equipment from Sector 11 and a longer-term incremental increase of an average of three to four worker vehicles and one truck. Considering SLAC's research population and the daily variability of construction traffic, this temporary increase in vehicle traffic would be negligible. Traffic impacts during operation of the LCLS-II-HE would be minor. The additional equipment would employ three additional SLAC staff and the added beam and FEH capacity would accommodate six additional researchers. Nitrogen deliveries would add four to five truck trips per week. This level of increase in operational traffic is within the normal variability in traffic arriving at SLAC, including from facility shutdowns.

Therefore, because of the small, temporary increase in traffic during installation, and the small incremental increase in operational deliveries and workers, any related impacts would be within the original scope and impact envelope considered in the 2014 EA.

Likewise, the LCLS-II-HE would result in only a minor incremental increase in accidents from construction vehicles. In the 2014 EA, based on California statistics (CHP 2014), the calculated number of potential project traffic injuries was 0.5 and the number of traffic fatalities was close to zero. This was based on 40 workers driving 25 miles round-trip for a year, and 1,000 truck trips traveling one 35-mile round-trip each, resulting in a peak of 36,000 vehicle miles traveled. Because equipment removal would occur over a brief period of weeks and the installation of the additional cryomodules and supporting equipment would require only three to four workers and one truck for on-site trips, the incremental increase in accidents would be negligible. Furthermore, project truck drivers would be required to comply with SLAC's traffic safety policy. For construction, this policy requires signage and/or flashing lights, traffic cones, and flaggers to direct trucks where visibility is obstructed. Trucks would be required to adhere to on- and off-site speed limits. Traffic management would be incorporated into the construction contract. Cryomodule installation would not require the transport of substantial volumes of hazardous materials or any radioactive materials or wastes.

Similarly, the operational traffic would be low and any incremental impacts from vehicle accidents would be minor. The 2014 EA estimated that 6 SLAC employees and 15 additional researchers would drive approximately 1,950,000 vehicle miles over the 20-year project life. Based on CHP-published accident rates (CHP 2014), the EA estimated one injury and zero fatalities. Because operation of LCLS-II-HE would add only three SLAC staff and six researchers, any incremental increase in traffic accidents would be less than one single event and this would be within the original scope and impact envelope considered in the 2014 EA.

To minimize traffic impacts, the construction contractor and SLAC would follow the traffic management plan established for the LCLS-II. Construction vehicles and workers would be required to enter SLAC via Alpine Road or, in special circumstances, the western entrance of Sand Hill Road. To minimize traffic delays resulting from vehicles turning left from either entrance, the traffic control plan outlines constraints on making left turns against oncoming traffic. The traffic control plan also establishes project-specific traffic management measures such as arrival and departure times. Construction traffic typically occurs outside the normal commute peak periods. Heavy haul deliveries of the cryomodules would arrive after 9 a.m. and depart after 7 p.m. With implementation of these measures, SLAC would minimize off-site construction traffic impacts.

Any added traffic at the component fabrication sites would be negligible as there would be no construction (e.g., excavation, building construction) at these sites. The fabrication work would be completed by existing staff, and truck deliveries of materials would be consistent with the existing frequency of deliveries. This work would be completed at active machine shops, laboratories, and clean rooms at these locations. Because the work would be completed by existing staff, there would be no incremental increase in traffic volume or accidents and any transportation impacts would be within the original scope and impact envelope considered in the 2014 EA.

For project operation, the increased heat load and cooling requirements would increase nitrogen deliveries by approximately one per day. Based on the area traffic numbers described in the 2014 EA, and the low number of miles that would be driven for one additional delivery per day and three workers, any related traffic and potential injury impacts would be within the original scope and impact envelope considered in the 2014 EA and no additional quantitative analysis is required.

3.10 Visual Resources

The visual impacts of the LCLS-II were evaluated in Section 3.13 of the 2014 EA and included the cryoplants. The visual impacts of the LCLS-II-HE would be limited to the small alterations of the klystron gallery, including the new cupola. The klystron gallery is visible from Interstate 280 and SLAC facilities have been present in the area since the 1960s. The construction of the LCLS-II cryoplants and cooling tower was visible from limited vantage points on Interstate 280 and Sand Hill Road, although those views were distant and only visible to motorists and commuters with low sensitivity to transient views of SLAC facilities.

The LCLS-II-HE project would require additional workers and component and cryogen deliveries. The incremental increase in truck traffic would be limited to transporting removed equipment and the cryomodules and other components. Likewise, the removal of equipment and the delivery and installation of the additional cryomodules would be centered on Sectors 10 and 11 of the Linac, which are located in a topographical depression that would limit views of any installation activity. The additional cupola on the klystron gallery would be nearly identical to the structure’s two existing cupolas and would have very limited visibility from off-site areas.

