OAK RIDGE NATIONAL LABORATORY

FY 2019 SITE SUSTAINABILITY PLAN

With FY 2018 Performance Data
Prepared December 2018

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managed by
UT-BATTELLE, LLC
for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

U.S. Department of Energy
Sustainability Performance Office

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Acronyms

AFV	alternative fuel vehicle
ASCR	Advanced Scientific Computing Research
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
C&D	construction and demolition
CD	Critical Decision
CEDS	Central Energy Data System
CNMS	Center for Nanophase Materials Sciences
D&D	deactivation and decommissioning
DOE	US Department of Energy
ECM	energy conservation measure
EISA	Energy Independence and Security Act
EPAct	Energy Policy Act
EPEAT	Electronic Product Environmental Assessment Tool
EPP	environmentally preferred product
ESPC	energy savings performance contract
EUI	energy use intensity
EV	electric vehicle
E.O.	Executive Order
F&O	Facilities and Operations
FAR	federal acquisition regulation
FEMP	Federal Energy Management Program
FIMS	Facility Information Management System
FY	fiscal year
GHG	greenhouse gas
G/GSF	gallons per gross square foot
GP	guiding principle
GPP	General Plant Project
GSF	gross square footage
HEMSF	High-Energy Mission-Specific Facility
HFIR	High Flux Isotope Reactor
HPC	high-performance computing
HPSB	high-performance sustainable building
HRIBF	Holifield Radioactive Ion Beam Facility
HVAC	heating, ventilation, and air conditioning
IGPP	Institutional General Plant Project
IPM	Integrated Pest management
ISO	International Organization for Standardization
IT	information technology
JCI	Johnson Controls Inc.
KAT	Knoxville Area Transit
LDV	light-duty vehicle
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LI	line item
M&V	measurement and verification
MGY	million gallons per year
MSW	municipal solid waste
NTRC	National Transportation Research Center
OLCF	Oak Ridge Leadership Computing Facility
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OTC	once-through cooling
P2	pollution prevention
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
PSCC	Pellissippi State Community College
PUE	power use efficiency
R2	Responsible Recycling Practices
R&D	research and development
RA	Resource Advisor
REC	renewable energy credit
SC	DOE Office of Science
SCI	Sustainable Campus Initiative
SF_6	sulfur hexafluoride
SLI	DOE Office of Science, Science Laboratories Infrastructure Program
SNS	Spallation Neutron Source
SPO	Sustainability Performance Office
SSP	Site Sustainability Plan
UT	University of Tennessee
WUI	water usage intensity

Executive Summary

ORNL Sustainable Campus: From Initiative to Integration

The beginning of FY 2018 marked a significant transition for energy and water management at Oak Ridge National Laboratory (ORNL), the Department of Energy's (DOE's) largest science and energy laboratory. ORNL executes the widest range of mission capabilities of any DOE site, and is engaged in an extensive range of activities that support the agency's mission: ensuring security and prosperity for the United States by addressing energy, environmental, and nuclear challenges through transformative science and technology solutions. To execute these activities, ORNL is tasked with the management of the most extraordinary set of *distinctive scientific facilities and equipment* in the DOE. ORNL is mission driven, and our mission has grown significantly over the decades. ORNL has now attained 75 years of continuous operations; consisting of facilities with commissioning dates ranging from the 1940's to 2016. As such, conventional perceptions for achieving energy and water savings are not enough to deliver the crucial results in efficient operations. Such a diverse and unique set of major facilities, totaling over 5.8 million square feet, would need an innovative plan to accomplish advancements in operational efficiencies; supported by all stakeholders; from leadership commitment to the most engaged employees. **The ORNL Sustainable Campus Initiative (SCI) was formally chartered in 2008 during a time when federal governance in efficient and sustainable operations was moving to the forefront in facilities management.** ORNL leadership considered the SCI charter to be the logical advancement of a remarkable national lab transformation that launched in the very first year of the twenty-first century.

Beginning in 2000, through a creative mix of facility development funding, construction, and renovation, ORNL's World War II–era infrastructure became home to state-of-the-art facilities hosting major new research programs in areas such as high-performance computing. Advanced building technologies—many developed, tested, and proven at ORNL—were incorporated into new construction and renovation to further advance the laboratory's goal of efficient, sustainable operations.

It was recognized that continuous improvements in operational and business processes must be integrated into the fabric of the ORNL culture to maximize the return from the investment made in modernizing facilities and equipment,. For 10 years, SCI played a critical role in the advancement of innovations in sustainable and efficient facility operations. The program is a demonstrated instance of a legacy of system-wide best practices, management commitment, and employee engagement that will lead ORNL into a future of efficient, sustainable operations. ORNL leadership, facilities management, and SCI champions received regular status reports on the progress of each project and program area (also known as Roadmaps), and periodic summary reports for the program as a whole.

As FY 2018 emerged, ORNL leadership recognized that SCI has indeed been successful in utilizing innovation in equipment and processes to advance resource efficiencies and that an integrated, sustainable ORNL had evolved as envisioned.

Sustainable ORNL

Development of the Sustainable ORNL Roadmap concept was a key to the success of the SCI. In FY 2018 the roadmap structure was streamlined (reduced from 25 to 12 vital projects). Figure 1 summarizes the current project assignments and was redesigned to indicate that each project contributes to the well-being of the whole. Continuous engagements with ORNL associates and regular status reports to the ORNL Leadership Team are still a measure of the success of the program.

Figure 1. The 12 ORNL sustainability focus areas (Roadmaps) as determined in FY 2018.

Center: The new SCI logo, representing the ROI principle (results, operations, innovation).

Sustainable ORNL Highlights and Achievements: FY 2018

Employee Engagement

The transition to an integrated Sustainable ORNL program is being accomplished through announcements, promotions, and numerous activities, including the following activities during FY 2018:

- Article submissions to *ORNL Today*, a web-based newsletter
- Article submissions to the DOE *Sustainability SPOtlight* Newsletter
- Posting of public relations information on Scala screens throughout the campus
- Launch and promotion of a new web site (http://www.ornl.gov/sustainable-ornl)
- Quarterly workshops with Sustainable ORNL Roadmap owners
- Quarterly updates to the ORNL leadership team
- Planning and delivery of the Earth Day Campaign

- Manage and promote the ORNL Electric Vehicle (EV) Owners Club (for use of EV charging stations)
- Manage and promote bus service between the University of Tennessee (UT), Knoxville; Pellissippi State Community College (PSCC); and ORNL main campus

Awards

- 2018 Federal Energy Management Program (FEMP) Federal Energy and Water Management Award for Outstanding Program, "ORNL Sustainable Campus Initiative: From Initiation to Integration"

- 2018 Government Green Fleet Award, recognized in 2017 and again in 2018 with improved standing

- DOE Sustainability Honorable Mention for Outstanding Sustainability Program/Project Award, "ORNL's HPC Summit Facility—Designed for Success" (Figure 2)

- Tennessee Chamber of Commerce & Industry Energy Excellence Award, "ORNL's HPC Summit Facility—Designed for Success" (Figure 2)

Figure 2. Award-winning announcement of the Summit supercomputer.

Publications, Presentations, and Other Recognition

The following article was submitted for publication in FY 2018:

Moore, M. Lapsa, S. Curran, and A. Bittler, "Preliminary Routing for a National Laboratory Lab-Wide Commuting Program," *Transportation Research Record: Journal of the Transportation Research Board*, 2018.

- Submitted for consideration for presentation and publication at the TRB Annual Meeting; Washington, D.C. January 2019.

The following presentations were made in FY 2018:

- Sustainable ORNL Presentations
  - Technical Society of Knoxville, March 2018 (B. Hudey)

  - The University of Tennessee (UT) American Society of Civil Engineers Student Chapter, October 2017 (M. Lapsa)
- Sustainable Transportation at ORNL Presentations
  - Tennessee Environmental Conference, March 2018 (S. Curran)
  - 2018 Sustainable Fleet Technology Conference August 2018 (S. Curran)

Sustainable ORNL Showcase Projects

The following two showcase projects are examples of the encouragement, technical assistance, and funding for projects that were used in FY 2018 to promote efficiency and sustainable operations.

Showcase Project 1: Energy-efficient equipment and system upgrades package ($160k). Value proposition: New, high-efficiency, right-sized equipment replacing oversized, maintenance-intensive equipment; Increased control for smarter operation of existing equipment, only run when needed:

- Building 6000, C300 light emitting diode (LED) upgrade
- Building 7601/7603, Chiller Metasys integration
- Building 8600, boiler automation
- Building 4512, Liebert replacement
- Building 4500N, Wing 3 replacement of existing heating, ventilation, and air-conditioning (HVAC) air-handling unit and addition of an economizer

Showcase Project 2: Automatic Building Energy Modeling ($60k). Enhance and calibrate existing building energy models with advance utility meter data, and use calibrated models to make high-confidence return-on-investment comparisons for energy cost savings projects.

Value proposition: Faster, more accurate comparison of energy cost savings project concepts to identify the best returns on investments; automatic compliance with the Energy Independence and Security Act (EISA 432) Energy Audit Requirement:

- Building 4007—Audit and Oversight Office Building
- Building 5002—Guest Users Facility
- Building 6011—C&TD Office Building
- Building 6012—Computer Science Research Building
- Building 4515—Office/Lab

Sustainable ORNL 2018 Earth Day—Tread Lightly

Roadmap Owners, the ORNL leadership team, and other engaged employees from many divisions worked to demonstrate the commitment we all have for responsible, efficient, and sustainable operations during the FY 2018 Earth Day observances (see Figure 3).

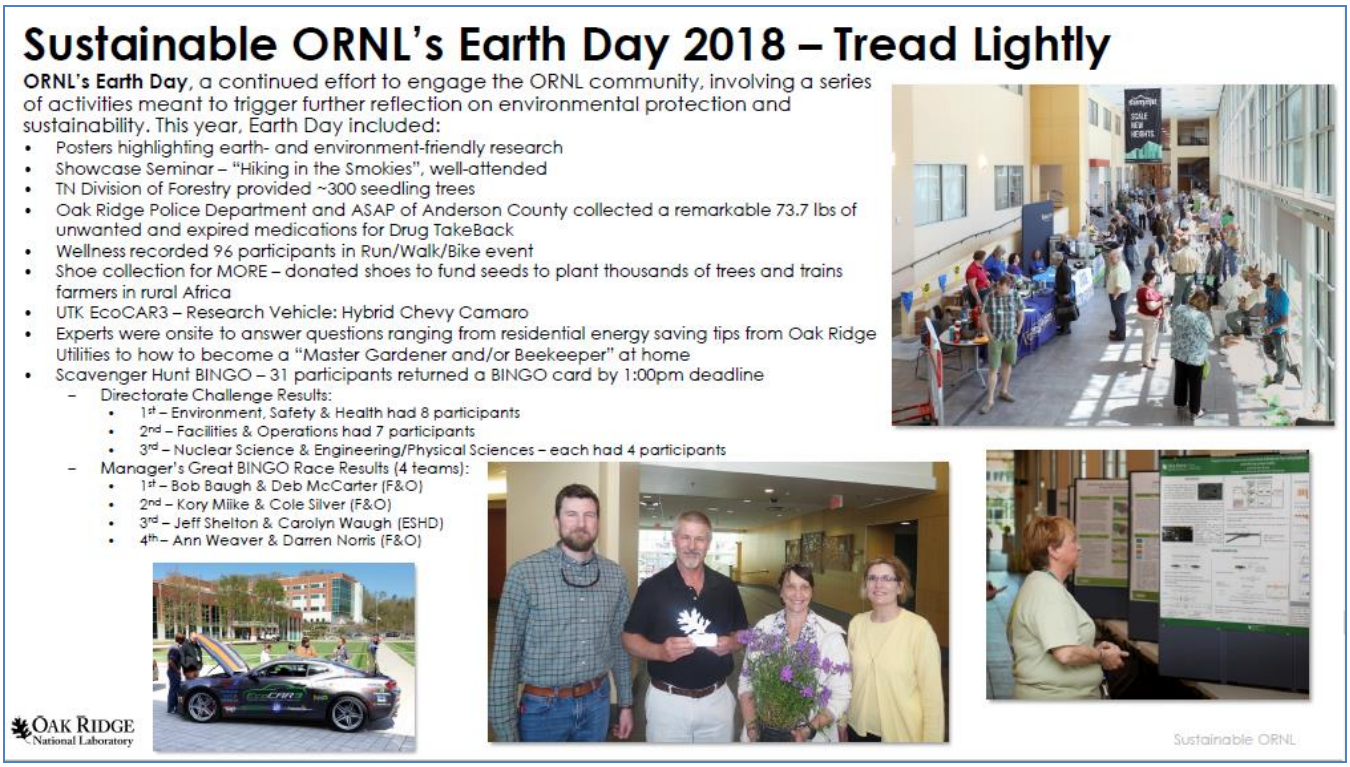


Figure 3. Earth Day activities at ORNL, 2018.

Annual Development of the Site Sustainability Plan

At the close of each federal fiscal year, the DOE Sustainability Performance Office (SPO) issues guidance documents necessary for DOE sites and national laboratories to complete sustainability reporting requirements. As required by DOE Order 436.1, *Departmental Sustainability*, each site will develop and commit to an annual Site Sustainability Plan (SSP) that identifies its respective contribution toward meeting the Department's sustainability goals. The SPO collects and compiles information reported by each site to develop an agency-wide sustainability report and implementation plan, which is used to report departmental sustainability progress to the federal government.

Each year ORNL provides the resources essential to fulfilling its commitment to deliver a complete and accurate SSP and prepares quality performance data for entry into the DOE SPO Dashboard. The performance data entered by each DOE site are combined to reveal the progress of each program office and are further combined to show progress for the agency as a whole.

FY 2018 proved to be a year of major change in sustainability progress and reporting. Executive Order (E.O.) 13834, *Efficient Federal Operations*, was issued on May 17, 2018. The new E.O. revokes the FY 2015 E.O. 13693, *Planning for Federal Sustainability in the Next Decade*, while directing federal agencies to manage their buildings, vehicles, and overall operations to optimize energy efficiency and environmental performance, reduce waste, and cut costs. The targets and goals of prior years have been replaced with directions to follow statutes and promises future mandates that are not yet fully developed. As DOE sites await newly defined targets and mandates, data are being collected and recorded in the SPO Dashboard, and the SSP report is written to focus on operational practices and efficiencies, with the expectation that target-driven guidance is forthcoming for future SSPs.

Mission Change

The Impact of ORNL Mission Change on Sustainable Operations

ORNL is a DOE research facility operation, established and sustained to deliver the scientific discoveries and technological innovations needed to realize solutions in energy and national security. Established in 1943 during World War II as part of the Manhattan Project, ORNL is the largest DOE science laboratory. FY 2017 marked 75 years of continuous operations for ORNL, consisting of facilities with commissioning dates ranging from the 1940s to 2016. Located near Oak Ridge, Tennessee, ORNL occupies more than 4,400 acres of 34,000 acres found on the Oak Ridge Reservation (ORR). Each work day approximately 6,500 people access the laboratory to conduct research and support activities. To support its research and development (R&D) missions, ORNL provides a wide variety of on-site services, including operation and maintenance of all supporting utilities and infrastructure, 24/7 security, dedicated fire and emergency response, medical facilities, unique fabrication and assembly services, and other support functions.

ORNL is tasked with the management of the most extraordinary set of distinctive scientific facilities and equipment for DOE. ORNL is mission driven, and its mission has grown significantly over the decades. ORNL's core research capabilities provide broad science and technology support for DOE missions in energy, environment, and national security. These capabilities, each of which requires world-class equipment and operational support, reflect a combination of exceptional people, equipment, and facilities. Synergies among these core capabilities enable scientific discovery and translational research to accelerate the delivery of technology solutions and allow ORNL to respond to changing priorities and the critical needs of the nation.

ORNL is a world leader in materials, neutron, and nuclear science and engineering and in high-performance computing and data analytics. These signature strengths and other core capabilities are combined across the spectrum of basic to applied R&D to support a wide range of programs. Several distinctive ORNL facilities are open to the science and engineering community, providing valuable resources for collaborative discovery. The Spallation Neutron Source and High Flux Isotope Reactor offer unique capabilities for understanding the structure and dynamics of materials, and robust plans for upgrades will ensure sustained US leadership in the field. The Center for Nanophase Materials Sciences is home to leading capabilities and expertise for synthesis, fabrication, imaging, and characterization at the nanoscale. The Oak Ridge Leadership Computing Facility (OLCF) hosts forefront computational resources, including the new Summit system (2018 deployment), and advanced data infrastructure. Other user facilities, such as the Manufacturing Demonstration Facility, provide tools for developing and testing new technologies in collaboration with industry.

ORNL's vast portfolio of research facilities must be maintained, and carefully upgraded, in order to protect the countries investment in scientific analysis. The goal of sustainable operations is to enable more effective execution of ORNL's science and technology mission. Sustainable operational practices strive for enhanced results while remaining diligent to energy and environmental stewardship.

ORNL's Campus Strategy is updated annually as part of the ORNL Annual Lab Planning cycle. Campus strategy is focused on advancing distinctive scientific missions. The execution of the strategy relies on achieving four primary objectives:

1. Advance science and energy leadership by
   - advancing the science and impact of neutrons,
   - scaling computing and data analytics to exascale and beyond for science and energy,

- accelerating the discovery and design of new materials and chemical processes, and
- advancing the scientific basis for breakthrough nuclear technologies and systems.

