2023 Basic Energy Sciences Advisory Committee Facilities Charge

In response to Dr. Berhe's December 2023 Facilities Charge, Basic Energy Sciences is providing the following list of projects for consideration by the subcommittee. Note that planned Major Items of Equipment (individually under $100M) for beamlines (e.g., APS, ALS, SSRL, LCLS, HFIR) and instrumentation (NSRCs) are not included in this assessment. Also not included is the Cryomodule Repair and Maintenance Facility at SLAC National Accelerator Laboratory whose total cost is less than $100M.

Linac Coherent Light Source (LCLS) – II – High Energy (HE) Upgrade
Total Project Cost (TPC) point estimate: $710M
SLAC National Accelerator Laboratory
The LCLS-II-HE project will increase the energy of the superconducting linac (recently completed as part of the LCLS-II project) from 4 giga-electron volts (GeV) to 8 GeV and thereby expand the high repetition rate operation (1 million pulses per second) of this unique facility into the hard x-ray regime (5-12 keV and up to 20 keV with emittance reduction). LCLS-II-HE will add new and upgraded instrumentation to augment existing capabilities including upgrades to the facility infrastructure as needed. The LCLS-II-HE project will upgrade and expand the capabilities of the LCLS-II to maintain U.S. leadership in ultrafast x-ray science. The project received CD-3B on January 27, 2023; CD-2/3 projected for 2Q FY 2024.

Second Target Station (STS)
Total Project Cost (TPC) range: $1,800–$3,000M
Oak Ridge National Laboratory
The STS project will expand Spallation Neutron Source (SNS) capabilities for neutron scattering research by exploiting part of the higher SNS accelerator proton beam power (2.8 MW) enabled by the Proton Power Upgrade project. The STS will be a complementary pulsed source optimized to produce the high flux of cold neutrons required to study materials and molecular systems at longer length scales and higher energy resolution to the current SNS capabilities. By optimizing the design of the instruments with advanced neutron optics, optimized geometry for 15 Hz operation, and advanced detectors, the detection resolution will be up to two orders of magnitude higher than current capabilities, enabling new research opportunities. At completion, the project will continue U.S. leadership in neutron scattering. The project received CD-1 on November 23, 2020, and is currently undertaking a major cost analysis, aiming at reducing the expected point cost estimate to less than $2.1B prior to CD-2.

National Synchrotron Light Source-II Experimental Tools (NEXT)–III
Total Project Cost (TPC) range: $350-500M
Brookhaven National Laboratory
The NEXT-III project will provide an additional suite of approximately 12 beamlines that will be optimized to close specific capability gaps of NSLS-II. NEXT-III will deliver a combination of performance and enterprise beamlines. Performance beamlines will enable cutting-edge research addressing BES mission need, as well as developing novel instrumentation and tools required to maintain the global competitiveness of the U.S. light sources. Enterprise beamlines will be designed to provide capabilities and techniques that are mature and have strong, well-established user communities. These beamlines will carry out more routine measurements that are typically highly automatable with a high throughput of experiments. Enterprise beamlines will enable multimodal (remote as well as on-site) research for a larger, more diverse community to broaden industrial research and provide new avenues to introduce new users to synchrotron research, including those from under-represented institutions and regions. The project will be structured into sub-projects, with each sub-project delivering 2-3 beamlines phased over time. The project received CD-0 on September 30, 2022, with CD-1 targeted for the end of FY 2024.

High Flux Isotope Reactor (HFIR) Pressure Vessel Replacement (PVR)
Total Project Cost (TPC) range: $300-740M
Oak Ridge National Laboratory
Beyond the simple replacement of an aging component of a major reactor research facility, the HFIR-PVR project will address two capability gaps. First, it will return HFIR to operations at the 100 MW design power. With the current pressure vessel (PV), the reactor operations were derated to 85 MW due to the discovery of PV embrittlement issues. Second, the anticipated PV design will enhance performance for both isotope production and neutron scattering missions. The new design would allow the addition of new mission-driven scattering instrumentation, enhanced isotope production capabilities, and potential flexibilities such as adding a second cold source and guide hall. This project responds to a BES Advisory Committee report recommendation to ensure continued availability of a high-flux, steady-state neutron source to provide thermal and cold neutrons and neutrinos for the scientific user community; isotope production for research, medicine, and federal and industrial applications including NASA deep space missions; and materials irradiation and neutron activation analysis for federal and industrial partners. As currently envisioned, the HFIR-PVR project will be delivered in two phases, with Phase 1 covering the design and manufacture of the pressure vessel, and Phase 2 covering the installation of the pressure vessel. The project received CD-0 on October 28, 2020, with CD-1 targeted for FY 2026.