Equipment removal would be staged in an existing paved area adjacent to the Linac; however, any views of the areas adjacent to the Linac or between the cryoplants and the klystron gallery from adjacent roadways are obscured by the intervening landscape. Furthermore, the increased cooling requirement would not substantially increase the size of the steam plume, which dissipates rapidly at low elevations. There would be no additional lighting, and thus no incremental effects on nighttime views. Moreover, the proposed modifications to the FEH, including the additional experimental hutch and upgraded equipment, would occur indoors and would not be visible from off-site.

Overall, the visual impacts of the LCLS-II-HE would be limited to several months of arriving delivery trucks. Installation work at Sectors 7 through 11 of the Linac would be obscured by intervening topography, trees, and buildings such that the work would not be visible from off-site. Therefore, any incremental visual impacts of the LCLS-II-HE would be within the original scope and impact envelope considered in the 2014 EA.

3.11 Waste Management

LCLS-II-HE would have only a minor incremental effect on waste volumes and the impacts would be nearly identical to those described in the 2014 EA (see Section 3.14 of the 2014 EA). The construction of the LCLS-II, including the removal of outdated equipment from the Linac and construction of the cryogenic plant foundation, generated substantial waste volumes. This included 542 tons of metals, including 200 tons removed from the klystron gallery, and 71 tons of electronic waste and universal waste combined. The cryoplant foundation and drainage improvements produced 16,000 cubic yards of excavated soil for on-site relocation. Much of this material was used on-site as clean fill near Linac Sector 16. In addition, SLAC successfully disposed of 185 tons of radioactive and mixed wastes from the Sectors 0–10 equipment removal and the beam switchyard in support of the LCLS II project construction. (SLAC 2017a).

In comparison, the LCLS-II-HE would generate a far smaller waste volume. With no excavation or grading, there would be no excavated soils. Removal of existing equipment from Sector 11 of the Linac would generate approximately 1,500 additional cy of equipment and utilities for recycling and approximately 80 cy of radioactive waste (e.g., copper and aluminum components). Construction would generate a minor additional increment of construction waste (e.g., waste paint, fuels, rags) and a small additional increment of solid waste, such as packaging, which would be handled by existing SLAC waste management programs and would be recycled to the extent practicable.

Any material removed from within the accelerator housing would be surveyed for residual radioactivity, labeled, and held on-site for disposal evaluation, in accordance with procedures established in the SLAC Radiological Protection Program (SLAC 2018c). Radioactive material with an identified future use may be stored indoors or on covered and properly controlled and maintained areas on-site (SLAC 2014c). Newly generated radioactive waste may be stored for up to 18 months or longer with DOE approval in compliance with the SLAC Radioactive Waste Manual (SLAC 2006), and mixed wastes must be disposed of within 90 days. Speculative accumulation is not consistent with DOE life cycle planning requirements. SLAC would handle and dispose of all wastes in accordance with SLAC procedures.

Any impacts from increased waste would be addressed by existing SLAC programs. The Chemical and Waste Management Department consists of the Chemical Management Group and Waste Management Group. The Chemical Management Group addresses the chemical life cycle from transportation, procurement, use, storage, and inventory management. This group also manages the Hazardous Material Reduction Plan. The Waste Management Group coordinates and manages off-site disposal of regulated and hazardous wastes and develops hazardous waste minimization plans.

SLAC established a goal of diverting at least 50 percent of non-hazardous solid waste by 2017 through new programs such as the Zero Waste Program. For example, in the most recent year for which data are available, SLAC diverted 89 percent of its construction and demolition debris and 76 percent of its municipal solid waste. Approximately 75 percent of SLAC's staff now work in buildings that are participating in the program. SLAC met the 2017 target with a 72 percent diversion rate. Similarly, the construction and demolition waste diversion goals were exceeded, with an 89 percent diversion rate for FY 2017 (SLAC 2017a).

The LCLS-II-HE would not affect other aspects of construction or operation and would not result in additional radioactive wastes. Any additional increment of waste generation at the fabrication sites would be managed at those locations. Similarly, any additional increment of wastes generated for operation of the additional cryomodules would be addressed by existing regulations and SLAC's existing policies and programs for safe handling, storage, and transport of hazardous materials, as described in detail in the 2014 EA. For these reasons, any impacts of the LCLS-II-HE on waste management would be within the original scope and impact envelope considered in the 2014 EA.

3.12 Cumulative Effects

This section identifies potential cumulative impacts of the LCLS-II-HE and whether additional impact analysis is required. It focuses on the project changes related to the additional equipment removal, installation of additional cryomodules, additional cryogen deliveries, and higher operating power. It identifies potential incremental cumulative effects of the LCLS-II-HE in light of other SLAC activities and other projects in the region. Current construction activity at SLAC is moderate and primarily consists of office construction and roadway maintenance. Other projects in the region include residential and commercial construction, including on the Stanford University campus. Other projects include research and development space, hospital facilities, electricity generation and transmission facilities, and wetland restoration.