2. Establish a modern adaptable infrastructure to support research.
3. Return the ORNL Central Campus to productive science missions.
4. Reduce excess facility liabilities.

Critical infrastructure needs related to each objective are identified and addressed through ORNL's annual Mission Readiness process, which defines the planned facilities and infrastructure investments for sustained operations. Investments in new research facilities and infrastructure upgrades will result in increased energy and water consumption in total; however **Btu consumption per square foot of goal subject building space (a key sustainability indicator) is expected to decrease as modern facilities replace older, inefficient operations.** Collectively, the four ORNL campus strategy objectives will be accomplished in part through successful completion of the following projects list below, with their Critical Decision (CD) process stage identified:

- Three programmatic line item construction projects:
  - SNS Proton Power Upgrade, supported by Basic Energy Sciences (CD-1 approved)
  - SNS Second Target Station (STS), supported by Basic Energy Sciences (CD-0 approved)
  - Advanced Nuclear Materials Laboratory (ANML), supported by NE (proposed)
- Two lease-to-own (LTO) leadership-class computing systems:
- OLCF-4 (Summit), supported by Advanced Scientific Computing Research (CD-4 expected in FY 2019)
  - OLCF-5 (Frontier), supported by Advanced Scientific Computing Research (CD-1 approved)
- One Major Item of Equipment (MIE):
  - Materials–Plasma Exposure Experiment (MPEX), supported by Fusion Energy Sciences (CD-0 for Linear Divertor Simulator approved)
- Three Science Laboratories Infrastructure (SLI) line item construction projects:
  - Translational Research Capability (CD-0 approved)
- Liquid Radioactive Waste System (CD-0 approved)
- Craft Resources Support Facility (proposed for FY 2022–FY 2023)
- Two programmatic General Plant Projects (GPPs):
- HFIR Sample Preparation Facility (proposed)
- Helium Recovery System (proposed)
- Two SLI GPPs:
- Fabrication Shop HVAC Upgrade (started FY 2018)
- Building 3500 Renovation (proposed for FY 2020–2021)
- Numerous smaller projects supported through Institutional GPP (IGPP) funding.

Infrastructure Investment Summary

Since FY 2002, when ORNL initiated core infrastructure improvements, 95 projects have been completed at a total cost of $203M. Over the next decade, ORNL expects to continue investing $20M to $25M per year in infrastructure to recapitalize and sustain aging assets, some of which are 75 years old (see Table 1).

Institutional investments are the predominant funding mechanism for continued site modernization. Funding requirements for disposing of excess facilities runs between 2% and 4% of the replacement plant value. Thirty-six percent of ORNL's operational non-mission-unique facilities, representing approximately 48% of the total gross square footage, are more than 50 years old and carry nearly 93% of the deferred maintenance liability.

Much of the ORNL utility system has been upgraded through major initiatives that began in FY 2002. **Future improvement priorities** include upgrades to the sewage treatment system and replacement of an aging chiller plant, which will be accomplished through chilled water system interconnections. The age and condition of the system that supplies ORNL with water is an ongoing concern. The water system is being evaluated with the goal of reducing the risks of interruptions in service and identifying alternative water supplies in case of extended outages. The plans are very much in the identification stage, and most will not require a CD process (see Table 1 for a summary of the DOE Office of Science (SC) 10-year Integrated Facilities and Infrastructure Investment).

Table 1. DOE Office of Science integrated facilities and infrastructure funding 10-year summary

Fiscal year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Capital investments ($)											
SLI LI	116,000	84,000	129,000	101,000	240,000	279,000	276,000	275,000	250,000	120,000	
SLI GPP		7,000	10,000								
GPP	3,000	4,600	5,000	4,000							
Total, DOE	**119,000**	**95,600**	**144,000**	**105,000**	**240,000**	**279,000**	**276,000**	**275,000**	**250,000**	**120,000**	**0**
IGPP	25,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000
Total, all sources	**144,000**	**117,600**	**166,000**	**127,000**	**262,000**	**301,000**	**298,000**	**297,000**	**272,000**	**142,000**	**22,000**
Predictive, preventative, and corrective maintenance and repairs ($)											
Direct	14,534	14,970	15,419	15,882	16,359	16,849	17,355	17,875	18,412	18,964	19,533
Indirect	69,679	71,769	73,922	76,140	78,424	80,777	83,200	85,696	88,267	90,915	93,643
Total	**84,213**	**86,739**	**89,341**	**92,022**	**94,783**	**97,626**	**100,555**	**103,571**	**106,679**	**109,879**	**113,176**

GPP General Plant Project
IGPP Institutional General Plant Project
LI line item
SLI DOE Office of Science, Science Laboratories Infrastructure Program

Energy Management

Energy Management Program Overview

The ORNL Energy Management Program begins with the organizations comprehensive understanding through an assessment of all energy and water consumption. The site utility services include electrical power, natural gas, fuel oil, steam, chilled water, and potable/process water to support ORNL's mission and the research community. Electrical services include basic power needs as well as chilled water service and direct cooling applications. Steam is generated onsite from a combination of fuel oil and natural gas. Natural gas and fuel oil are also used in direct heating applications. Potable water use supports mission-critical process applications as well as domestic water use, including restrooms and drinking water. ORNL's utility consumption and costs reflect the ORNL main campus, the SNS campus, various support facilities throughout the property, and leased spaces, primarily the National Transportation Research Center (NTRC) campus. The continued knowledge gained from the analysis of past and current energy consumption will better position ORNL to develop plans for improved energy efficiency in facility operations. ORNL's Energy Efficiency and Sustainability Program began the DOE's Better Buildings Initiative, the *50001 Ready Program*, in May, 2018. Based on ISO 50001, a voluntary global standard for energy management systems, the DOE *50001 Ready Program* has helped ORNL establish better documentation of ORNL's existing energy baseline and improvement efforts. In the coming fiscal year, ORNL plans to use *50001 Ready* to help establish energy target goals, identify and prioritize project improvement opportunities, implement and track energy conservation measure (ECM) improvement projects, and document performance metrics.

ORNL's unique research mission (as described in the "Mission Change" section of this report) results in energy efficiency challenges not seen in conventional office and laboratory buildings. The DOE and SC have designated

a unique facility category for these exceptional operations, defined as High-Energy Mission-Specific Facilities (HEMSFs). A section containing brief program information for ORNL HEMSFs follows the utility consumption narrative, and is offered to better document this challenge in energy performance improvement efforts.

Utility Consumption

Electricity, the largest energy commodity for ORNL, currently accounts for approximately 75% of its total energy consumption (see Figure 4). Electrical services dominate ORNL's energy, primarily due to critical operations at HEMSFs. Natural gas is the primary fuel used for steam generation at the ORNL Steam Plant and the Melton Valley Steam Plant, and for hot water generation at the Central Utilities Building, supporting SNS. Other direct natural gas heating and research applications result in a total of 25% of energy consumption. Fuel oil, which is used for steam generation during curtailment and maintenance periods and direct heating applications, accounts for less than 1% of the total energy consumed. Electricity accounts for 87% of the utility provider commodity budget at ORNL (see Table 2).

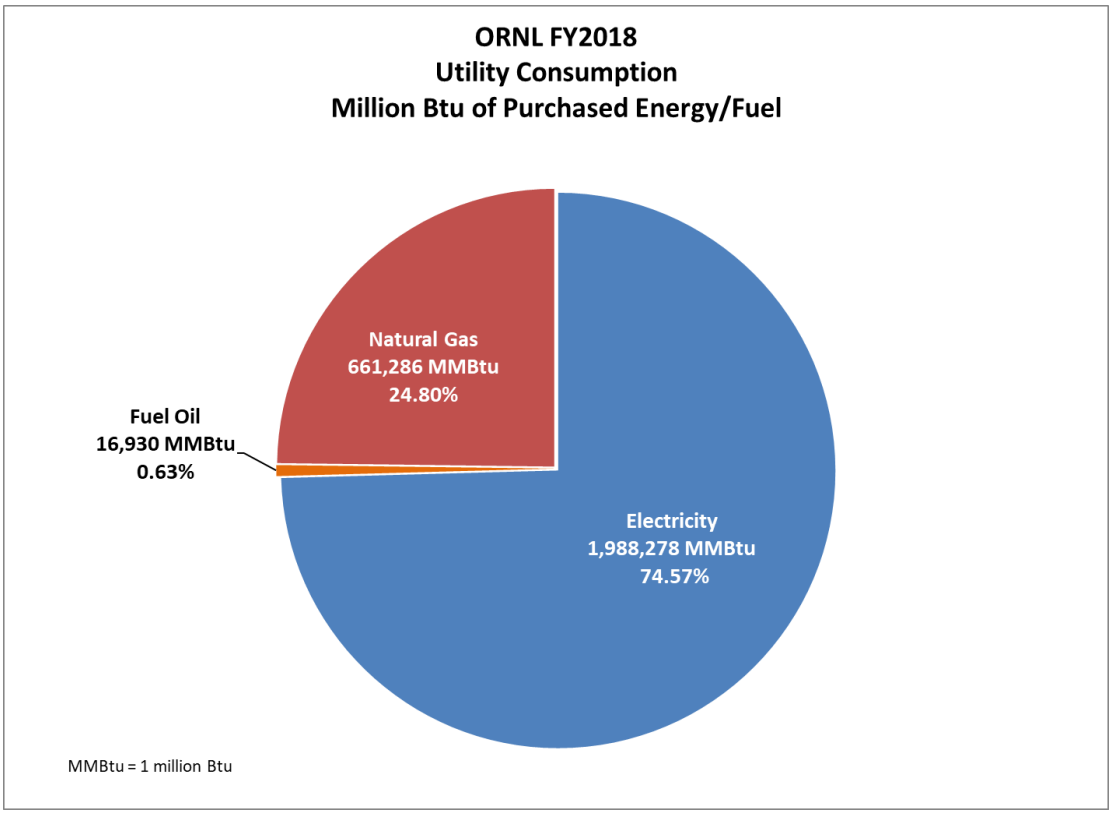


Figure 4. FY 2018 total energy consumption at ORNL.

Table 2. ORNL FY 2018 utility consumption and cost		
Utility	**Consumption**	**Cost (1,000)**
Electricity	582,731(MWh)	$ 33,069
Natural Gas	644,529 (Dkt)	$ 3,112
Fuel	122 (kgal)	$ 278
Potable Water	701 (Mgal)	$ 1,376

Program Information for ORNL HEMSFs

Currently ORNL's designates and tracks four unique facility/research systems as HEMSFs.

High Flux Isotope Reactor (HFIR)

The neutron scattering research facilities at HFIR allow scientists to study the molecular and magnetic structures and behavior of a variety of materials, including high-temperature superconductors, polymers, metals, and biological samples (Figure 5). These studies are leading to scientific and technical advances in a wide range of fields, such as physics, chemistry, materials science, engineering, and biology. The reactor is also used for isotope production, materials irradiation, and neutron activation analysis.

Figure 5. The ORNL High Flux Isotope Reactor.

High Performance Computing (HPC)

Figure 6. The ORNL Computational Sciences Building.

The HPC mission includes the Computational Sciences Building (Figure 6), part of the Oak Ridge Leadership Computing Facility (OLCF), giving the world's most advanced computational researchers an opportunity to tackle problems that would be unthinkable on other systems.

To date, OLCF has produced three supercomputers, each bearing the title "world's fastest computer" in its time. The most recent highly efficient pre-exascale system, Summit, reached a speed of 143.5 petaflops in FY 2018. At its theoretical peak, Summit is capable of 200 petaflops, eight times more performance than the previously top-ranked HPC system, known as Titan. As supercomputing strategy continues to evolve, the design features championed at ORNL will ensure that DOE remains positioned at the forefront of HPC on the international stage.

As Summit was conceptualized, ORNL leadership and the design team discerned that more efficient design would result in lower annual operating cost. The team was relentless in balancing reliability and cost objectives in the construction phase as facility-level power and cooling upgrades were required to support Summit.

The engineering design team optimized the system footprint and Central Energy Plant's cooling system to support Summit and achieve cost-effective system reliability. The result was substantially better power use efficiency (PUE) and significant reductions in the operating cost for the system.

Data Center PUE is one of DOE's top Environmental Scorecard indicators. Summit's initial operations performed at a PUE of 1.14, which is expected to be closer to 1.10 at the end of the first year of operation. The overall PUE for the OLCF's datacenters is expected to continue to improve over time with increasing use of warm-water cooling. With construction of the facility's distribution systems completed in 2017, Summit was deployed in 2018 to much fanfare as the world's most powerful research computer.

"ORNL's HPC Summit Facility – Designed for Success" project depiction and award nomination documentation resulted in two energy awards in 2018:

- DOE Sustainability Award Honorable Mention for Outstanding Sustainability Program/Project
- Tennessee Chamber of Commerce & Industry Energy Excellence Award

Spallation Neutron Source (SNS)

Figure 7. The ORNL Spallation Neutron Source.

SNS is an accelerator-based neutron source that provides the most intense pulsed-neutron beams in the world for scientific research and industrial development (Figure 7). The beams deliver short pulses of protons—60 times a second—to a target system where neutrons are produced through a process called spallation. SNS gives researchers more detailed snapshots of smaller samples of physical and biological materials than ever before possible. The diverse applications of neutron scattering research are providing opportunities for exploration into the structure and dynamics of materials in practically every scientific and technical field. Each year more than 1,000 scientists from around the world compete for valuable research time at the SNS facility.

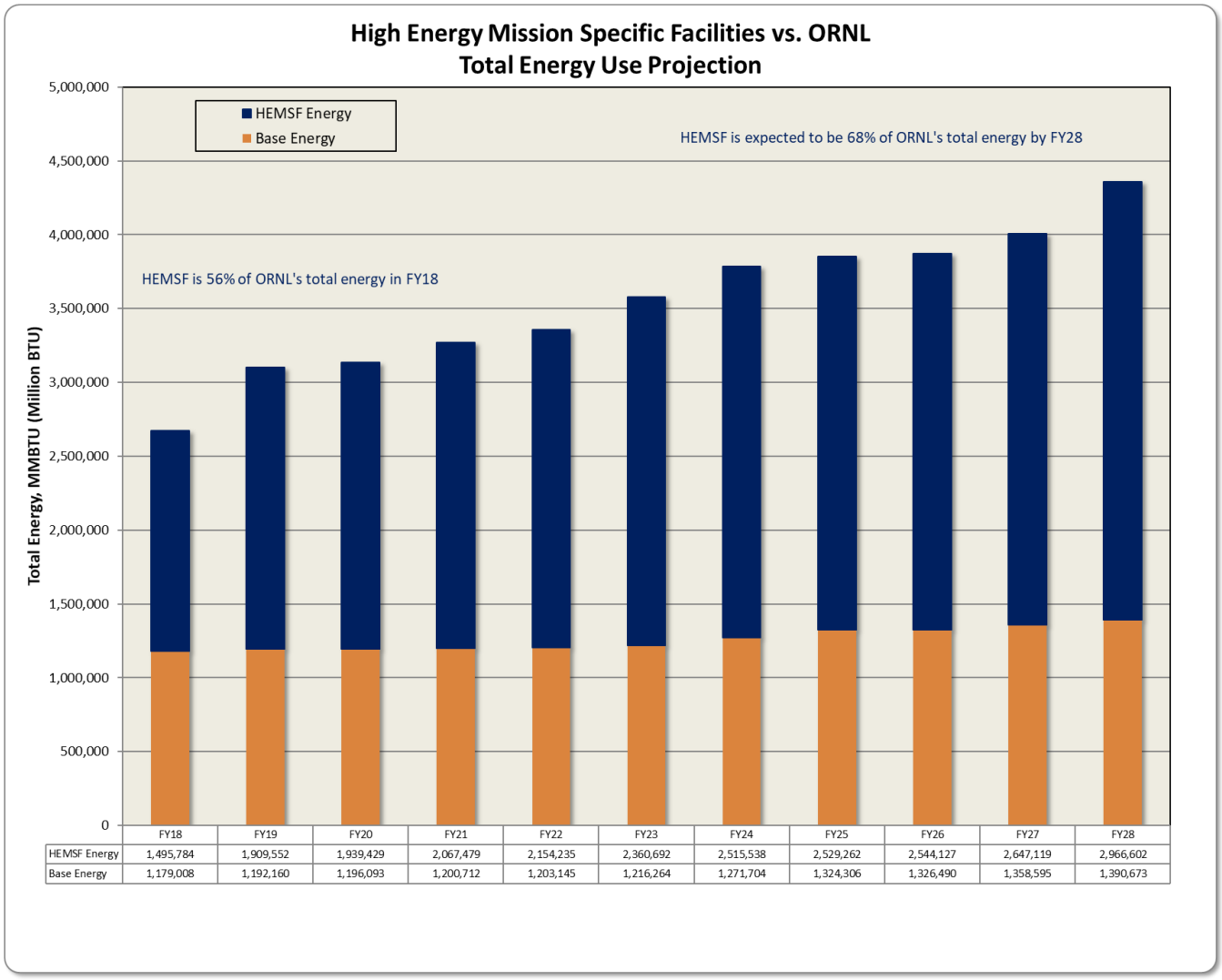
Center for Nanophase Materials Sciences (CNMS)

Figure 8. The ORNL Center for Nanophase Materials Sciences.