LCLS Low Emittance Injector (LEI)
Total Project Cost (TPC) range: N/A (pre-conceptual cost estimate is $210M)
SLAC National Accelerator Laboratory
The LEI would provide a second injector parallel to the LCLS-II injector, significantly improving the quality and availability of the superconducting linac beam. The LEI would provide a world-leading transverse beam emittance and allow lasing with photon energies above 20 keV (extending the energy range enabled by the LCLS II HE upgrade) and further improving facility performance and availability. The LEI would include a state-of-the-art superconducting high gradient radiofrequency gun, which would also facilitate operation with a high quantum-efficiency photocathode, both of which would reduce the electron beam emittance significantly. The LEI would be installed in a separate tunnel upstream of the existing LCLS-II Injector. The LEI project would also include a small cryoplant and distribution system and related infrastructure. A request for CD-0 is tentatively planned for FY 2027.

National Synchrotron Light Source (NSLS) – II Upgrade (NSLS-II-U)
Total Project Cost (TPC) range: N/A (pre-conceptual cost estimate is $1,000M)
Brookhaven National Laboratory
NSLS-II currently has 29 beamlines, and over the next 10 years, approximately 15 additional beamlines are planned for construction to further build-out the facility’s beamlines. Cumulatively, these current and future beamlines will provide the multimodal portfolio required for the next generation of research platforms. However, by 2030, the existing NSLS-II 3rd generation x-ray source will be nearly 20 years old with outdated technology and infrastructure that will not be able to deliver the required brightness, coherence, and beam size for the next generation of science challenges. The currently proposed NSLS-II-U is based on a non-linear lattice design employing a novel accelerator concept called a “complex bend” magnet system, which dramatically lowers emittance and allows more advanced insertion devices. The new design is estimated to increase the hard x-ray brightness by factors of 10x at 1 keV, and 50x-100x at 10 keV, relative to the brightness of the NSLS-II. A request for CD-0 is tentatively planned for FY 2030.

Linac Coherent Light Source (LCLS) – X
Total Project Cost (TPC) range: N/A (BES pre-conceptual cost estimate is $1,500M)
SLAC National Accelerator Laboratory
The combination of the high repetition-rate superconducting linac, the high-energy Cu linac, and other infrastructure being developed at SLAC could feed 10 or more independent undulators, creating an opportunity to move X-ray FEL science into a synchrotron-like mode of operation with multiple beamlines displaying unprecedented performance and providing community-wide impact. The LCLS-X facility would construct a second tunnel from the linac to new sets of superconducting undulators generating photons for several new experimental end stations. When operational, dozens of experiments could be supported simultaneously, allowing the deployment of dedicated specialized instruments with tailored infrastructure and sample environments optimized to support specific areas of science. As currently conceived, to maintain U.S. leadership in FELs, the facility will target delivery of up to a thousand-fold increase in brightness, full 3D coherence, X-ray FELs photon energies to >100 keV, and creation of the shortest possible multi-terawatt X-ray pulses. A request for CD-0 is tentatively planned for FY 2032.

Future Light Source
Total Project Cost (TPC) range: N/A (BES pre-conceptual cost estimate is $2,000M)
To be determined.
The current upgrades to the ALS and APS, and the proposed upgrade to the NSLS-II, will transform these facilities into fourth-generation synchrotrons. However, the demands of the scientific community and national research priorities will require even more advanced x-ray light sources. BES has begun preliminary planning for this future light source with the 2023 Basic Research Needs workshop for Next Generation Accelerator-Based Beam Instrumentation. However, the model for this facility—a large ring facility, a network of high precision compact synchrotrons, a next-generation ultra-compact X-ray FEL, or some combination thereof—remains under consideration. The selection of a future light source concept will depend on engagement and planning with the community to define the performance parameters (brightness, coherence, throughput, etc.) that are needed to make transformational advances in the enabled science, as well as to define the required accelerator technology research. A request for CD-0 is tentatively planned for FY 2033.