For resources on which the LCLS-II-HE would have no effect, and in the case of component fabrication at distant sites and within existing buildings, cumulative impacts would not be relevant. Therefore, this section does not identify cumulative effects on biological resources, cultural resources, land use, geology and soils, and socioeconomics and environmental justice, and visual effects.

According to CEQ regulations for implementing NEPA (40 CFR Section 1508.7), an action may cause cumulative impacts on the environment if its impacts overlap in space and/or time with the impacts of other past, present, or reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place through time.

Sections 3.12.1 through 3.12.7 identify the potential for cumulative effects on air quality, health and safety, hydrology and water quality, noise, traffic, visual resources, and waste management.

3.12.1 Air Quality

The LCLS-II-HE would result in small incremental emissions of criteria pollutants that would be below permit limits. Other projects at SLAC, Stanford University, and throughout the region would contribute to regional emissions. As demonstrated in Section 3.15.1 of the 2014 EA and in the 2015 SA, LCLS-II emissions will be a small fraction of regional emissions. Therefore, any impacts of the LCLS-II-HE on regional air quality would be within the original scope and impact envelope considered in the 2014 EA.

The LCLS-II-HE would also result in an incremental increase in construction GHG emissions. Based on the 2014 EA (see Section 3.15.1) and the 2015 SA, any incremental construction GHG emissions would be within the original scope and impact envelope considered in the 2014 EA. However, the increased power demand of the higher energy Linac would generate an additional increment of GHG emissions during operation. The 2014 EA and 2015 SA showed that the increased energy consumption required to operate the LCLS-II superconducting Linac increased the annual operational GHG emissions above the previously published CEQ reference point cited in the 2014 EA for quantifying GHG emissions under NEPA. Therefore, this SA provides an additional comparison of annual operational emissions with the CEQ reference point[5] for quantifying GHG emissions under NEPA of 25,000 metric tons of GHG emissions per year ($MTCO_2e$/year) (CEQ 2014). This additional evaluation of operational GHG emissions is presented below.

Table 3-5 provides a summary of the estimated cumulative operational GHG emissions for the LCLS-II and LCLS-II-HE. The 2014 EA estimated GHG emissions at 20,358 $MTCO_2e$/year. With the larger cryoplants, the 2015 SA estimated a total of approximately 32,209 $MTCO_2e$/year. For the LCLS-II-HE project, this SA assumed that the project's increased power use and related GHG emissions would be proportional to the increase in the number of cryomodules. With this assumption, the LCLS-II project would generate approximately 74 percent of the LCLS-II's energy (electricity) emissions (12,819 $MTCO_2e$/year for operating the 35 LCLS-II cryomodules), bringing the estimated combined GHG emissions for LCLS-II and LCLC-II-HE to approximately 46,000 $MTCO_2e$/year (46,353 $MTCO_2e$/year).

5 The previous CEQ reference point of 25,000 MTCO2e/year, which was previously used as the point at which projects should quantify emissions, was used in the 2014 EA for LCLS-II. This value was not included in CEQ's updated guidance (Federal Register, Vol. 84, No. 123, June 26, 2019). The revised guidance states that federal agencies should use the "rule of reason" for quantifying and evaluating the effects of GHG on the environment.

Table 3-5 Estimated Proposed Action Operational GHG Emissions for LCLS-II, LCLS-II with Reconfigured Cryoplants, and LCLS-II-HE

Source	Annual Emissions ($MTCO_2e$/year)			
	LCLS-II Project	LCLS-II with Reconfigured Cryoplants	LCLS-II-HE	
			Incremental increase	Total
Indirect (Annual Operational Emissions)				
Electricity	17,324	27,718	12,819	40,537
Water Use	3,034	4,490	1,326	5,816
Waste Generation	0.35	0.35	0	0.35
Total Indirect	**20,358**	**32,209**	**14,145**	**46,353**

Note: $MTCO_2e$ = metric ton carbon dioxide equivalent; N/A = not applicable

The CEQA reference point of 25,000 $MTCO_2e$/year was used in the 2014 EA but was not included in the revised 2019 CEQ guidance (Federal Register, Vol. 84, No. 123, June 26, 2019) for consideration of GHG emissions.

Sources: 2014 EA and 2015 SA calculations

To offset the increase in power consumption, government agencies are taking steps to reduce GHG emissions and impacts from climate change. These steps include conserving energy, reducing demand, and promoting renewable energy. SLAC is implementing its Site Sustainability Plan and continues to purchase renewable energy certificates, replace aging equipment with highly efficient equipment, construct energy-efficient buildings, and reduce emissions from worker commutes. Although LCLS-II-HE would be energy intensive, it would be consistent with SLAC's updated Site Sustainability Plan (SLAC 2018a). For example, SLAC implemented an energy dashboard tool to help monitor variations in building energy use. In addition, according to SLAC's most recent annual report, up to 34 percent of SLAC's total electric energy came from renewable sources such as wind and hydroelectric sources. This reduces SLAC's GHG emissions by approximately 15,000 $MTCO_2e$/year.