CNMS is one of five DOE Nanoscale Science Research Centers (Figure 8). The centers provide leading-edge tools and scientific expertise for synthesis, characterization, and computation for interdisciplinary research at the nanoscale. Providing its own unique capabilities, CNMS enables scientists worldwide to "see," make, control, and understand nanoscale matter. Nanoscience aims to understand advantageous yet sometimes strange physical and chemical behaviors that arise in structures 1 to 100 nanometers wide that do not occur in larger structures. The CNMS program integrates nanoscale science with neutron science; synthesis science; and theory, modeling, and simulation. The facility is equipped with a wide range of specialized tools for synthesis, characterization, and fabrication of nanoscale materials and assemblies, including the integration of hard and soft materials.

ORNL HEMSF Energy Use and Projections

The current and projected values for total energy consumption (in millions of British thermal units) by all sources at ORNL are shown in Figure 9 in comparison with the energy consumed by the HEMSF systems. HEMSF energy consumption accounted for 56% of ORNL's total energy use in FY 2018. It is expected to grow to 68% of total energy use by FY 2028. As shown previously in Figure 4, electricity is the dominant utility at ORNL (at 74%) for all of ORNL, both HEMSF and the base site.



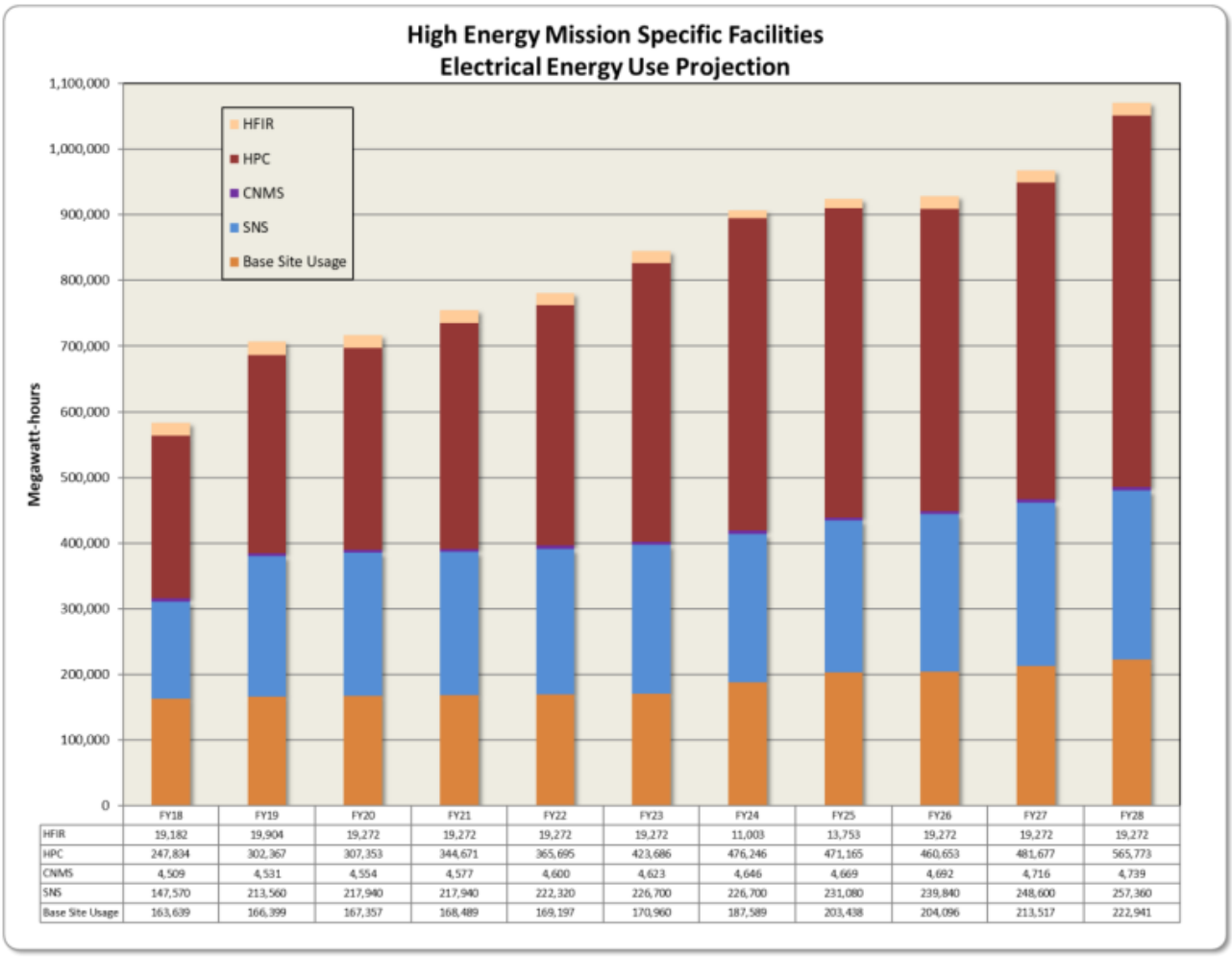
	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
HEMSF Energy	1,495,784	1,909,552	1,939,429	2,067,479	2,154,235	2,360,692	2,515,538	2,529,262	2,544,127	2,647,119	2,966,602
Base Energy	1,179,008	1,192,160	1,196,093	1,200,712	1,203,145	1,216,264	1,271,704	1,324,306	1,326,490	1,358,595	1,390,673

Figure 9. Total energy use at ORNL vs. the energy use for HEMSF

The top section of bar graph covers all HEMSFs. Other ORNL energy is shown on the bottom section of the bar graph and is identified as "Base Energy" consumption. Note: for all comparisions Base Energy includes electricity and other fuels used for basic facility operations, and not consumed at HEMSF systems.

The HEMSF Electrical Energy Use Projection bar graph is provided to demonstrate the importance of electrical energy at ORNL. Electricity consumption is the largest component of HEMSF energy. 72% of all ORNL electricity is consumed at these research facilities, and that number will grow to 79% by FY 2028.

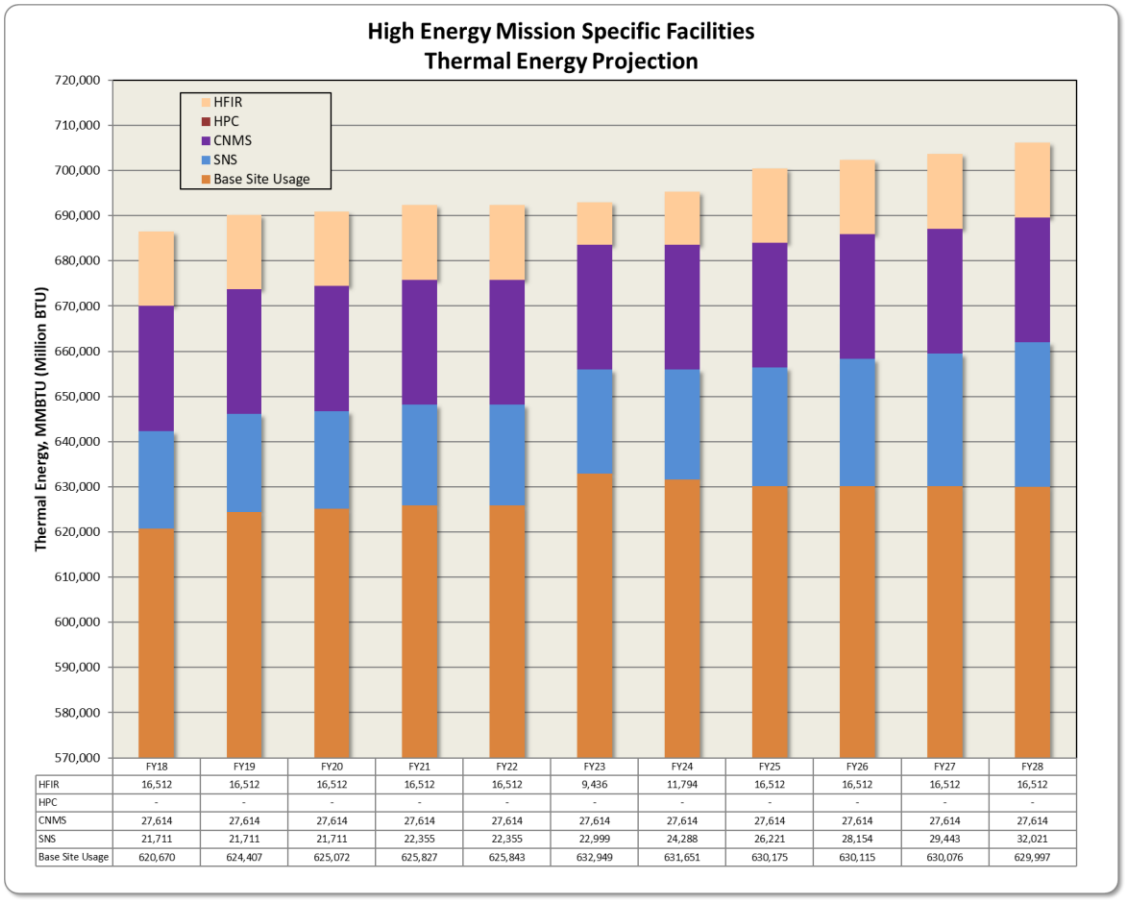
The bar graph in Figure 10 shows the electricity use and projections for each of the four HEMSF systems. All other electricity consumption is also shown on the bar graph as Base Site Usage.



	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
HFIR	19,182	19,904	19,272	19,272	19,272	19,272	11,003	13,753	19,272	19,272	19,272
HPC	247,834	302,367	307,353	344,671	365,695	423,686	476,246	471,165	460,653	481,677	565,773
CNMS	4,509	4,531	4,554	4,577	4,600	4,623	4,646	4,669	4,692	4,716	4,739
SNS	147,570	213,560	217,940	217,940	222,320	226,700	226,700	231,080	239,840	248,600	257,360
Base Site Usage	163,639	166,399	167,357	168,489	169,197	170,960	187,589	203,438	204,096	213,517	222,941

Figure 10. Electricity consumption of the 4 identified HEMSFs at ORNL.
All other electricity consumption is shown on the bar graph as "Base Site Usage."

Thermal energy consumption is also expected to increase with ORNL mission growth as HEMSF research needs increase (see Figure); however, electricity will remain the dominant energy source.



	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
HFIR	16,512	16,512	16,512	16,512	16,512	9,436	11,794	16,512	16,512	16,512	16,512
HPC	-	-	-	-	-	-	-	-	-	-	-
CNMS	27,614	27,614	27,614	27,614	27,614	27,614	27,614	27,614	27,614	27,614	27,614
SNS	21,711	21,711	21,711	22,355	22,355	22,999	24,288	26,221	28,154	29,443	32,021
Base Site Usage	620,670	624,407	625,072	625,827	625,843	632,949	631,651	630,175	630,115	630,076	629,997

Figure 11. Projections of thermal energy consumption for the HEMSF systems at ORNL. All other heating-energy values are shown on the bar graph as "Base Site Usage."

The sources of greenhouse gas (GHG) emissions at ORNL and the inventory for FY 2018 are listed in Table 3. GHG emissions are expected to increase as research grows because federal accounting guidance for the GHG emissions inventory contains no exceptions or exclusions, regardless of mission.

Table 3. Sources of greenhouse gas (GHG) emissions at ORNL in FY 2018

Sources of GHG emissions	FY 2018 inventory ($MTCO_2e$)	Percentage of total
Purchased electricity (net)	275,260	71%
Natural gas, facilities	35,124	9%
SF_6 process losses	14,467	4%
Transmission and distribution losses	18,132	5%
Employee commute	14,399	4%
Business air travel	7,204	2%
Fugitive gases (other than SF_6)	1,980	1%
Fuel oil, facilities	1,256	less than 1%
Fleet fuels	797	less than 1%
Business ground travel	778	less than 1%
Minor sources	210	less than 1%
ORNL, All GHG emission sources	**369,607**	**100%**

Energy Management: Energy Usage Intensity (EUI)

Performance Status

Executive Order (E.O.) 13834, *Efficient Federal Operations*, signed on May 17, 2018, directs federal agencies to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs.

Based on FY 2018 data, energy use in the buildings category at ORNL is 1,295 billion Btu, not including ORNL's excluded facilities as defined by the Energy Policy Act of 1992. Given an area of 5,199,825 GSF of energy-consuming buildings, trailers, and other structures and facilities identified in the Facilities Information Management System (FIMS), the FY 2018 calculated EUI is 248,953 Btu/GSF. This results in a cumulative reduction of 31.6% since FY 2003 (Figure 9).

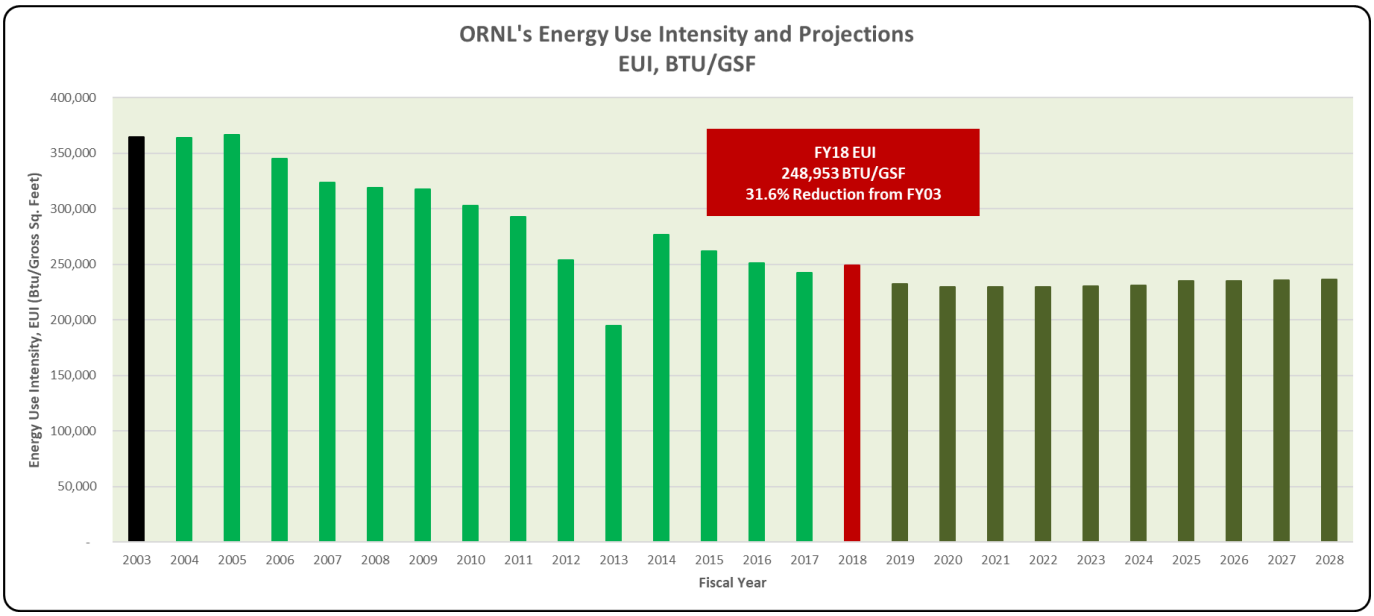


Figure 9. Historical, current (FY 2018), and projected energy use intensity at ORNL.

To maintain steady progress toward EUI reductions, ORNL focuses on energy-efficient and sustainable design in new construction projects as well as smart repurposing of existing facilities and a drive for continuous improvement in facility and utility operations. ORNL continues to modernize by demolishing old, energy-inefficient buildings to make way for the construction of new, high-performance buildings that better serve the ORNL mission.

EUI reduction in existing ORNL facilities is data-driven, and ORNL makes efforts to quantify and bring awareness to building energy performance so that operations staff can make informed decisions. Initiatives in FY 2018 included new approaches to energy consumption awareness using data visualization and reporting. Building data analytics, including fault detection and diagnostics, are also being added to ORNL's energy conservation tools. To bolster this effort, ORNL has elected to participate in the Better Buildings Smart Energy Analytics Campaign. New and innovative methods were accompanied by time-tested approaches to energy conservation, including LED lighting upgrades, existing building commissioning, and HVAC control system improvements.

Improvements in utilities services have reduced energy/fuel cost, reduced maintenance costs, and increased reliability in the delivery of steam, chilled water, and potable water.

Steam system improvements include steam trap repairs and replacement and commissioning of a new deaerator. Boiler efficiency was improved with scale removal from one unit. ORNL installed additional steam flow metering for better monitoring of how the steam is distributed throughout the laboratory and to help identify future energy projections and new facility locations. A new natural gas boiler was installed for direct heating to replace distribution losses.

Chilled Water System improvements include initial operations of the Medium Temperature Water System for cooling select HPC processes, utilizing more cooling tower than chiller operations for energy savings. Other improvements include new chiller control panels for improved reliability and continuous flow of chemical treatment as well as heat tracing and insulation upgrades.

Electrical distribution system upgrades included installation of additional switchgear to optimize existing loads and to allow improved capacity as ORNL expands its mission. Intelligent reclosers were installed for better power conditioning. More efficient transformers were installed. In addition to being more efficient, they improve reliability and reduce maintenance.