The beneficial indirect impacts of LCLS-II and LCLS-II-HE are potential advancements in basic science in the fields of materials, medicine, and energy. As described by DOE's BESAC in "Directing Matter and Energy: Five Challenges for Science and the Imagination" (DOE 2007), a goal of the LCLS-II would be advancements in control of materials processes, chemical reactions, and energy conversion. Advancements in energy could lead to more efficient renewable energy technologies.

Although the LCLS-II-HE project would increase GHG emissions, the proposed action would have minimal effects on climate change. Further, SLAC would continue to increase its energy efficiency in compliance with Executive and DOE Orders and reduce its emissions across all programs. Thus, by continuing to increase the energy efficiency of DOE's operations and those of all federal agencies, the potential effects of the project's increased GHG emissions would be within the original scope and impact envelope considered in the 2014 EA.

3.12.2 Health and Safety

In conjunction with the LCLS-II, the LCLS-II-HE would affect worker health and safety during removal of old equipment in Sector 11 and installation of new equipment, and by increasing beam power, and adding to the frequency of cryogen deliveries. However, these impacts would be managed under DOE and SLAC safety programs and by adding shielding to the Linac to minimize beam loss; therefore, any cumulative effects would be within the original scope and impact envelope considered in the 2014 EA. In addition, the LCLS-II and LCLS-II-HE projects would benefit public health as a result of presumptive scientific breakthroughs related to energy and medicine.

3.12.3 Hydrology and Water Quality

LCLS-II-HE would not require ground disturbance, would not add impervious surface, and would have no impacts on hydrology. Thus, there would be no contribution to cumulative impacts from stormwater runoff or flooding, which is within the impact envelope considered in the 2014 EA. Any increased pollutants resulting from additional workers and truck deliveries or additional operation and maintenance activity would be offset by SLAC's compliance with stormwater regulations and the implementation of site-wide SWPPP and Erosion and Sedimentation Control Plans. Thus, any incremental effect on water quality would not contribute substantially to cumulative effects on hydrology or water quality in adjacent waterways, which are addressed at the regional level as described in the 2014 EA (i.e., by the Santa Clara Valley Urban Runoff Pollution Prevention Plan, and by San Mateo County).

As part of the LCLS-II-HE design, the Linac and beam dumps would be evaluated for potential beam loss and additional shielding would be added to reduce the potential for residual activity in the soil and groundwater. The added shielding is designed to keep tritium concentrations below detection limits and groundwater wells would be used to monitor water quality at those sites. Beam line operations are the only sources of tritium or other radionuclides in soil or groundwater at these sites. The additional shielding and continued monitoring would ensure that the cumulative impacts of the LCLS-II-HE would be within the original scope and impact envelope considered in the 2014 EA.

3.12.4 Noise

Construction and operation of the LCLS-II-HE would result in an additional increment of noise during installation of outdoor components near Sector 4, and transport of removed equipment and the new cryomodules through the adit at Sector 10. However, other SLAC projects would be located approximately 2 miles away, and no other projects with noise would overlap. Therefore, no cumulative impacts would occur, and the project's impacts are within the original scope and impact envelope considered in the 2014 EA.

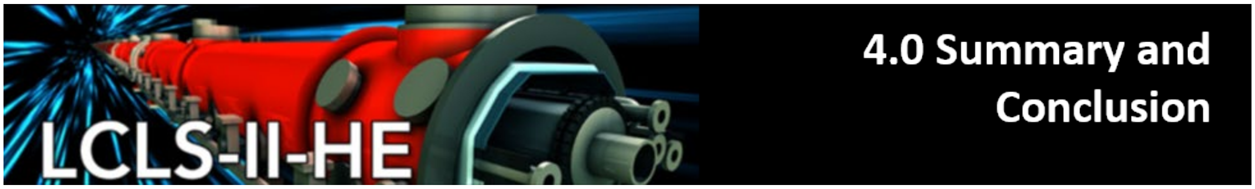
3.12.5 Transportation

The 2014 EA identified the potential for minor, short-term (construction-related) cumulative traffic impacts on Alpine Road from workers and truck traffic. However, as described above, LCLS-II-HE would have a negligible contribution to traffic and accidents and would have an even smaller contribution to cumulative impacts. This is within the original scope and impact envelope considered in the 2014 EA.

3.12.6 Waste Management

The LCLS-II-HE would have only a minor incremental effect on the generation of construction and operational waste that would be addressed by site plans and policies, including requirements for reduction and recycling in the SLAC Site Sustainability Plan (SLAC 2018a). The LCLS-II-HE would generate solid waste from dismantling and removing outdated equipment from the Linac; however, this radioactive, hazardous, and mixed waste would be managed using the same procedures used for the LCLS-II, including reuse and recycling. Other projects also would produce solid waste, including excavated material and construction and demolition wastes. However, in compliance with state and local regulations as well as federal Executive Orders, much of this material would be reused or recycled, reducing its effects on waste management. Considered together with these projects, no cumulative impact would occur, which is within the original scope and impact envelope considered in the 2014 EA.