Life-Cycle Cost Analysis at ORNL utilizes building/system/equipment data, engineering principles, and personnel expertise to perform the calculations and validate efficiency measures. ORNL tries to be consistent with its Life-Cycle Cost Analysis calculations, procedures, and methods to manage the wide range of projects throughout ORNL. In FY 2018, ORNL began utilizing a project planning tool, which included steps to measure and validate efficiency measures and a Life-Cycle Cost Analysis project completion dashboard.

Figure 10 identifies the current EUI values for buildings in the goal subject category that are greater than 5,000 GSF with an EUI of 150,000 Btu/GSF or greater. In FY 2018 a total of 64 buildings meet the SC criteria. Those buildings will be the focus of energy conservation activities in the future because improvements in EUI are necessary in order to meet several of the DOE energy management and sustainability objectives. As is expected, buildings with the greatest EUI are associated with HEMSF research systems.

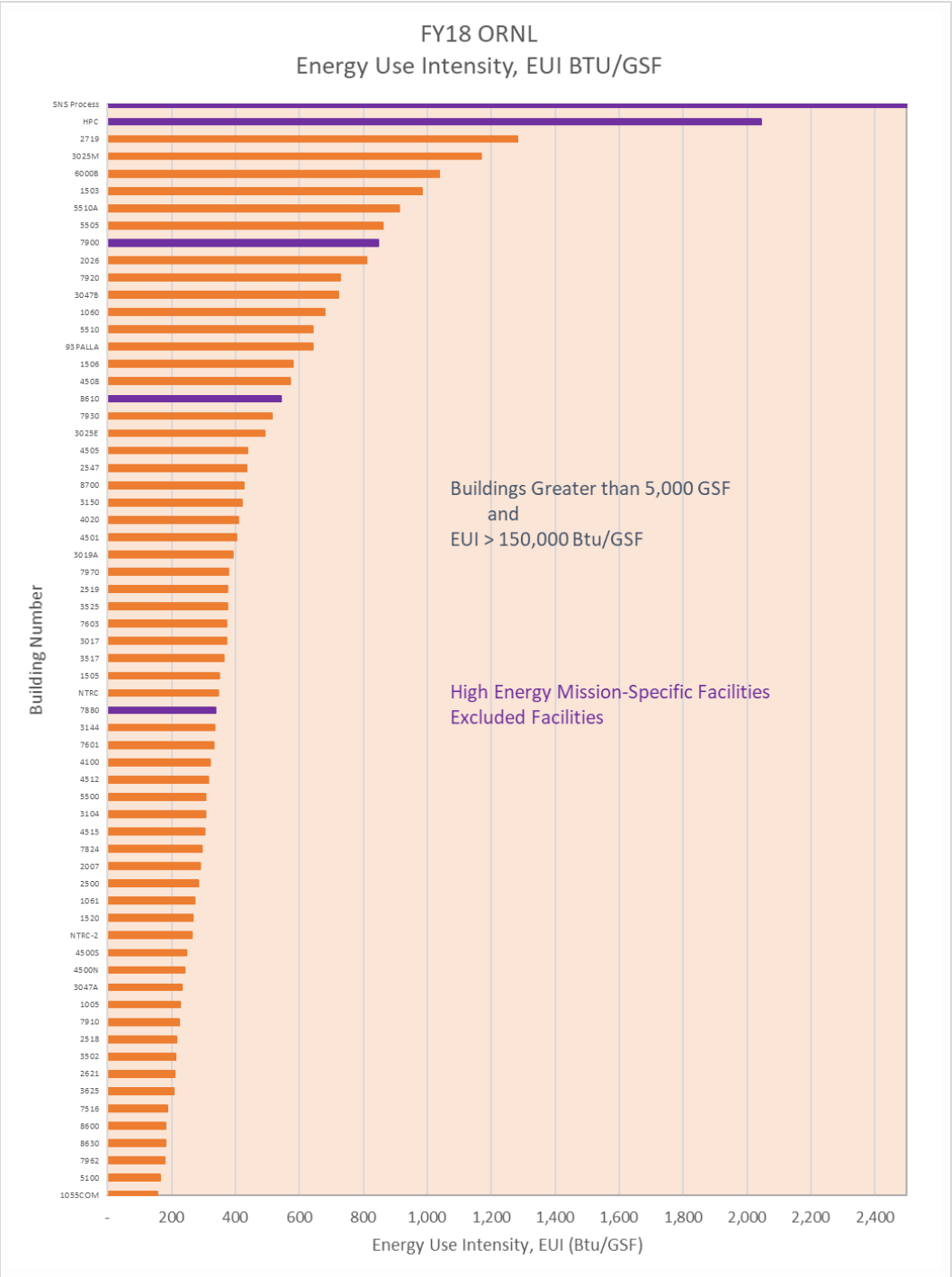


Figure 10. FY 2018 energy use intensity by building at ORNL.

Plans and Projected Performance

ORNL's effort toward energy intensity reduction has resulted in significant progress by targeting readily applied ECMs in existing buildings. As these types of opportunities become less prevalent, ORNL will shift focus to a deeper level, leveraging the cooperation of data and operations staff to find new, innovative energy-savings potential.

ORNL is continuing to build a foundation of awareness to make energy efficiency increasingly part of daily operations. A goal has been established to make energy implications part of consideration for specific ECMs in addition to being the daily operation, maintenance, and update of buildings and their systems. Energy managers cannot be a part of all decisions, so it is important that the decision-making process includes considerations of energy efficiency and life-cycle cost.

ORNL will continue to leverage the power of building operations data from existing systems, including the building automation and metering systems. New sensors and meters will be added in strategic locations, and new capabilities will be built out in existing systems or layered on with new systems as necessary. Focus will be placed on developing tools for operations staff to maintain building systems in a way that supports reliability, meets the needs of building occupants, and achieves energy efficiency.

The Utility Division will continue to evaluate utility systems for improving operations, improving reliability, and reducing maintenance costs. Future steam distribution projects include a new dry lay-up process for one boiler to reduce natural gas and water required to maintain the boiler in hot stand-by condition during the summer months. A new steam treatment program is planned to reduce further corrosion of the carbon steel components in the condensate return system, decrease the amount of caustic in the boiler water and reduce the amount of salt and regeneration water to operate the polisher system.

Future expansion of the Medium Temperature Water System to support significant growth in HPC is expected in the next few years. HPC is expected to increase 70% in FY 2023 and double by FY 2028, compared to FY 2018's utilization.

Continued improvements such as new transformers and switchgear will provide additional reliability and maintenance savings. A project to install a feeder unground is expected to increase service reliability as it will be more protected and less subject to weather and tree impacts.

Energy Management: EISA Section 432 Benchmarking and Evaluations

Performance Status

In FY 2017, ORNL began a new 4-year energy audit cycle using a graded approach that incorporates American Society of Heating, Refrigerating and Air-Conditioning Engineers audits, as well as laboratory-specific evaluations. The graded approach also leverages technology in the form of fault detection diagnostics (FDDs), meter data analytics and building energy modeling in addition to facility walkdowns.

In FY 2018, the application of building energy models to the energy auditing process began through collaboration with ORNL's Energy and Transportation Science Division research staff. As part of a previously-funded Laboratory Directed Research and Development project named Urban-MET (FY 2016–2017), ORNL staff applied AutoBEM technologies and manually-collected data (e.g. laser scans for measurement of window-to-wall ratio of every building façade) of 31 buildings on the ORNL campus. DOE has invested $85 million since 1995 in the development of EnergyPlus and OpenStudio – which simulates thermodynamics and energy consumption of buildings as well as provides tools to rank individual ECMs (e.g. add insulation, change HVAC control) by cost-effectiveness. The Urban-MET project created EnergyPlus and OpenStudio models of ORNL buildings, resulting in a virtual ORNL campus that can be simulated. FY 2018 efforts were focused on a subset of these buildings calibrating to industry standards with real advanced meter data and quantifying the impact of ECMs.

Measurement and verification (M&V) of ORNL's ESPC installed ECMs is ongoing per the contract between Johnson Controls Inc. (JCI) and DOE. JCI employs a full time, onsite performance assurance engineer who leads the M&V effort. M&V activities are witnessed by the ORNL DOE Site Office contracting officer's representative

with the engagement of UT-Battelle's Energy Efficiency and Sustainability Program as well as Utilities Division staff. Monthly ESPC performance reviews are held by JCI with ORNL DOE Site Office and UT-Battelle personnel and annual M&V report review and comment resolution process is conducted with the same group.

ORNL strives to measure and verify the performance of internally funded projects as well. This process aims to balance the rigor, time and cost of M&V with the scope, scale and data availability associated with each project. Processes have been developed to imbed M&V into maintenance and operations work flow. For example, an LED class has been established in ORNL's computerized maintenance management system to routinely collect pre and post retrofit wattage as well as lighting controls related information from the work supervisors prior to work order closeout.

Energy Management: Facility Metering

Performance Status

As part of the FY 2015 SSP, ORNL created an extensive site-wide metering plan that included the status and plans for all metered utilities on campus. The metering plan is a comprehensive document that charts a course for ORNL's continued advanced metering deployment which is consistent with the *November 2014 Update to the Federal Building Metering Guidance* and with current DOE directives focused on adding electricity, natural gas, steam, and water meters where cost-effective and appropriate. The metering plan is updated at least annually to document progress that has been made and to note any shifting in priorities.

In FY 2018 ORNL installed 47 new advanced utility meters across all utilities, including electrical, steam, chilled water, natural gas, and potable water. The meters were connected to ORNL's Central Energy Data System (CEDS) for data archiving and analysis. CEDS can log multiple parameters from each meter on a standard 15-minute interval. This system also enables meter data trend analysis, report generation, and energy awareness dashboard deployment as well as data export for use in other analyses.

Meters at service entrances to ORNL are also used to validate services for utility provider payments (electricity, natural gas, and water). The service-level meters along with building-level metering is used to distribute utility service costs among programs at ORNL for cost recovery and energy/fuel/water tracking for various reporting and identification of problems and potential conservation opportunities.

Metering is also used in the review of the Measurement and Verification report for the Energy Savings Performance Contract (ESPC) with Johnson Controls.

As with any project undertaking of this scale, continued meter deployment will not be without barriers. These barriers may include installation funding limitations, alternative prioritizations of the installation labor force, utility outages or service interruptions required to accommodate installations, and technical challenges.

In FY 2017 ORNL began deploying a new module for the CEDS system called "Resource Advisor" (RA). In FY 2018, ORNL used RA's advanced configuration capabilities to easily calculate and quickly display total building energy consumption using data from the advanced utility meters. RA provides more comprehensive dashboard and energy-analysis capabilities that align with ORNL's continued maturation in energy data utilization. RA directly feeds metered energy data into Energy Star for benchmarking.

ORNL has used its robust network of building-level utility metering to establish a system for continuous energy monitoring using a meter alert capability in the CEDS system. Alerts are placed on real-time mechanical utility meters including steam, chilled water, natural gas, and potable water for all buildings that have these mechanical meters in CEDS. Alert parameters are determined by reviewing meter trend history, analyzing as many months or

years prior as possible to obtain an accurate representation of each building utility "base" or "normal" trend usage. Meter alerts can be sent out through email or text to the designated person responsible for investigating and, if needed, correcting the issue. Meter alerts have identified and prevented unnecessary waste. Some examples of successful utilization of these alerts include: preventing steam waste (e.g. a steam valve failing open or a pressure regulator valve failure) and water waste (a make-up water valve being left open to a chiller during maintenance, or the float for a tower sump periodically sticking and flooding the sump with unnecessary water usage.)

Plans and Projected Performance

ORNL will follow its metering plan to continue installing additional advanced utility meters, where cost-effective and appropriate, on all utilities. All of these meters will be connected to ORNL's CEDS for data analysis and archiving. Resource Advisor will be used to expand energy awareness with more robust dashboards and analyses for facility managers, facility engineers, and eventually the greater lab population. ORNL will continue to learn and explore Resource Advisor's capabilities to leverage the full potential of the system. Along with RA, energy data threshold alerts will be optimized, and continued efforts will be made to leverage meter data for facility and utilities operational awareness and improvement. Additional metering will expand building-level EUI and WUI tracking for potential project opportunities and reporting metrics as well as enhance cost recovery efforts.

Energy Management: Non-Fleet Vehicles and Equipment

Performance Status

At only a fraction of 1% of all facility energy, Non-Fleet Fuels (Facility Vehicles and Equipment) are a comparatively minor source of energy usage and emissions at ORNL. We remain in compliance with reporting and tracking the use of these fuels (diesel, biodiesel, gasoline, and oils) for DOE SSP reporting and performance.

Plans and Projected Performance

Alternative fuel source landscape equipment has been discussed as a more efficient option for landscaping requirements, and a possible factor in reduction of non-fleet fuel consumption. Sustainable ORNL and the Fleet management team are in discussions concerning a possible procurement to obtain and evaluate this type of equipment for use at the lab.

Water Management

Water Management: Water Usage Intensity (WUI)

Performance Status

ORNL procures potable water from the City of Oak Ridge for domestic use (handwashing, flushing), cooling (cooling towers, chillers), heating (steam generation, hot water generation), limited landscape irrigation, laboratories, and special research processes. ORNL does not utilize gray water or industrial, landscape and agricultural (ILA) water.

ORNL has long been aware of the benefits of effective water management, having already experienced a 61.1% reduction in water use compared with its highest level of water use experienced in FY 1985. A firmly established aggressive plan continues to be deployed. Numerous strategies are engaged to reduce water consumption which includes repairing leaks, replacing old lines in the site water distribution system, and eliminating once-through cooling (OTC) where possible; resulting in a 20% reduction in annual total water use since FY2007 (Figure 14).. The cumulative result of these efforts is a WUI value of 123.1 gallons per gross square foot (G/GSF) in FY 2018, which is a reduction of 30% from FY 2007 (Figure 12).

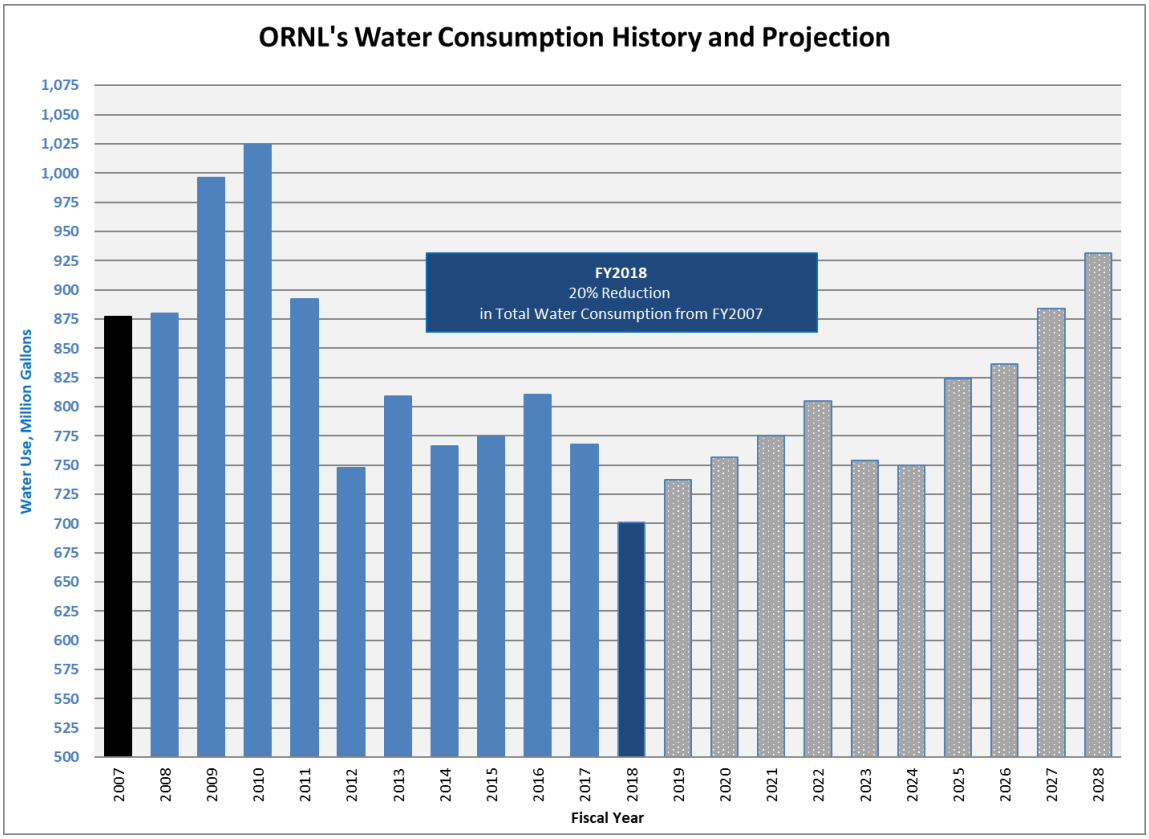


Figure 11. Historical, current (FY 2018), and projected water use at ORNL.