The LCLS-II-HE would also contribute to radiological waste in the form of irradiated components and after several decades would substantially increase the volume of such wastes during decommissioning of the cryomodules. However, these components would be managed together with the 35 existing cryomodules and would only have cumulative impacts in the context of potential wastes from other DOE sites and potentially regional hospitals and industry. SLAC and DOE's contribution to irradiated components that would require long-term storage would be managed under DOE Orders and any cumulative impacts would be within the original scope and impact envelope considered in the 2014 EA.



4.0 SUMMARY AND CONCLUSION

DOE completed this SA to determine whether the impacts of the proposed LCLS-II-HE project are within the original scope and impact envelope considered in the 2014 EA completed for the LCLS-II. The SA considered the impacts of installing additional cryomodules and supporting equipment, and of operating the Linac at a higher energy level. The LCLS-II was subject to NEPA review in 2014, and DOE published an EA and FONSI. However, because BESAC recommended upgrading to higher energy and expanded experimental capability and capacity, DOE prepared this SA to support a decision regarding whether further environmental analysis and documentation are required under NEPA.

The LCLS-II-HE project was compared with the original proposed action evaluated in the 2014 EA and 2015 SA. The preparatory work of removing equipment from Sector 11 would follow existing procedures used to clear space in Sectors 0 through 10. The additional cryomodules would be installed within the existing accelerator housing and klystron gallery and thus within the same footprint as the approved action. The LCLS-II-HE would not require new activities outside of those already being implemented for installation tasks and would comply with existing DOE requirements and SLAC procedures, and the project-specific avoidance and minimization measures described in the 2014 EA. This includes the ongoing multi-agency efforts to improve energy efficiency and reduce GHG emissions. Therefore, DOE has determined that the impacts of the LCLS-II-HE project are within the original scope and impact envelope considered in the 2014 EA completed for the LCLS-II, such that there are no significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts, and that no additional NEPA environmental analysis is needed.

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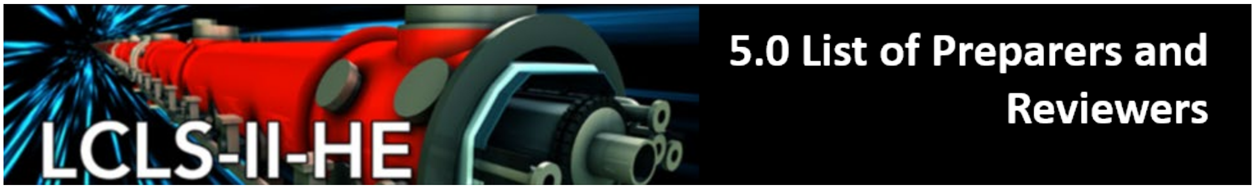

5.0 LIST OF PREPARERS AND REVIEWERS

The following table lists the individuals responsible for preparing this EA SA. The SA was prepared for DOE and SLAC through a contract with Michael Baker International.

Name	Resource Area
DOE Reviewers	
Marie Heard	ES&H and Facility Operations, Bay Area Site Office
Katatra Vasquez	NEPA Compliance Officer, SC Integrated Support Center, Oak Ridge Office
John Cummins	SC Legal Counsel, Bay Area Site Office
SLAC Reviewers	
Ian Evans	LCLS-II-HE, ESH Manager
Greg Hays	LCLS-II-HE, Project Director
Michael Hug	ESH Division, NEPA/NHPA and Spill Prevention Program Manager
Helen Nuckolls	ESH Division, Environmental Protection, Department Head
Michelle DeCamara	Environmental Compliance, Section Lead
Maia Coladonato	ESH Division, Air Quality Program Manager
Wendy Greene	ESH Division, Wildlife Program Manager, NEPA assistant
April Giangerelli	ESH Division, Water Resources Program Manager
Janet Argyres	ESH Division, Environmental Restoration, Section Lead
Rohendra Atapattu	ESH Division, Sustainability Program Manager
Susan Witebsky	ESH Division, Environmental Engineer
Sayed Rokni	ESH Division, Radiation Protection Department, Department Head
Saurabh Anand	Stanford Legal Counsel
Carole Fried	ESH Division, Director
Michael Baker International Preparers	
Peter Boucher	NEPA Specialist (subconsultant)
Patrick Hindmarsh	Project Manager
Ana Cotham	Technical Editor
Amanda Lukondi	Document Production

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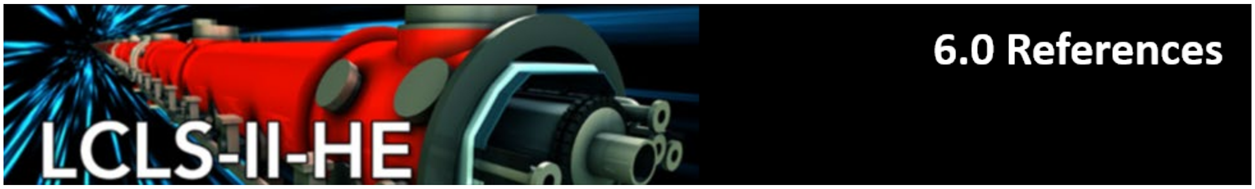