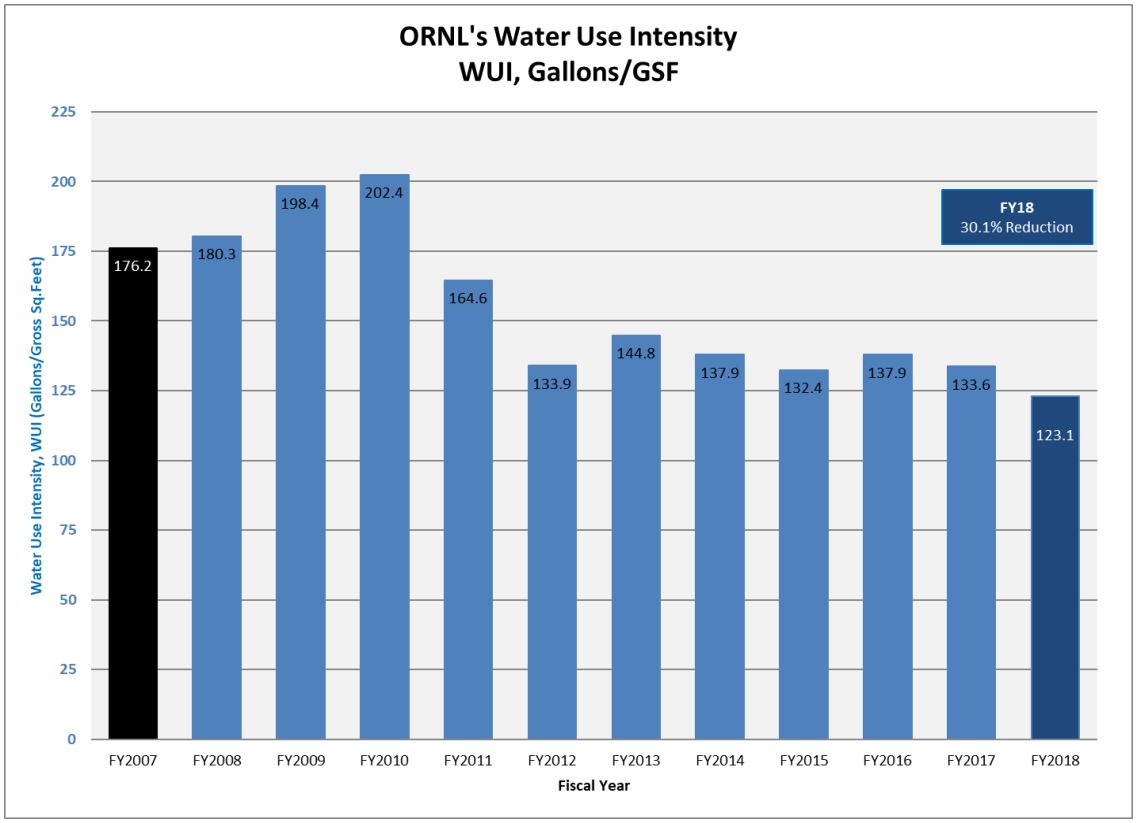


Figure 12. Baseline (FY 2007) and current (FY 2018) water use intensity at ORNL.

Water Management ECMs and initiatives in FY 2018 include:

- The closed-loop process cooling water system to replace the OTC method in Building 4508 has eliminated approximately 23 million gallons in FY 2018.
- Efforts to maintain the WUI-improving measures initiated in FY 2008 upon the award of an Energy Savings Performance Contract (ESPC) and will continue to save an estimated 170 MGY.
- The ORNL Utilities Division has identified and repaired twelve significant leaks in the water distribution system, including replacing over 230 feet of pipe sections, six valves/isolation points and five hydrants. Several leaks appeared to have been leaking for some time undiscovered until the repair was underway.
- Additional water system enhancements include new instrumentation screen for the Control Room operations, and new equipment installation for water quality improvements and sewage treatment facilities.
- To gain a better understanding of water use at ORNL, a water-metering plan is being implemented. Many of ORNL's most significant water-consuming facilities have been updated with advanced meters that are connected to ORNL's Central Energy Data System (CEDS) and are collecting interval data. These data are used to understand water end uses, consumption patterns, and potential opportunities for WUI reduction.

Plans and Projected Performance

Current performance and future projections indicate that ORNL's WUI is subject to rise due to increased demands for cooling tower makeup water to support growth of HPC systems. Therefore, ORNL must aggressively pursue additional water-savings opportunities to offset mission-specific demands to continue to reduce overall water consumption. With continued modernization activities that include elimination of old facilities and the addition of new facilities, ORNL must consider more water-efficient systems and must maintain a focus on water management best practices to meet future WUI reduction goals:

- Planned growth to support ORNL's HPC mission is projected to result in additional water consumption for cooling towers. While the HPC mission growth has begun, it is expected to peak in FY 2028 at 389 MGY and perhaps further.
- New building-specific locations and strategic points on the site's water distribution system will be evaluated for installation of advanced metering. Deep analysis of accumulated water meter interval data will be an increased focus area.
- Continue to aggressively identify and repair leaks and replacement component failures in the vintage water distribution system.
- An enhanced site-wide water balance is being developed to better account for specific water end uses and to prioritize additional advanced water meters. This effort will also serve to identify new water conservation opportunities.

Water Management: Water Consumption and HEMSF Research

ORNL's mission utilizes water for processes and cooling services. The 19 facilities identified in Figure 13 had the highest WUI at ORNL in FY 2018, several of which are associated with chilled water and steam production. As with energy, ORNL's water consumption is directly tied to mission-critical research growth and is expected to increase in the next 10 years.

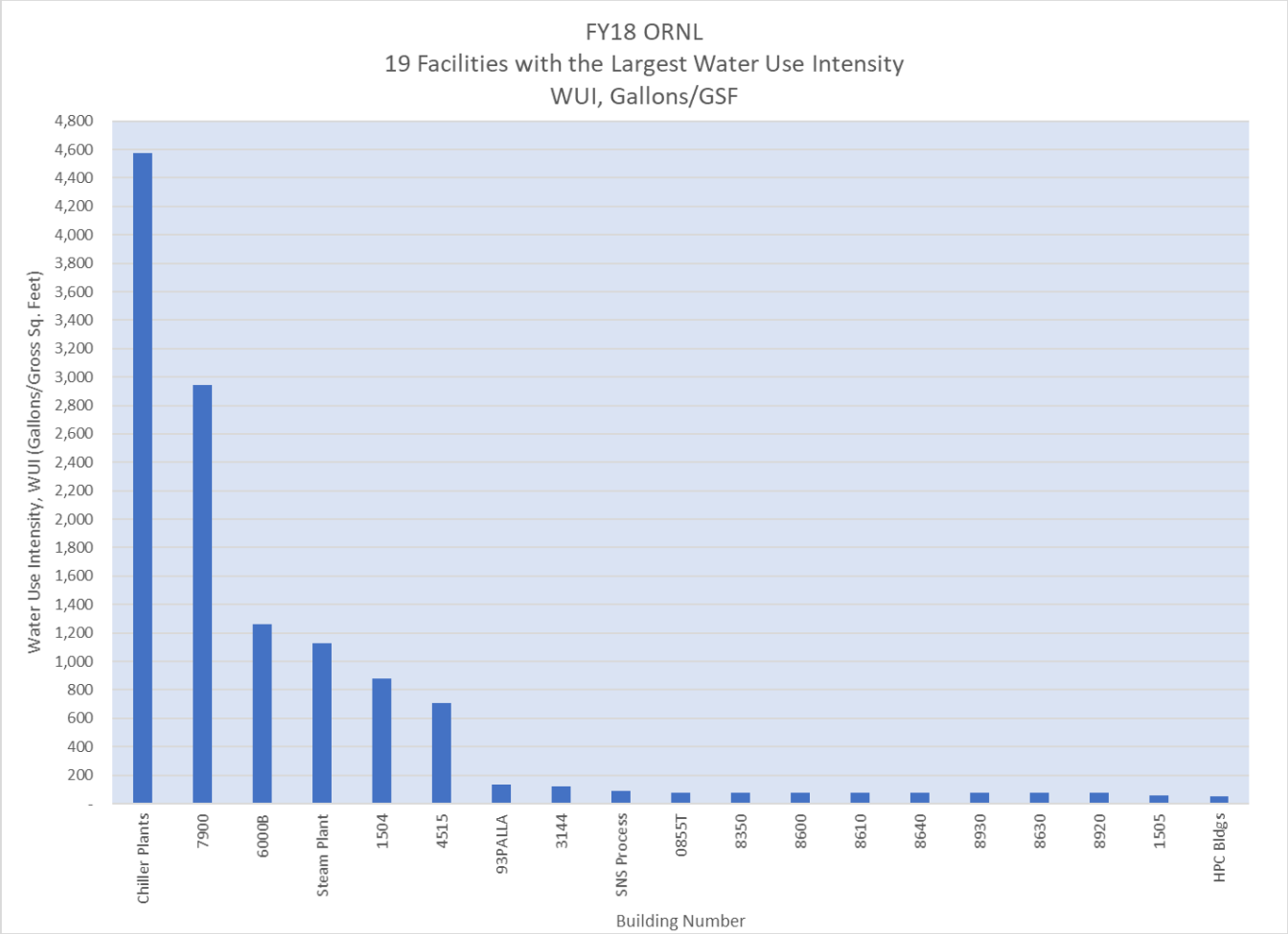


Figure 13. The ORNL facilities with the highest water use intensity in FY 2018.

Eleven facilities are responsible for 80% of ORNL's total water consumption. Building 7900 (HFIR) and is ORNL's largest user (Figure 14).

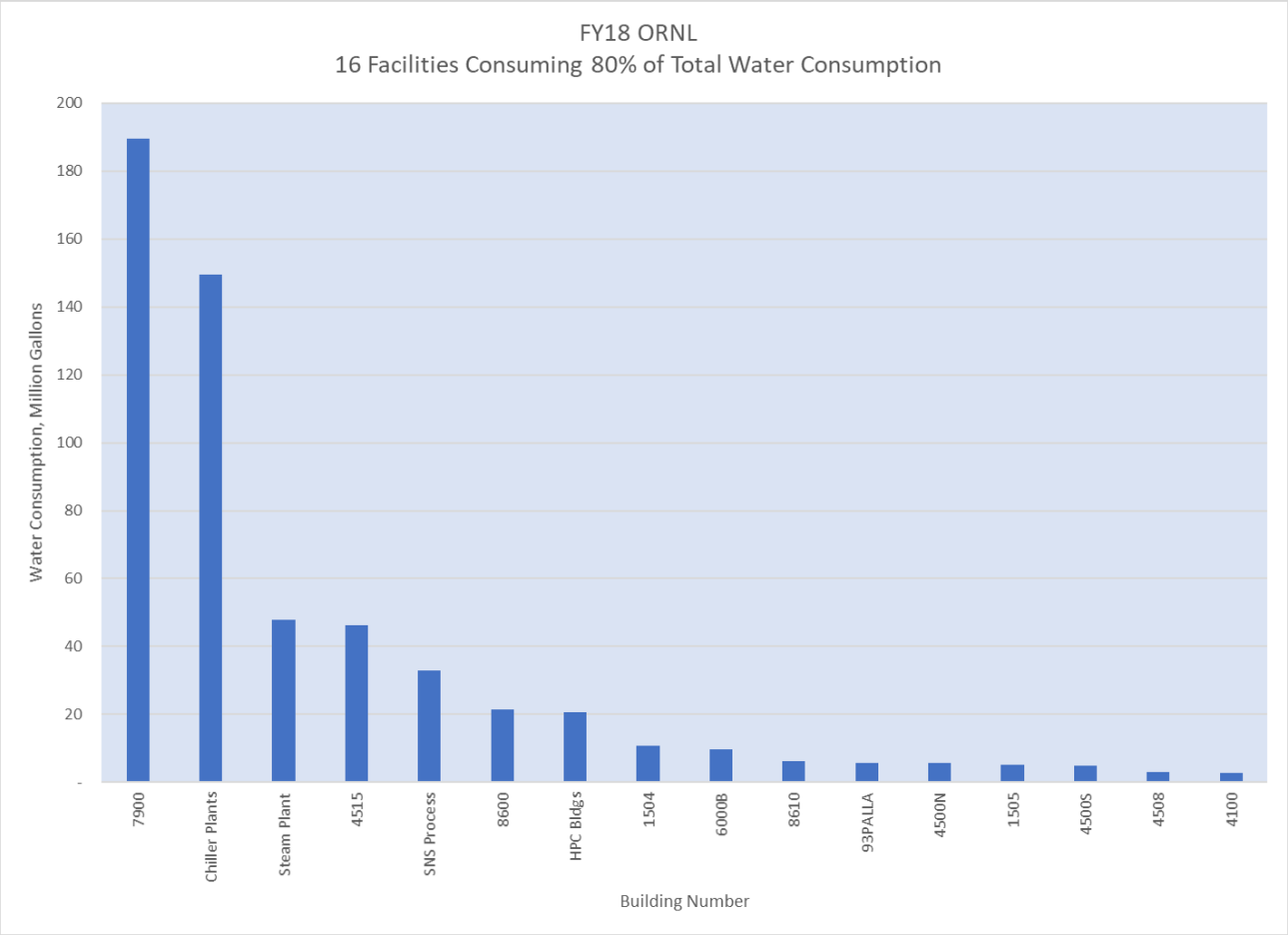
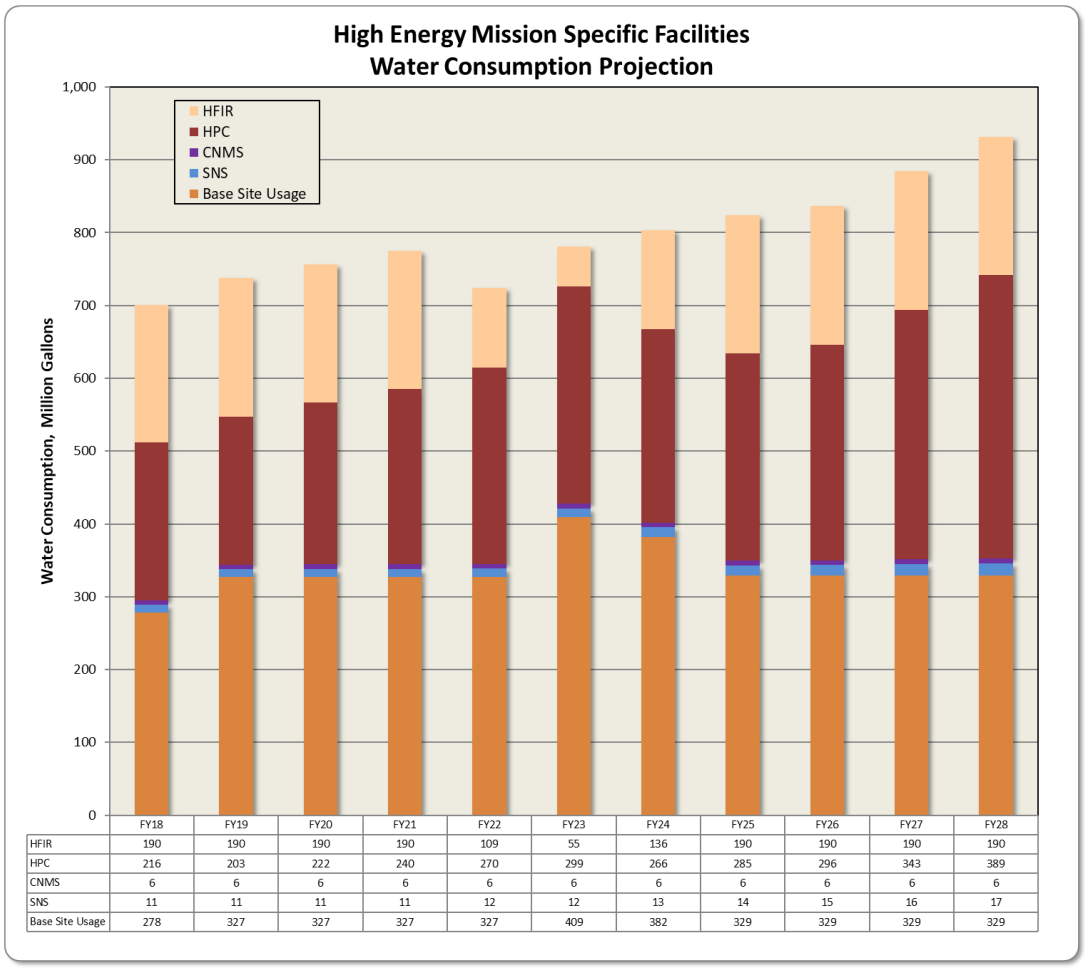


Figure 14. Water usage in the 16 facilities that consumed 80% of water at ORNL in FY 2018.

ORNL's HEMSF systems consumed 60% of ORNL's water use in FY 2018 and are expected to increase to 65% by FY 2028. HPC activities were responsible for 31% of ORNL's water consumption in FY 2018; that amount is expected to increase to 42% by FY 2028 (Figure 15).



	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
HFIR	190	190	190	190	109	55	136	190	190	190	190
HPC	216	203	222	240	270	299	266	285	296	343	389
CNMS	6	6	6	6	6	6	6	6	6	6	6
SNS	11	11	11	11	12	12	13	14	15	16	17
Base Site Usage	278	327	327	327	327	409	382	329	329	329	329

Figure 15. Current (FY 2018) and projected HEMSF water consumption at ORNL.

Waste Management

Waste Management: Municipal Solid Waste and Construction & Demolition Waste

Performance Status

ORNL's annual performance for Waste Management starts with source reduction. The ORNL pollution prevention (P2) program vision, approach, program, and plan embody the commitment of ORNL management and staff to embrace sustainability, including reducing waste generation and toxicity. Accomplishing successful, sustainable results requires the merger of administrative and cultural changes with new technologies and procedures. Within waste management, the generation of waste and pollutants is minimized first through source reduction, and then by reuse and recycling if a waste must be generated.

An example of a P2 focus area has been to reduce and divert the amount of material going to the landfill with efforts including the following:

- Development and use of contract language requiring construction contractors to recycle as much construction debris as possible and to report the recycled amounts

- Extensive use of training, awareness, presentations, and outreach and of placement of recycling containers throughout the lab to encourage source reduction and recycling
- Identification and implementation of pollution prevention practices through project planning, operational assessments, trash can and dumpster monitoring, and National Environmental Policy Act reviews
- Maximized recycle/reuse for municipal solid waste (MSW) and construction and demolition (C&D) waste, including off-site recycling of scrap metal, pallets, broken furniture, equipment, wood, tires, paper, cardboard, toner cartridges, asphalt, and drums.

The quantities of landfilled waste and diverted waste are highly dependent on ORNL's continued significant mission growth and associated on-site research and support activities, which are further detailed in the "Mission Change" section of this report, as well as the types of projects funded. Also, specific efforts to extensively characterize wastes from deactivation and decommissioning (D&D) activities prevents costly disposal as low-level radioactive waste and reduces costs by managing it as C&D waste. Furthermore, the presence of certain regulated materials (e.g., asbestos) prevents the recycling of some demolition waste and thus prevents the laboratory diversion rate from being even higher. Although these situations cause landfilled and diverted waste values to fluctuate, ORNL has emphasized source reduction efforts across the lab, such as the use of paperless systems, as its preferred pollution prevention technique. Even with mission growth, these source reduction efforts along with other factors, such as diversion, have contributed to the overall downward trend observed in the combined amount of MSW and C&D waste sent to on-site landfills by ORNL and an overall increase in reuse and recycling.

Specifically in FY 2018, ORNL's diversion rate for MSW reached 42% and the rate for C&D waste materials and debris reached 80%. Also, ORNL does not currently have waste-to-energy system and does not plan to obtain one.

As part of its source reduction efforts, ORNL increases the use of acceptable nontoxic or less-toxic alternative chemicals and processes while minimizing the acquisition of hazardous chemicals and materials through material substitution; operational assessments; and inventory management, including using the ORNL Chemical Management Center. One example implemented in FY 2018 involved a researcher who took the initiative to identify and implement a replacement for xylene using a nonhazardous solvent, which was successfully used as a cleaning agent in a histology experiment. This success was shared within ORNL and will be shared at future conferences with researchers from other labs.

Anirban Guha, a postdoctoral researcher at ORNL, holding samples prepared with a newly developed, nontoxic agent

Plans and Projected Performance

While expected future mission and population growth could cause diverted waste and landfilled waste values to increase, the use of source reduction and recycling will allow the lab to somewhat minimize the impact of this growth on landfilled waste. Furthermore, ORNL will continue to use extensive characterization of D&D wastes to minimize the generation of low-level radioactive waste, which may increase the amount of landfilled C&D waste.

Planned activities include:

- Identification and implementation of additional source reduction opportunities
- Identification of new streams to recycle followed by cost effective implementation
- Use of awareness activities to increase source reduction and recycling implementation by staff across the lab
- Reevaluation of opportunities for composting by the ORNL cafeteria operator and continuing discussions with neighboring organizations and the City of Oak Ridge, researching the feasibility for a regional composting pilot

Waste Management: Pest Management and Landscape Management

Performance Status

ORNL implemented the Integrated Pest Management (IPM) program, which includes both interior and exterior strategies for the entire ORR. Practices include environmental controls such as ensuring that all cracks and holes are sealed to minimize pathways for pests to enter a building and educating building occupants as to the importance of good housekeeping regarding food storage, waste collection, and plant maintenance. The goal is to reduce the exposure of building occupants and maintenance personnel to potentially hazardous chemical, biological, and particulate contaminants that adversely affect air quality, human health, building finishes, building systems, and the environment while controlling potential infestations of insects, rodents, fungi, and invasive plant species.

The IPM includes removal of invasive plants, nuisance wildlife, and hazardous trees along roads and monitoring forest pests (emerald ash borer, walnut twig beetle, hemlock woolly adelgid, gypsy moth, pine beetle). The following activities were carried out in FY 2018:

- A variety of nuisance animals (131 in all) that were presenting employee safety concerns and/or damaging infrastructure were removed from the ORNL campus.
- Control of invasive plants (e.g., kudzu) was conducted in a number of areas in and around the ORNL campus, including along Bethel Valley Road and multiple secondary roads, riparian zones, Clinch River Cabin, and multiple kudzu infestations near campus.
- Exclusion methods such as filling groundhog burrows and bird exclusion netting were utilized.
- Artillery fungus was identified as the source of tiny black dots that were getting on employee's cars. The problem was solved by replacing the old mulch; no fungicide was necessary.
- To limit the spread of fire ants, new landscaping plant purchases were checked for fire ants, and existing mounds were treated with an IPM-approved pesticide.

Plans and Projected Performance

ORNL continues to demonstrate commitments to programs that enhance the physical environment through its Landscape Management practices:

- Planning based on sustainable principles in the Sustainable Landscapes Initiative 2020
- Increasing and improving pollinator habitats

Fleet Management

Performance Status

During the last 3 years the ORNL Fleet Office has purchased 25 alternative fuel vehicles (AFVs) to replace many diesel-fueled vehicles. During FY 2018, the Fleet replaced larger diesel trucks with more duty cycle relevant, smaller alternative fuel (E85 or GAS-PHEV) vehicles. In the vehicle acquisition planning process with DOE, ORNL fleet management works to maximize the acquisition of AFVs and PHEVs. As vehicles are retired from service, they will be replaced with models that are more efficient; the number of fleet vehicles is not expected to increase.

- ORNL works to expand the use of les AFVs, including plug-in electric vehicles (PEVs), to help meet ORNL goals and those set forth in federal directives for reduced use of petroleum-based fuels and increased fleet fuel economy. One goal was that 75% of light-duty vehicle (LDV) acquisitions must be AFVs by 2016. ORNL exceeded that goal; 100% of its LDV acquisitions are AFVs.
- Via telematics, ORNL collects data on use, battery charging, and fuel economy of one fleet PHEV and one fleet non-PHEV. In FY 2016, ORNL purchased four additional telematics devices with advanced capabilities. By applying ORNL's expertise in PHEV data analysis, the laboratory can monitor for problems and quickly provide solutions. It can also aid in decisions of where to best use PHEV and charging infrastructure as more PHEVs are added to the fleet.
- In terms of fleet optimization and vehicle right-sizing, when new vehicles are considered and discussed, the ORNL Fleet Manager meets with the custodian/drivers of vehicles to verify that the vehicles meet the the job requirements. For example, five diesel-fueled light-duty trucks with numerous engine issues were replaced with E85-fueled light-duty trucks. The continued practice of obtaining replacements will improve all aspects of the ORNL fleet's performance.
- ORNL continues to encourage anti-idling practices; signs are placed in key areas, and regular reminders are sent to all employees who use fleet vehicles.
- Researchers used data from sustainable ORNL fleet to complete a vulnerability analysis on the electronic networks, sensors, and telematics data communications of transport vehicle operational and security functions for the National Nuclear Security Administration Office of Radiological Security.

Alternative Fuel Use and Infrastructure:

ORNL has worked to maximize the amount of biodiesel (B20) in equipment and applicable diesel vehicles. ORNL also has dedicated E85 pumps on our closed-campus fueling site (Figure 16). In addition, use of E85 is encouraged and marketed for ORNL fleet vehicles.

Figure 16. E85 fuel pumps at ORNL.

Plans and Projected Performance

ORNL plans to pursue the following tasks in its ongoing efforts to increase the fuel efficiency of its fleet:

- Continue to increase alternative fuel use (including electric, biodiesel, ethanol)
- Investigate the feasibility of conducting a trial run of one or two mowing machines powered by alternative fuels on ORNL grounds and to report on further recommendations
- Investigate options for idle reduction for new ORNL protective force vehicles that are being added to the ORNL fleet (General Services Administration) vehicles, which have separate rules for modification) and report of recommendations
- Pilot trial of renewable diesel in a fleet vehicle/ or low speed vehicle – draft report on experience and recommendations for further use

Renewable Energy

Performance Status

In FY 2018, ORNL purchased renewable energy credits (RECs) to supplement onsite renewable energy generation, representing 8.8% of the lab's electrical energy consumption. ORNL onsite renewable energy and REC purchases resulted in calculated renewable electricity usage of 51,690 MWh for the year. The result is a performance of 8.9% exceeding DOE's 7.5% target as identified in the Energy Policy Act of 2005 (EPAct2005).

ORNL has identified multiple sources of renewable energy to offset the site's total electrical consumption of 582,731 MWh, including the following:

- 145 MWh of electricity produced onsite by the five solar arrays account for approximately 0.025% of ORNL electricity, which includes the double bonus allowed for onsite generation at federal facilities. Associated RECs are retained for use by the site.
- Continued participation in the Tennessee Valley Authority Southeastern REC pilot by purchasing 14,400 MWh of renewable energy in FY 2018.
- Via a competitive procurement, ORNL purchased 37,000 MWh of RECs from wind resources in 2018.

- ORNL's bid request included an opportunity to offer RECs for purchase from Indian Lands; however, no bids were received with the option to purchase RECs from the requested source.

Plans and Projected Performance

For the near-term future, ORNL will continue with recent strategies to purchase sufficient RECs to meet the renewable energy goal, until additional renewable and/or clean energy goals are identified. We will continue to investigate onsite economically feasible renewable energy projects to minimize annual REC purchases. Strategies used to meet the renewable energy goals will also result in progress toward GHG emissions reduction. Specific plans include the following:

- Sustainable ORNL will take the lead in the continued investigation for a potential large-scale solar project at the main campus or a remote campus location. ORNL would like to encourage a project development plan that would combine/pair research opportunities, such as microgrid research, with large solar installations for renewable credit. The Hardin Valley campus specializes in grid technology and may be a candidate for additional consideration in the future. We will continue to evaluate project concepts that include financial benefits such as investment tax credits and research grant opportunities.

- Along with other Guiding Principles, incorporation of energy efficiency and renewable energy features will be considered in new building design conceptualization.

- Life-Cycle Cost Analysis and project payback are critical when investing public funds; and sustainable solutions must include financial considerations. Until renewable projects are identified and implemented to meet onsite renewable objectives, RECs will be the primary cost-effective means to meet DOE goals. ORNL's primary strategy is to develop onsite capabilities, ideally incorporating research possibilities, before considering other options.

ORNL REC purchase strategy options will include:

- Periodic monitoring of the REC open-market and consider purchasing opportunities as they arise. We will also monitor changes in renewable goals, and strive to purchase the quantity of RECs needed to meet or exceed renewable targets as they change.
    - Note: The current renewable energy goal of 7.5% is covered under EPAct2005. Any modification in targets/goals will be followed.
- Plan for multiple strategic purchases throughout the year based on energy consumption projections and REC pricing to best fit the identified annual targets.

- Develop specific REC strategic purchasing guidance to help incorporate these strategies into a viable document to help determine the best value for the long term. Guidance should encourage brokers to provide better tribal options, include dedication of RECs to specific buildings for Leadership in Energy and Environmental Design (LEED) certification, consideration for premium REC cost from Tribal Land resources, and other goals.
- Will seek options to engage in a multi-year purchasing agreement that will provide a more streamlined and flexible procurement process.

Green Buildings

Green Buildings: Guiding Principles

Performance Status

In FY 2018, ORNL's high performance sustainable building (HPSB) inventory included a total of 20 buildings that are certified as having attained 100% of the HPSB Guiding Principles (GPs). This represents 15% of the total applicable site buildings according to the *Guiding Principles for Federal Leadership in Sustainable Buildings*. This meets the current GP target (15% by building count) for DOE Green Buildings, 100% GP attainment.

In prior reports, ORNL included three third-party and joint-institute facilities in the HPSB total because they are operated and maintained by ORNL and because they had been grandfathered. The revised HPSB GPs stipulate that contractor-owned leased facilities should not be included in HPSB GP accounting. ORNL's third-party and joint-institute facilities are categorized in FIMS as contractor owned; therefore, they will no longer be included as applicable site buildings or in the total HPSB count.

Employing a systematic approach to identifying HPSB candidates and applying the GPs has been an effective way to ensure continued progress. HPSB candidates have been identified based on building space use, existing metering infrastructure, and known energy conservation opportunities. Action plans for achieving building-specific GPs are developed and executed while laboratory-wide standards are used to fulfill HPSB applicable policies and procedures. Engagement of facility managers, facility engineers, and other technical personnel has been essential to acquiring quality benchmarking data, performing commissioning activities, and implementing energy conservation measures.

As experience with the GPs has grown, the focus of ORNL's HPSB efforts has begun to shift from office buildings to include laboratory and mixed-use buildings. The existing building-commissioning process has proven very beneficial in identifying opportunities to optimize existing equipment and systems to better align with current space use. With the evolution of research programs and projects, buildings are often used in a manner that is different from their original designs. Therefore, identifying, evaluating, and adjusting HVAC airflow volumes, set points, control sequences, and related actions have provided the best return on investment.

Achieving HPSB status is only the beginning of an ongoing cycle of "plan, do, check, act." Advanced metering and building automation system data are leveraged to monitor ongoing performance. This ensures the persistence of savings and may even help to increase them over time.

Plans and Projected Performance

ORNL will continue to work on evaluating applicable site buildings to achieve greater compliance with GPs and will continue to strive to progress toward 100% compliance (Figure 17). ORNL will focus on leveraging energy data and performance analytics whenever possible to make progress towards fulfilling GPs. Partial GP compliance, for many buildings, can be achieved through referencing existing site policies, procedures, and engineering standards. As it becomes increasingly more challenging to apply 100% of the GPs to ORNL's most complex buildings, intensive effort and often capital investment will be required to make significant changes to reduce energy consumption. Additional time will also be required to measure performance and verify savings. Efforts will continue toward expanding the existing HPSB inventory at a pace that does not compromise the ability to effectively manage the buildings that have already achieved HPSB status.

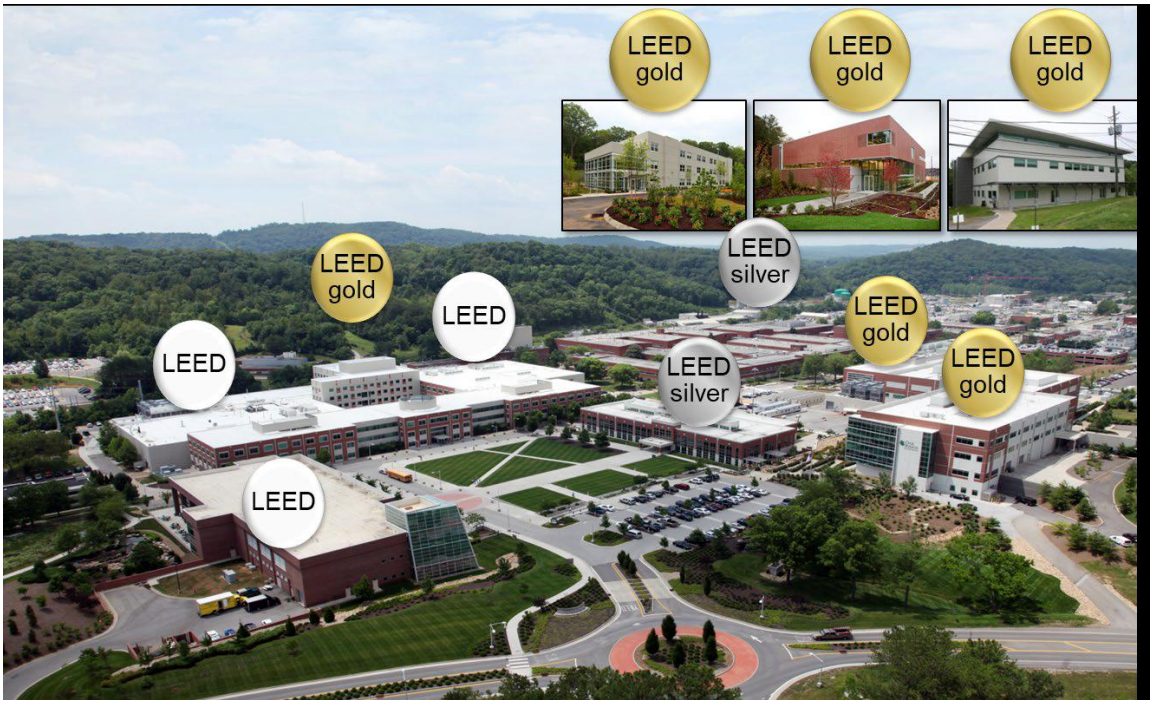


Figure 17. Examples of LEED Certified buildings on the ORNL campus.

Green Buildings: New Building Design

ORNL has been designing and constructing new buildings to achieve LEED Certification since 2004. Beginning in 2010 and extending through 2016 ORNL established a goal to design and construct all new buildings to achieve LEED God Certification. In 2017 the policy was modified to require all new construction to be fully compliant with the 2016 Guiding Principles for Sustainable Federal Buildings (Guiding Principles) to the fullest extent technically and economically feasible.

Inherent to the Guiding Principles, all new construction is designed at 30% more energy efficient than the baseline established by ANSI/ASHRAE/IESNA Standard 90.1. As of August 2018, the current version in effect is ASHRAE 90.1 2013 (10 CFR 433.100). ORNL's policy to require compliance with the Federal Guidelines will ensure new construction meets this requirement.