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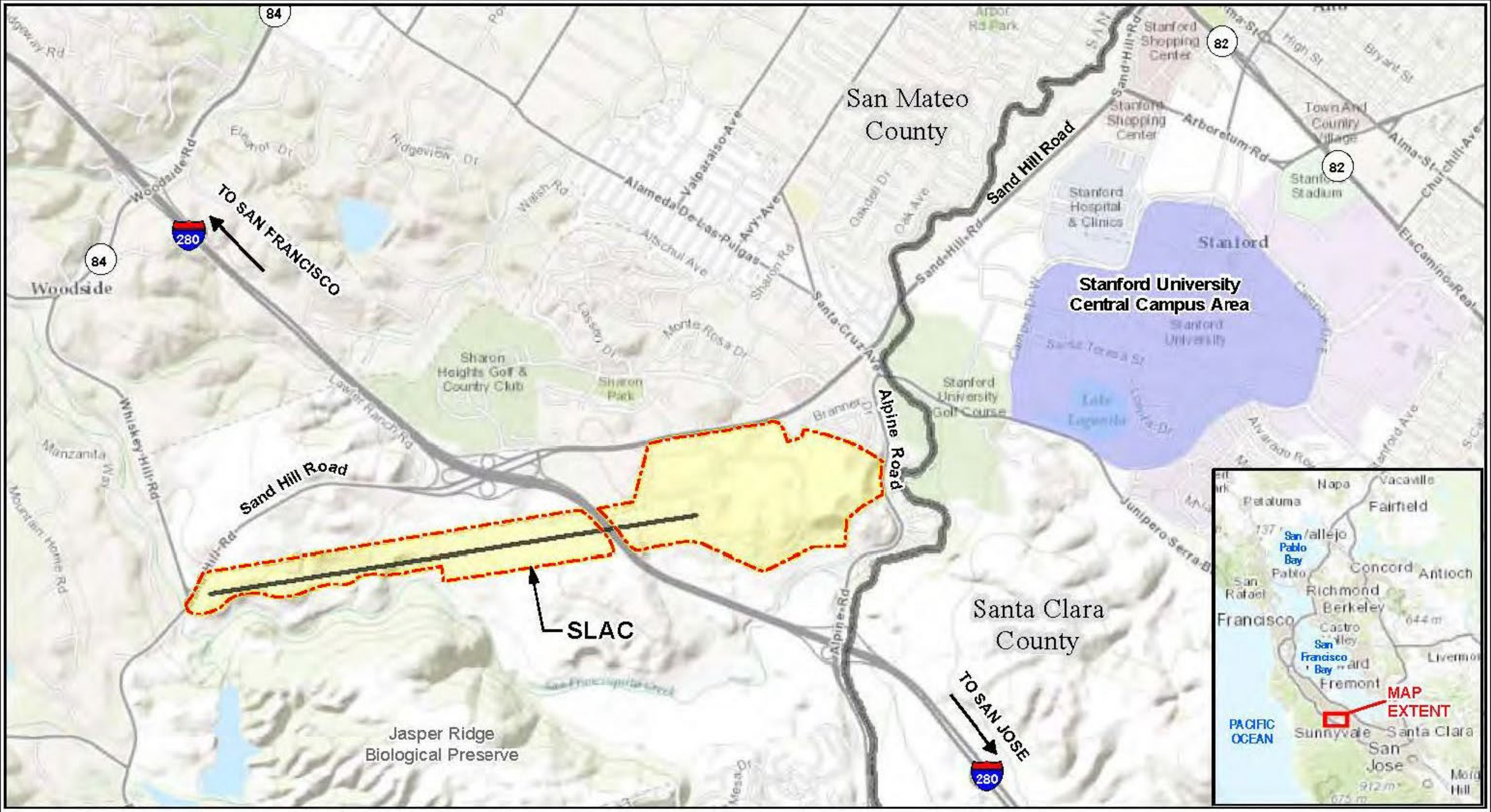
Appendix A

LCLS-II Environmental Assessment – selected figures

6.0 References



Basemap: World_Topo_Map serviced by ESRI ArcGIS Online

LEGEND

- SLAC NATIONAL ACCELERATOR LABORATORY BOUNDARY
- STANFORD UNIVERSITY CENTRAL CAMPUS AREA
- LINEAR ACCELERATCR
- COUNTY BOUNDARY

N

0 3,000 Feet

Graphic Scale: 1" = 3000'