Acquisition & Procurement

Performance Status

All applicable contracts in FY 2018 contained terms and conditions that invoke requirements for sustainable acquisitions. To solidify DOE sustainable acquisition strategies, three federal acquisition regulation (FAR) clauses were added to the standard commercial items in terms and conditions contracts beginning in January 2016. Since that time, all subcontracts are reviewed for these terms prior to release.

Standard contract terms and conditions, which are made part of all procurement actions for commercial items and services, invoke the pertinent FAR contractual requirements for energy efficiency and sustainability. Those clauses were included in 100% of the following FY 2018 subcontract actions:

- ORNL issued 15 new construction subcontracts and 4 demolition subcontracts in FY 2018, 100% of which were reviewed and verified to contain the sustainability contractual requirements. No new janitorial contracts were issued in that period; however, Kel-San (janitor contract vendor) recognizes ORNL's interest in sustainability and has made environmentally preferred products (EPPs) a point of emphasis in their product line for ORNL. Kel-San offers more than 100 items that are either EPP or Green Seal certified. The items include all paper, hand care, and cleaning chemicals that it provides for our janitorial staff. The excellent product line provided by Kel-San helps support our sustainability goals.
- In FY 2018, all unique subcontracts, purchase orders, and task orders met the DOE procurement requirements for sustainable acquisitions.
- Terms and conditions issued with blanket ordering agreements contain all FAR provisions as well as additional requirements for promoting and providing environmentally preferable products. The Contracts Division includes subcontract language for key commodity suppliers, requiring that the vendors provide detailed reports on the purchases of electronics products designated as ENERGY STAR and the Electronic Product Environmental Assessment Tool (EPEAT).

Plans and Projected Performance

The ORNL Contracts Division includes various purchasing groups and a group responsible for policies, procedures, records, reports, and compliance. Advances and improvements in these processes to promote sustainable acquisitions and procurement are among the highest priorities, as the division remains committed to maintain 100% compliance with DOE 436.1 SSP goals.

Measures, Funding, & Training

Efficiency & Conservation Measures (ECM)

The "Energy Management: Energy Usage Intensity" section and the "Water Management: Water Usage Intensity" section of this report contain details of the ORNL strategies for prioritizing and implementing projects undertaken for ECMs and other operational improvements. The "Plans and Projected Performance" narratives for both EUI and WUI highly emphasize the importance of finding ECM projects that will increase operational and organizational improvements. ORNL is continuing to build a foundation of awareness to make energy efficiency increasingly part of daily operations. A goal has been established to make energy implications part of consideration for specific ECMs and for the daily operation, maintenance, and update of buildings and their systems.

M&V efforts include Life-Cycle Cost Analysis employing building/system/equipment data, engineering principles, and personnel expertise to perform the calculations and validate efficiency measures. ORNL tries to be consistent with its Life-Cycle Cost Analysis calculations, procedures, and methods to manage the wide range of projects throughout ORNL. In FY 2018, ORNL began utilizing a project planning tool, which included steps to measure and validate efficiency measures, and a Life-Cycle Cost Analysis project completion dashboard.

Funding

ORNL assesses the environmental, economic, and social benefits of proposed activities on an individual, project-specific basis. Through the mission readiness process, ORNL gauges the abilities of its facilities and infrastructure to accomplish mission objectives now and in the future. Projects are identified to meet the safe, compliant, efficient accomplishment of mission objectives, including sustainable operations. Funding sources for projects are evaluated and established by considering all available and appropriate funding venues, including private sector

financing, cost sharing, institutional investment, and programmatic appropriations. Allocation of funds is based on multiple considerations, including mission impact, sustainability, and return on investment. (Table 4).

The Sustainable ORNL program invests in sustainability activities (other than projects, ECMs) in support of the 12 Roadmaps, all at varying stages of implementation. Each roadmap has specific fiscal year deliverables that are kept on schedule by holding regular review meetings with individual roadmap owners and team leads. In addition, the Facilities and Operations (F&O) director has made success on these roadmaps a part of the directorate's performance plan. Roadmaps are reviewed quarterly. These scheduled reviews also provide a forum for the program associates to present new roadmap proposals.

Table 4. FY 2018 budget and future funding for sustainability funding categories

ORNL sustainability funding categories ($ × 1,000)	FY18 Actual	FY19 Planned/ Request	FY20 Projected
Sustainability projects	929	1,127	1,130
Sustainability activities other than projects	949	751	748
Sustainability Program Office (SPO) funded projects (SPO funding portion only)	0	0	0
Site contribution to SPO funded project	0	0	0
ESPC/utility energy service contract (UESC contract payments	10,351	10,691	11,042
Renewable energy credits (REC) purchase costs	54	70	82
Total	**12,283**	**12,639**	**13,002**

Energy Savings Performance Contracts

ORNL's Energy Savings Performance Contract (ESPC) with Johnson Controls, Inc. (JCI) was the primary mechanism for achieving the goals established to meet Energy Policy Act (EPAct) directives. A delivery order with JCI was awarded in July 2008 and was accepted in July 2012. This ESPC is creating opportunities for ORNL to improve its depth of experience in performance contracting and to develop an understanding of the most effective utilization of this funding mechanism. The ESPC is in year 7 of the 21-year contract term.

A dual-fuel natural gas/fuel oil boiler replaced the Biomass Gasification System that experienced operational difficulties. The new boiler has been in operation since FY 2016, and reductions in natural gas and fuel oil consumption have been achieved, complementing two similar dual-fuel natural gas/fuel oil boilers that replaced a vintage boiler installed under a separate activity. Steam distribution decentralization, including the new Melton Valley steam plant and steam production efficiency improvements, further increase ORNL's steam service and reliability.

Other ESPC improvements include lighting upgrades and water conservation measures. Equipment upgrades, a building management system, and modernized HVAC control systems provide the means to significantly reduce or eliminate energy-intensive simultaneous heating and cooling in several large air-handling units.

Training & Education

In FY 2018, two F&O personnel attended the DOE Better Buildings Summit and Energy Exchange in Cleveland, Ohio. Two other personnel attended the Energy and Sustainability Perspectives Summit hosted by Schneider Electric in Nashville, Tennessee. ORNL's Energy Efficiency and Sustainability Program personnel participated in periodically scheduled webinars hosted by the Better Buildings Smart Energy Analytics Campaign and the

Energy Facility Contractors Group (EFCOG) Sustainability and Environmental Sub Group (SESG). More than ten F&O personnel hold and maintain the Association of Energy Engineer's (AEE) Certified Energy Manager (CEM) credential and one attended the AEE World Energy Engineering Congress (WEEC) in Charlotte, North Carolina.

Plans and Projected Performance

- ORNL will continue life-of-contract activities associated with its current ESPC. This includes participation in monthly project performance review meetings, review of the annual measurement and verification report, and other support as requested by DOE. All funding paths for ECMs, including performance contracting, will be considered as ORNL works to meet sustainability goals.
- When considering financing mechanisms for performance contracting, ORNL identifies challenges such as the potential for savings interactions between existing and new projects as well as the impact of mission and facility changes inherent to ORNL's operating environment.
- Training for DOE's *50001 Ready* Navigator Tool, ISO: In the first quarter of FY 2019, four ORNL energy efficiency and sustainability associates will attend a 2-day seminar designed to improve energy performance in operations. The Ready Navigator expedites the integration of international best practices for energy management systems (Figure 18).

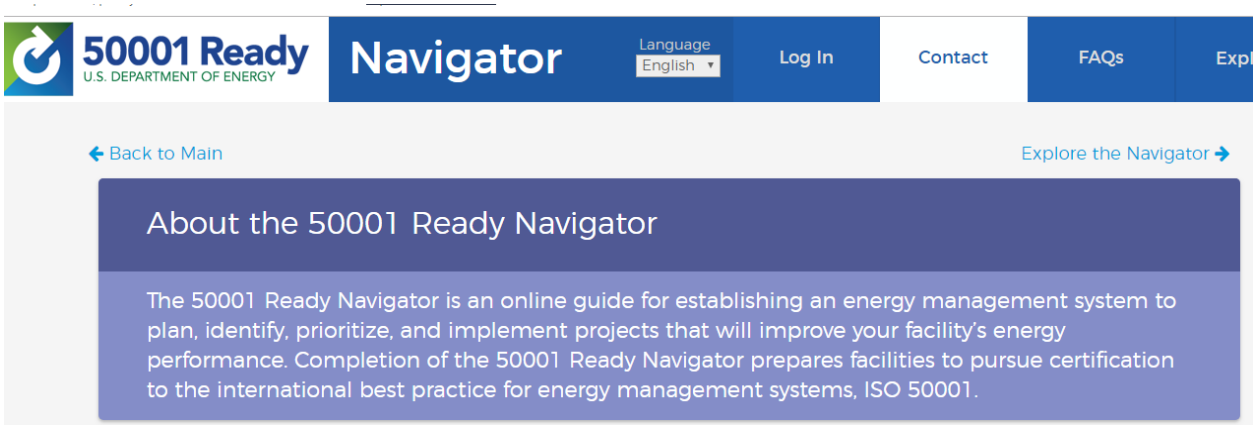


Figure 18. The DOE 50001 Ready Navigator tool.

Travel & Commute

Performance Status

Activities described in detail in previous ORNL SSP submittals include projects that promote sustainable employee commuting options. With the help of Sustainable ORNL and leadership support, employees are educated in the benefits of using carpools, alternative work schedules, and the proper use of EV charging stations. The ORNL NTRC Research Campus and Sustainable ORNL co-leads work together to study the development of more efficient transportation options and how those options could benefit the lab and lab employees in the near-term and over time. Projects such as improved videoconferencing tools in lieu of expensive business travel continue to yield positive results in travel budgets and associated emissions.

ORNL employees participated in the following commuting options/programs in FY 2018:

- 57 employees participated in assigned parking programs for official carpools and vanpools. Of these, 42 entered data into the Smart Trips™ system, a regional transportation project. Many more ORNL employees participate in ride share and carpools on an informal basis.
- More than 170 employees have completed a formal telework agreement over the past 3 years.
- Bus transit experienced increases in ridership and frequency of service for the dedicated route that connects ORNL/UT/PSCC route. The average bus ridership for 2018 was 46 employees and associates.
- 126 employees participated in alternative work schedules via 9/80 and 4/10 shift designs.

ORNL is a leader in the region in promoting electric vehicle use and has been actively participating in regional workplace charging efforts, including installation of 47 EV supply equipment charging stations at SNS, NTRC, and ORNL's main campus. An ongoing electric vehicle program allows ORNL employees access to charging stations (Figure 19). In 2018 there were 58 members in the ***ORNL EV Owner's Club*** with access to 41 staff charging station locations. Employees and associates pay an annual fee to join the club; then are allowed to charge their EVs in one of the charging stations during work hours. The club funds support the cost and maintenance of the EV chargers devoted to non-fleet charging.

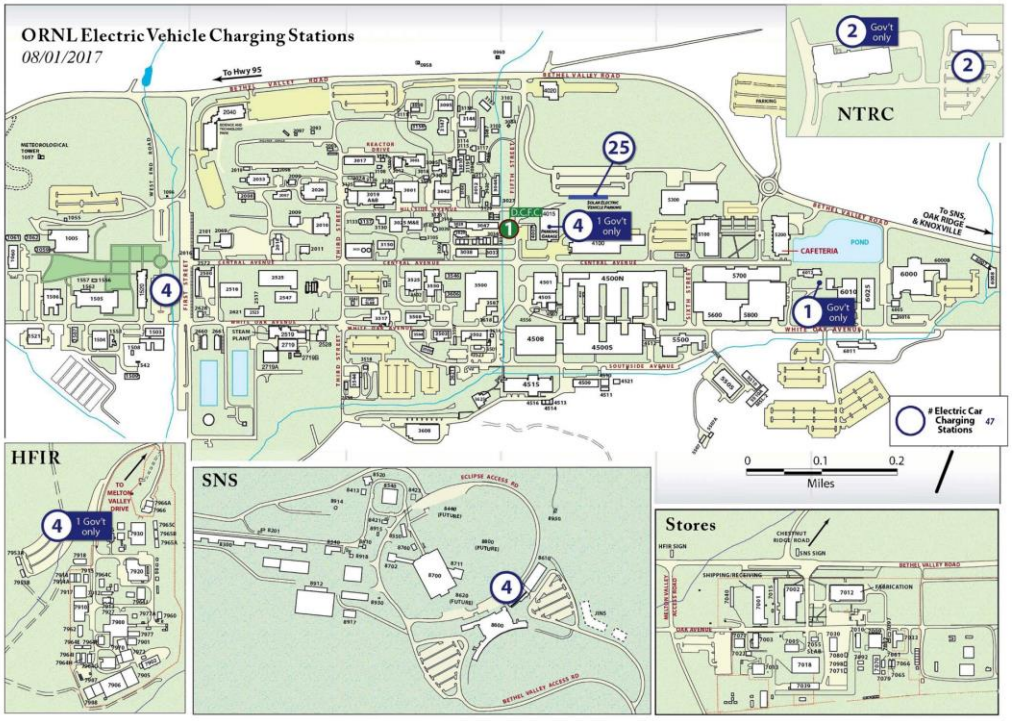


Figure 19. Locations of ORNL electric vehicle charging stations.

The "***Bike It Green***" Program is part of the Green Transportation Initiative at ORNL. Of the original 100 bicycles in the campus bike-sharing program, most are still operational. In order to participate in the program, members must complete online training, wear a helmet while riding the bikes, and avoid using sidewalks. More than 1,700 lab employees have completed the training.

FY 2018 Outreach Activities and Presentations include the following:

- ***Sustainable Transportation at ORNL*** Outreach Presentations were shared with the professional community
  - Tennessee Environmental Conference, March 2018 (S. Curran)
  - Technical Society of Knoxville, March 2018 (B. Hudey)
  - UT American Society of Civil Engineers Student Chapter, October 2017 (M. Lapsa)
- Continued collaboration with the local *DOE Clean Cities* coalition and regional stakeholders, including board service and active participation in quarterly meetings.

- Transportation research article, "Preliminary Routing for a National Laboratory Lab-Wide Commuting Program," was submitted for publication to the *Journal of the Transportation Research Board*

- Demonstration of AFV/PHEV for outreach events such as ORNL Earth Day (Figure 20).

Figure 20. Energy-saving demonstration vehicle, Earth Day at ORNL, 2018.

ORNL's travel and conference planning systems continue to evolve in order to simplify various aspects of the workflow and overall user experience. We also continue to rely upon and expand collaboration solutions to reduce travel expenses such as web-based meeting and remote collaboration. These solutions have conservatively saved more than $300k in annual travel expense. As an example, data analysis from the ORNL TravX business travel system shows that employees took 390 fewer business air flights in 2018 compared to the same 12-month time period in 2017.

Plans and Projected Performance

- Sustainable ORNL co-leads are working to bridge R&D capabilities with F&O needs.

- Currently discussing options for pilot Knoxville Area Transit (KAT) bus route to ORNL from West Knoxville, and connecting employees to the rest of KAT's bus service throughout Knoxville. Incentives such as Wi-Fi access on KAT buses will allow employees to work while commuting

- Step up efforts to inform employees of the benefits of carpooling and encourage local commuting partnerships such as Smart Trips™

- Continue to support research employees in collaboration such as *DOE Clean Cities* coalition
- Additional demonstration of ORNL transportation research such as alternative fuel/plug-in electric vehicle research
- Planning is underway to partner on electric vehicle ride-and-drive events to allow employees to drive the newest electric vehicles in support of the ***ORNL EV Owner's Club***
- Continue to track the benefits and cost savings of alternatives to business travel and will upgrade systems for better employee experience and increased productivity.

Fugitives & Refrigerants

Performance Status

When conducting the initial ORNL GHG inventory in FY 2008, Sulfur hexafluoride (SF_6) was identified as a significant contributor to ORNL's Scope 1 GHG estimates. It was determined that active management of SF_6 emissions was necessary to meet DOE's GHG reduction goals at the time. An overall awareness of the global-warming potential of SF_6 has resulted in a more cautious approach to the requisition and purchase of this potent GHG. ORNL is committed to evaluating processes and purchasing improvements with the potential to reduce SF_6 emissions.

The Holifield Radioactive Ion Beam Facility (HRIBF), located in Building 6000, was a national user facility for research with radioactive ion beams that is now being decommissioned. Operation of the tandem accelerator required the use of an insulating gas (SF_6) to prevent electrical discharge from the high-voltage terminal and accelerating column to the pressure vessel. At the end of FY 2018, 74,000 lb of SF_6 was transferred off site to a private company that purchased the gas from DOE SC. During transfer operations, SF_6 emissions were closely monitored for leaks and any fugitive losses. The transfer of the entire SF_6 inventory was completed in December 2017. There were an estimated 1,200 lb of SF_6 emitted from the HRIBF for FY 2018 (Table 5).

Other GHG emissions from miscellaneous fugitive gases (such as lab and testing gases) have decreased by 74% from the baseline year.