SLAC LCLS-II EA

REGIONAL LOCATION MAP

ARCADIS

FIGURE **1-1**

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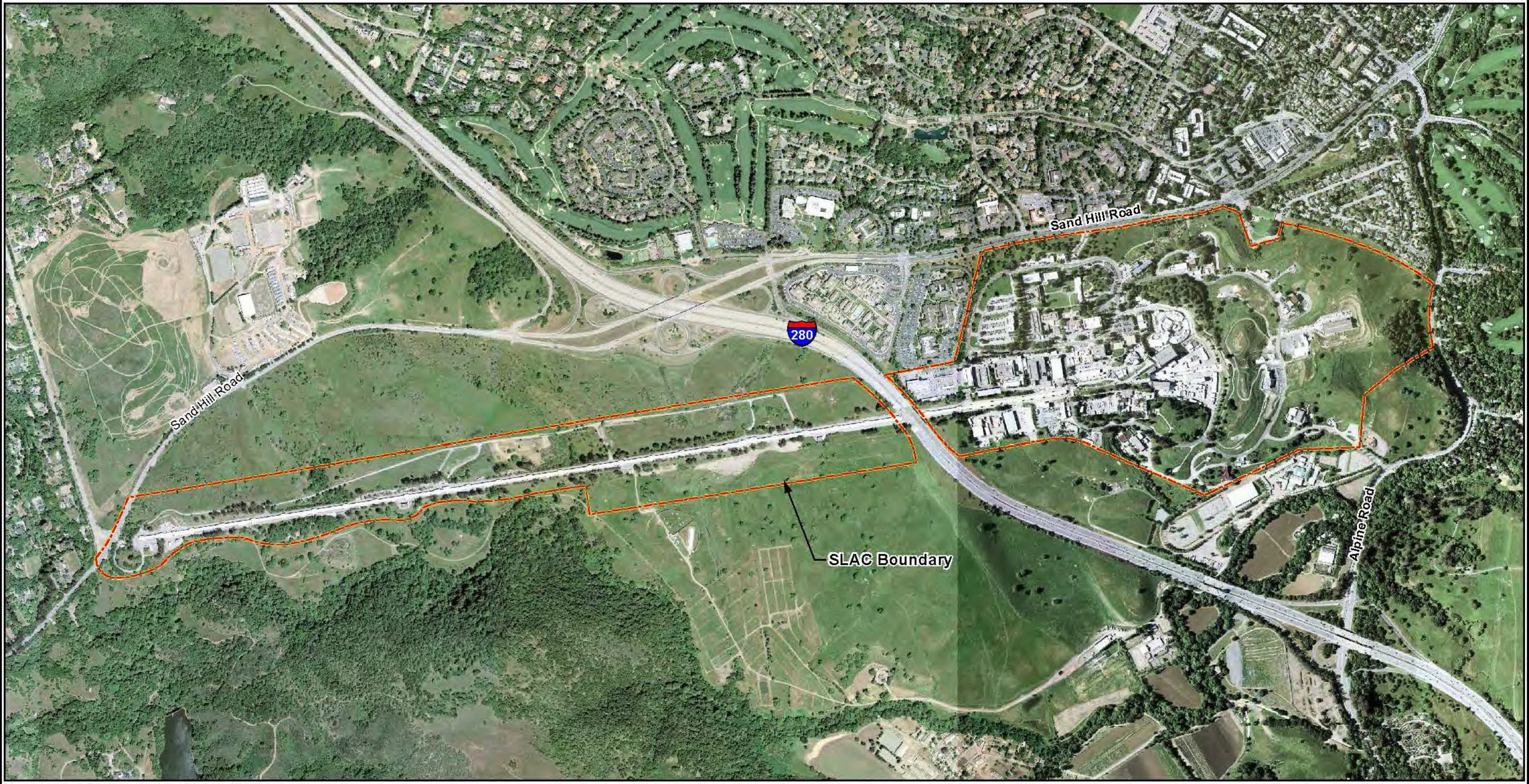

Basemap: City of San Frencisco, photo dated on 04/2011.

LEGEND

SLAC NATIONAL ACCELERATOR LABORATORY BOUNDARY

N

0 1,000 Feet

Graphic Scale: 1" =1000'

SLAC LCLS-II EA

EXISTING SLAC FACILITIES

ARCADIS

FIGURE **1-2**

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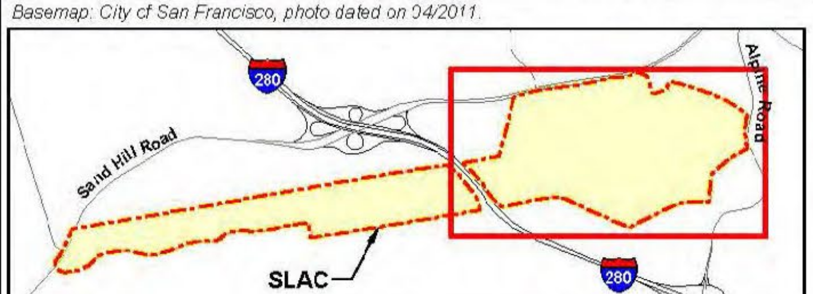
Basemap: City of San Francisco, photo dated on 04/2011.