Table 5. DOE Office of Science SF_6 data call—ORNL, FY 2018

Facility	FIMS Asset No.	Inventory (lb)		Emissions by fiscal year (lb)												
				Past									Actual	Projected		
		Current	Device	2010	2011	2012	2013	2014	2015	2016	2017	Total	2018	2019	2020	Total
HRIBF	97322	74,000	0	2,500	10,400	1,700	1,326	2,008	1,766	1,660	2,560	23,920	1,200	0	0	0
Balance of site	NA	4,538	NA	450	247	235	2	24	20	33	181	1,193	107	100	100	200
Total		**78,538**		**2,950**	**10,647**	**1,935**	**1,329**	**2032**	**1,786**	**1,693**	**2,741**	**25,113**	**1,307**	**100**	**100**	**200**

Note: During FY 2018, 74,000 lb of the SF_6 at the ORNL HRIBF was purchased from the DOE Office of Science by a private company and was transferred off site.

Plans and Projected Performance

- In FY 2019 and forward is it expected that no on-site process will utilize SF_6. The HRIBF SF_6 inventory has been sold and was transferred off site over a period of about four months spanning the end of FY 2017 and the beginning of FY 2018. During transfer, the SF_6 inventory was managed and monitored as it has been for more than 30 years.
- Site-wide fugitive emissions should continue to decline as research scientists are made aware of less potent alternatives for tracer gases and for gases used in research. Overall, the site-wide fugitives and refrigerant GHG emissions have a minor impact on the GHG emission estimates across ORNL.

Electronic Stewardship

Electronic Stewardship: Acquisition Strategies

In FY 2018, ORNL continued to exceed 95% compliance with EPEAT standards for purchases of computers, monitors, and laptops and purchases of other Energy Star–qualified equipment.

More than 98 percent of the computers, monitors, and laptops procured by ORNL in FY 2018 were EPEAT-compliant. Acquisition strategies include the following:

- All purchases of tablets and thin clients were EPEAT-compliant
- Continued to replace older workstations with new standard EPEAT workstations that are certified for computer-aided design and that meet researchers' requirements
- Continued the implementation of a standard set of shared network printers, which has allowed ORNL to optimize purchasing print devices and has greatly reduced the cost of ink-jet cartridges
- New to the Dashboard data request this year, ORNL bought 155 EPEAT-certified servers. All servers in the EPEAT Registry show Bronze certification. No Gold or Silver models are available for purchase at this time. Information on new mobile phones purchases was unavailable in 2018.

ORNL continues to meet the requirements for electronics purchases with respect to EPEAT, Energy Star, and FEMP via the use of a guided procurement system to route staff to the approved electronic devices. The multifaceted policies and procedures associated with this system ensure maximum purchasing of compliant systems while meeting research needs:

- The ORNL Managed Hardware Program provides a listing of approved standard hardware (i.e., desktops, laptops, and tablets) that may be purchased without further approvals. All listed electronic devices meet EPEAT, Energy Star, and FEMP requirements.
- Established automated procurement governance ensures that all nonstandard requests are reviewed to determine whether the devices comply with cyber security, configuration management, EPEAT, Energy Star, and FEMP requirements.
- The Green Information Technology Team and Procurement closely monitor nonstandard (i.e., non-EPEAT) requests. Specifically, when an occasional request for a noncompliant item is made to meet

research requirements, a standardized exemption review and approval process is in place to determine whether an EPEAT product is available to meet the need and to exempt it if a substitute is not available.

Electronic Stewardship: Operation Strategies

Power Management: The ORNL Green Information Technology (IT) team has successfully met the electronic stewardship goal of power-managing 100% of the eligible personal computers, laptop computers, and monitors in use by ORNL staff since 2009.

- All ORNL Windows computers, including servers, desktops, and laptops, are required to be power-managed and to have a secure screen saver with a timeout setting between 1 to 15 minutes. Windows screen saver configuration settings are enforced by the System Center Configuration Manager, which is managed by the Information Technology Services Division.
- All ORNL Macintosh/MacOS systems are required to have a password-protected screen saver with an inactivity timeout (unless a system has an exception). Settings are checked and changed, if necessary, every 12 hours by automated systems.
- Linux screen saver settings vary based on the operating system version and the desktop environment. Because of the large number of configurations and the lack of centrally configurable policies for some desktop environments, screen savers on the Linux platform are managed on a best-effort basis.

Automatic Duplexing: ORNL has successfully implemented a shared print services program to update existing multifunction print devices (print/scan/copy/fax devices) and to provide for other shared print devices. All new print services include automatic duplexing set as the default. An individual can override duplexing for a print job that requires single-side printing. In addition, locked print is an option for all new shared printers, so users can release an individual print job by entering a personal identification number at the printer as needed to limit others' access to a print job prior to retrieving the printout from the shared printer. Existing printers without duplexing capability are being replaced with printers that require duplexing capability.

The shared network printer services model is helping to standardize equipment, reduce energy consumption, reduce landfill waste, reduce the cost of operations, improve printing services in general, and provide more efficient use of consumable products. Over time, ORNL plans to shrink the printer equipment footprint and to save essential overhead costs by reducing toner purchases, support costs, and power demands.

Plans and Projected Performance

- Green IT plans to continue power management using the Verdiem Surveyor software. The Green IT progress on sustainable practices for FY 2019 includes continued operation of the computer power management and monitoring system in a manner that will enable the power management of the latest versions of Windows and MacOS systems.
- Green IT plans to continue to (1) implement shared network print devices with automatic duplexing set as the default and (2) reduce the number of local print devices by providing additional shared network printers.

Electronic Stewardship: End-of-Life Strategies

Due to ORNL property management and environmental management policies and procedures within its Standards-Based Management System, we ensure that 100% of used electronics are reused or recycled using

environmentally sound disposition options. Options include transfer to other DOE contractors, nonprofits, and schools by means of programs such as the Computers-For-Learning Program. Electronics that have reached end of life are recycled through a Responsible Recycling Practices (R2)-certified recycler. Beyond using certified programs, current and future success is based on a strong, corporately-engrained foundation:

- ORNL continues to be strongly proactive in the transfer of specific electronic components to other DOE contractors, nonprofits, and the Computers-For-Learning Program as it has for decades.
- Since May 2012, ORNL has exclusively used an R2-certified recycler to recycle its electronics that have reached end of life.
- ORNL continues to abide by established processes to reuse and recycle electronics in an environmentally sound manner, even before certifications were available by doing on-site assessments of the recycling facilities.
- ORNL continuously reviews procedures and certifications to ensure that recyclers are in compliance with all regulations, are using best practices, and are in good standing with professional recycling associations.

Electronic Stewardship: Data Centers

Performance Status

Keeping the ORNL Computational Sciences Mission sustainable is a multifaceted and dynamic effort and requires multiple resources and subject matter experts. Per DOE directive, the ORNL Computational Facility Complex continues to focus on consolidation to close smaller computer rooms, contributing to more efficient operations. Recent accomplishments include actively moving 12 racks into the Computational Facility Complex. Approximately 7,500 ft^2 of data center space has been successfully transformed into contiguous whitespace by clearing out legacy IT equipment (Figure 21).

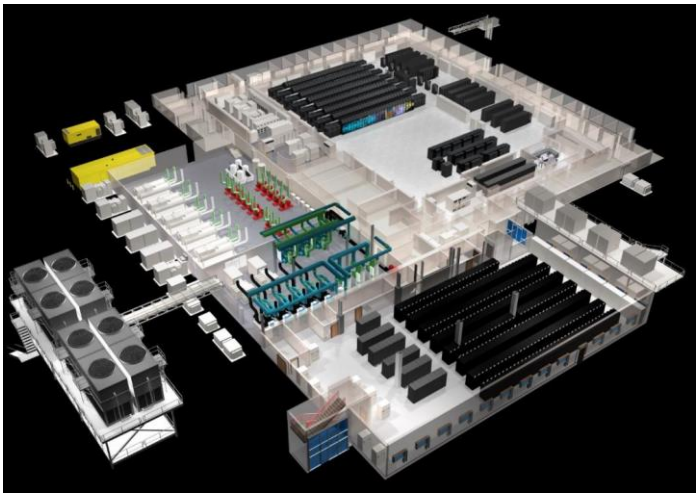


Figure 21. Reconfigured of parts of the Computational Facility Complex.

Virtualization continues to be the first choice when new applications need to be deployed. The ORNL email system is being transferred to the cloud, which will eventually reduce the number of physical servers on site. The DOE metric for data center efficiency performance is termed PUE (power utilization effectiveness). The current cooling system for Summit is performing as designed. With 8 months of operation (March–October 2018), its

PUE is 1.14, with 4 upcoming winter months approaching; the annual PUE should trend downward to ~1.10 (Figure 22).

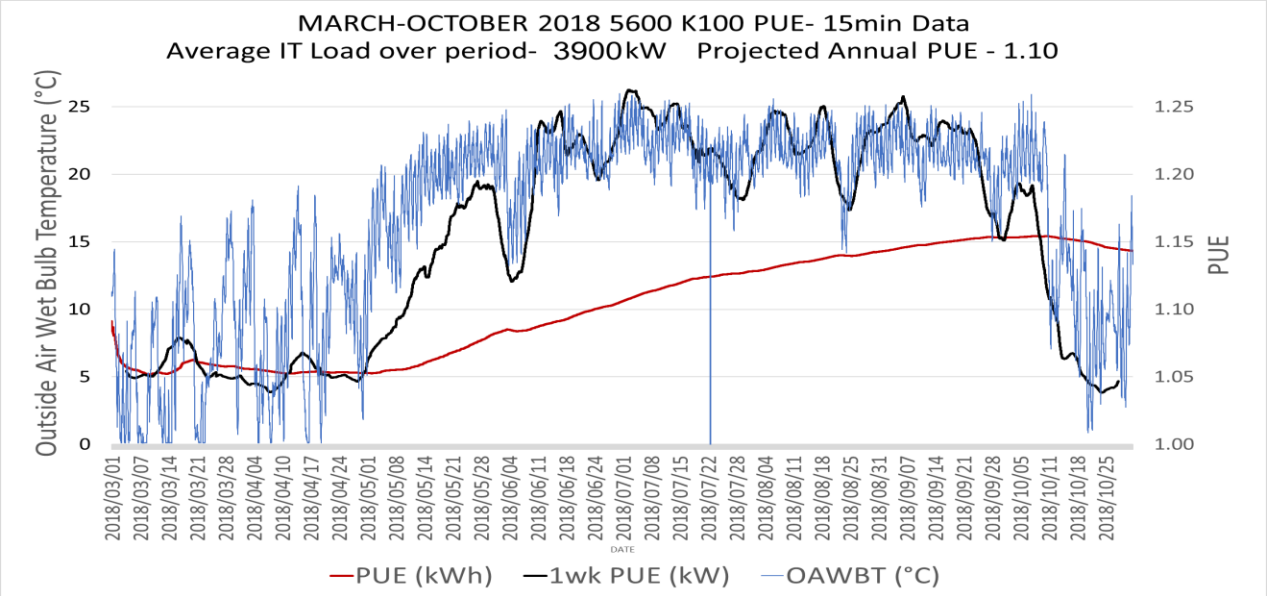


Figure 22. ORNL data center power utilization effectiveness, March–October, 2018.

Within the coming year, a large system, Titan, will be taken off line. A targeted strategy will be taken at that time to deactivate support equipment to ensure energy is not being wasted. Among these items include half a dozen or more computer room air-handling units. The chiller plant will also be reconfigured to find the optimally efficient operating point. Between the time Titan goes down and the 2021 HPC system is brought online, Summit will be the ORNL HPC flagship system, with PUE performance to be admired.

Plans and Projected Performance

Figure 23. Upgrades to one of the HPC water-cooling system.

Master planning tasks have been completed and help to identify where various types of hardware will be located within ORNL's various data centers. This includes a new FY 2021 exascale system, other smaller clusters, and business enterprise systems. The most densely loaded racks associated with smaller systems will be installed close to warm water cooling systems to leverage those systems' higher efficiencies (Figure 23). For the lower-density racks, provisions are being made to slowly move their cooling over to systems less reliant on chilled water. For the future 2021 HPC systems and beyond, high-temperature water systems will be the primary cooling source. The high-temperature water cooling system for the 2021 HPC system is currently being built. Future expansion capabilities are being incorporated into the design. For the lower-density HPC support racks implementation of an innovative strategy is planned to adapt cooling distribution units to provide partial to full economization by utilization of the same high-temperature water loop that serves the HPC compute system. Its temperatures will be allowed to fall quite low during the winter months. Reuse of data center waste

heat, which would decrease our water consumption by removing cooling load from the cooling tower systems, is also being investigated. For all these reasons, the overall PUE for the entire ORNL data center portfolio is expected to continue to decrease for the next 10 years. Over the same time period, we expect IT power consumption to double or triple.

Organizational Resilience

ORNL Strategies to Enhance the Resiliency of Strategic Partnerships

Strategic Partnership Projects at ORNL, together with programs for the Department of Homeland Security, represent approximately 15% of the laboratory's budget and are a major part of the way that ORNL fulfills the DOE mission. The portfolio of projects is as diverse as ORNL's research capabilities. These vital partnerships are expected to experience growth in support of science and technology research. Representative research includes the following examples:

- Partnerships research at ORNL focuses on developing secure, sustainable, and resilient energy infrastructure by advancing microgrid controls and operations, discovering power flow control solutions, developing low-cost sensors to securely measure and communicate energy pathways, and developing exascale HPC solutions for real-time grid modeling and contingency analysis (including interdependencies).
- ORNL cyber and physical security solutions will focus on secure communication and information systems to create a cyber-resilient infrastructure.
- New capabilities in secure quantum communications for grid security were developed via a program funded by the DOE Office of Electricity Delivery and Energy Reliability Cybersecurity for Energy Delivery Systems program.
- Several technologies and processes are being used to support preventive and predictive operational capabilities, including monitoring, alerting, and automation to drive enhanced reliability, stability, and operational response.
- Research support for the Department of Defense technology development programs span energy supply, efficiency, and security as well as resilient energy infrastructure. ORNL applies computational research, data analytics, and laboratory and field experimentation to national defense challenges in energy, cyber, nuclear, and environmental security.

Organizational Resilience is the Planning Process

ORNL is taking an integrated and proactive approach to including sustainability efforts and organizational resilience into the operational planning process. Representatives include F&O senior management and staff in the Facilities Development Division as well as staff working in the areas of site strategic planning, environmental management, and natural resources. ORNL is committed to the incorporation of climate-resilient design and management elements into the planning process and to determining the specific risks and level of resiliency required. Planning steps for future activities include the following:

- focus on resilience strategies and procedures that identify and respond to events with the potential to disrupt, strain, compromise, or destroy DOE activities or facilities
- apply this knowledge to missions and operations

- develop and prioritize actions based on site-specific risks and threats
- build awareness and improve skills to respond to potential events
- apply organizational resilience best practices into the facilities-planning process and the design of new agency buildings

Emergency Response

In FY 2018, construction began on a new Research Operations Support Center. This facility will house all emergency response and security personnel, allowing the demolition of two 1940s-vintage facilities in the Central Campus area. The enhanced, modernized emergency response center will facilitate the integration of emergency response procedures with organizational resilience measures at the site.

ORNL continues to engage with state, local, and regional entities to address emergency response and preparedness. The entities include the Tennessee Department of Environment and Conservation; the City of Oak Ridge; and the Roane County fire departments, emergency medical services, and first responders. The primary functions of the ORNL Emergency Management System include:

- protecting workers, the public, the environment, and national security
- serving as a resource to line management for emergency preparedness activities
- coordinating with other first-response entities to mitigate risk in extreme events
- furnishing first responders with support in emergency situations
- planning for and respond to all emergency situations, including extreme weather events

The emergency management process is accomplished through training, counseling, oversight, policy and procedural development, guidance, and successful event resolution. Through these methods, it provides for the coordination and direction of planning, preparedness, and response to emergency conditions and/or abnormal events where the potential exists for personal injury; damage to facilities or equipment; release of toxic, radioactive, or hazardous materials; release of chemical or biological toxins; and/or impact to projects or programs, including extreme weather impacts.

Workforce Health and Safety

ORNL has several communication protocols in place for staff to receive more timely and precise communications about lab conditions, which allow them to make safe choices to either telework from home or travel to their on-site office:

- Staff can check the ORNL Weather Line and *ORNL Today* for current conditions.
- Upgrades of internal notification system features allow messages concerning extreme weather events (and other emergency concerns) to better reflect current technology. Messages are broadly disseminated through a variety of methods, including alerts sent via email, text message, and cell phones.
- The Standards-Based Management System contains the on-line procedure, “Handle Absences Related to Weather, Adverse Events, and the Laboratory’s Operational Status.”
- The Facilities Management Division has instituted a more formalized system of identifying priority areas for snow removal.

Organizational Resilience and Weather Extremes at ORNL: Hot and Cold

One area of concern and key focus for ORNL is staff safety during inclement weather events for both hot and cold weather extremes. Examples of improved communications include the following:

- Workforce health and safety concerns are elevated when there is an extended period of days in which high temperatures reach more than 90°F and heat and humidity indexes are heightened. During these times the *Worker Safety Toolbox*, a weekly newsletter for workers and supervisors, provided information on heat issues continually.
- In winter months, extreme cold weather conditions can occasionally make travel to ORNL hazardous. We continue to promote various arrangements to accommodate staff members who must determine whether to travel to work or stay at home (and possibly work remotely) in heavy snow and/or ice.
- Each winter, the snow-ice priority removal policy is communicated to road crews and to all staff who can safely travel to ORNL during times of icy weather and snowfall. In addition, staff and supervisors will be reminded of the importance of making safe choices, including telework.