LEGEND

- SLAC NATIONAL ACCELERATOR LABORATORY BOUNDARY
- EXISTING LCLS UNDERGROUND FACILITY
- EXISTING LCLS ABOVEGROUND FACILITY

N

0 400 Feet

Graphic Scale: 1" =400'

SLAC LCLS-II EA

EXISTING LCLS FACILITIES

ARCADIS

FIGURE 1-3

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Appendix B

LCLS-II 2014 EA and 2015 Supplement Analysis – air emissions calculation summary tables

2014 Environmental Assessment Air Emissions Calculations

Construction

The construction emissions values predicted for 2018 for installation of 35 LCLS-II cryomodules were used to estimate emissions from installation of the LCLS-II-HE cryomodules.

Table 3-4 Estimated Proposed Action Construction Emissions

Construction Year	Annual Emissions (tons per year)			
	VOCs	NO_x	PM_{10}	$PM_{2.5}$
2016	0.86	10.5	1.17	0.78
2017	0.45	5.76	0.97	0.60
2018	0.25	2.28	0.84	0.48
de minimis Levels	100	100	100	100
Overall SLAC Emissions*	12.8	19.5	<1	<1
SLAC's SMOP Limits	35	35	35	35
Exceed *de minimis* Levels or SMOP Limits?	No	No	No	No

Note:
* Overall SLAC emissions do not include emissions from the Proposed Action.

Operations

The operational emissions values predicted for energy consumption by LCLS-II were used to estimate energy generation emissions from LCLS-II-HE.

Table 3-5 Estimated Proposed Action Operational Emissions

Emission Source	Annual Emissions (tons per year)			
	VOCs	NO_x	PM_{10}	$PM_{2.5}$
Area	0.305	0.000	0.000	0.000
Energy	0.004	0.034	0.003	0.003
Motor Vehicles	0.005	0.010	0.009	0.003
TOTAL	**0.31**	**0.04**	**0.01**	**0.01**
de minimis Levels	100	100	100	100
Overall SLAC Emissions*	12.8	19.5	<1	<1
SLAC's SMOP limits	35	35	35	35
Exceed *de minimis* Levels or SMOP Limits?	No	No	No	No

Note:
* Overall SLAC emissions do not include emissions from the Proposed Action.

2015 Supplement Analysis Air Emissions Calculations

Construction

The revised construction emissions values predicted for LCLS-II are presented in the LCLS-II-HE SA.

Table 3-1 Proposed Action Construction Emissions from 2014 EA and Incremental Change with Reconfigured Cryogenic Plants

Construction Year	Annual Emissions (tons per year)			
	VOCs	NO_x	PM_{10}	$PM_{2.5}$
2016	0.86	10.5	1.17	0.78
2017	0.45	5.76	0.97	0.6
2018	0.25	2.28	0.84	0.48
Construction Emissions (2014 EA)	1.56	18.54	2.98	1.86
Revised Construction Emissions with Reconfigured Cryogenic Plants †	2.00	23.83	3.83	2.39
de minimis Levels	100	100	100	100
Overall SLAC Emissions*	12.8	19.5	<1	<1
SLAC's SMOP Limits	35	35	35	35
Exceed *de minimis* Levels or SMOP Limits?	No	No	No	No

Notes:
† Total cryogenic plant power capacity increase from 5 kW to 8 kW.
* Overall SLAC emissions do not include emissions from the proposed action.
Sources: 2014 EA and AECOM 2015 calculations

2015 Supplement Analysis Air Emissions Calculations (cont.)

Operations

The operational emissions from energy consumption and motor vehicles predicted for LCLS-II were used to estimate emissions from LCLS-II-HE.

Table 3-2 Proposed Action Operational Emissions from 2014 EA and Incremental Change with Reconfigured Cryogenic Plants

Emission Source	Annual Emissions (tons per year)			
	VOCs	NO_x	PM_{10}	$PM_{2.5}$
Area	0.305	0	0	0
Energy	0.004	0.034	0.003	0.003
Motor Vehicles	0.005	0.01	0.009	0.003
Operational Emissions (2014 EA)	0.314	0.044	0.012	0.006
Emissions from increased energy consumption from reconfigured cryogenic plants †	0.0064	0.0544	0.0048	0.0048
Emissions from increased motor vehicle trips	0.005	0.01	0.009	0.003
Revised Operational Emissions with Reconfigured Cryogenic Plants	0.33	0.11	0.03	0.01
de minimis Levels	100	100	100	100
Overall SLAC Emissions*	12.8	19.5	<1	<1
SLAC's SMOP Limits	35	35	35	35
Exceed *de minimis* Levels or SMOP Limits?	No	No	No	No

Notes:
† Total cryogenic plant power capacity increase from 5 kW to 8 kW.
* Overall SLAC emissions do not include emissions from the proposed action.
Sources: 2014 EA and AECOM 2015 calculations

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