National Renewable Energy Laboratory

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

Innovation for Our Energy Future

National Renewable Energy Laboratory

Ten-Year Site Plan FY2007-FY2018

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National Renewable Energy Laboratory
Ten-Year Site Plan FY2007-FY2018
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Preface

The following changes have been made in this Ten-Year Site Plan compared to the June 2006 National Renewable Laboratory Ten-Year Site Plan (TYSP):

1) The NREL 25-year site plan, the Grand Buildout Vision, has been updated during the last year to be more specific with regard to the functionality of future buildings. This has resulted in the identification and addition of several facility projects to the Ten-Year Site Plan, including:
   a) Biological and Chemical Research Facility
   b) Renewable Fuels & Vehicle Systems Facility
   c) Solid-State Research Facility
   d) Energy Systems Integration Facility II
   e) Next-Generation Biorefinery
   f) Research Support Facilities Phases III and IV
2) Several projects continue to be requested but have changed in scope or name:
   a) Energy Systems Integration Facility – This was previously titled “Facility for Integrated Renewable Systems Testing.” Its scope has been changed to eliminate much of the transportation-related research capabilities and include buildings-related research capabilities.
   b) The Ten Tera-flop Computational Science Initiative has been folded in with Institutional Capital Equipment—New Capabilities.
   c) The STM Site infrastructure Expansion project has been enlarged in scope to include the need for parking structures and additional road/utility extension expectations.
   d) The Biosciences Modernization project has been largely canceled. We have developed a different strategy for biosciences, which is a combination of the Biological and Chemical Research Facility and a future focus for the existing Field Test Laboratory Building (FTLB) on mid-scale biotechnology development.
   e) The one piece of the former Biosciences Modernization project that remains very important is the addition of energy-efficient office and cubicle spaces for research staff, the FTLB Expansion/Energy Efficiency Upgrade project.
   f) Institutional Facilities and Infrastructure—Reinvestment now includes an additional 0.25% of replacement plant value in FY2009-FY2013 to cover the costs of contracted maintenance in the $2,000-$50,000 per project level, projected during FY2009-FY2013 as General Plant Projects Operating.
   g) Institutional Capital Equipment—Reinvestment now includes the cost of maintenance contracts for scientific instrumentation and computational equipment.
3) Program Capital Equipment has been added as a capital planning category for analysis and projection of general need.

At the time of preparation (December 2006), FY2007 capital budgets were not yet determined, but efforts were made to indicate the best available information in this Ten-Year Site Plan. The status of FY2008 capital requests was uncertain at the time of preparation, and FY2008 requests were included according to the Laboratory’s needs to support the current strategies and planning.

An electronic version of this document will be available on the World Wide Web:
http://www.nrel.....

1.0 Executive Summary

1.1 Accelerating Technology Development to Meet America's Energy Challenges

The U.S. Department of Energy's 2006 Strategic Plan promotes America's energy security through reliable, clean, and affordable energy. The importance and sense of urgency related to this strategic theme has never been greater. At the beginning of the 21st Century, the global demand for clean energy is growing much faster than supply. The nation faces daunting energy challenges. Demand for energy is projected to more than double by 2050 and to triple by the end of the century.

Incremental improvements in existing energy networks will not be adequate to meet demand. The energy infrastructure is aging, and this represents additional risks in terms of reliability and security. Our dependence on unstable regions for crude oil poses both an economic and a national security risk. Dependence on fossil fuels impairs the quality of local environments and threatens the stability of the global climate.

Americans are increasingly aware of the need to transform the nation's energy system and are making their concerns known. In January 2006, President Bush announced the Advanced Energy Initiative to reduce our dependence on foreign energy supplies through the accelerated development of energy alternatives that will change the way we power our homes and businesses and the way we power our automobiles. Additionally, he announced the American

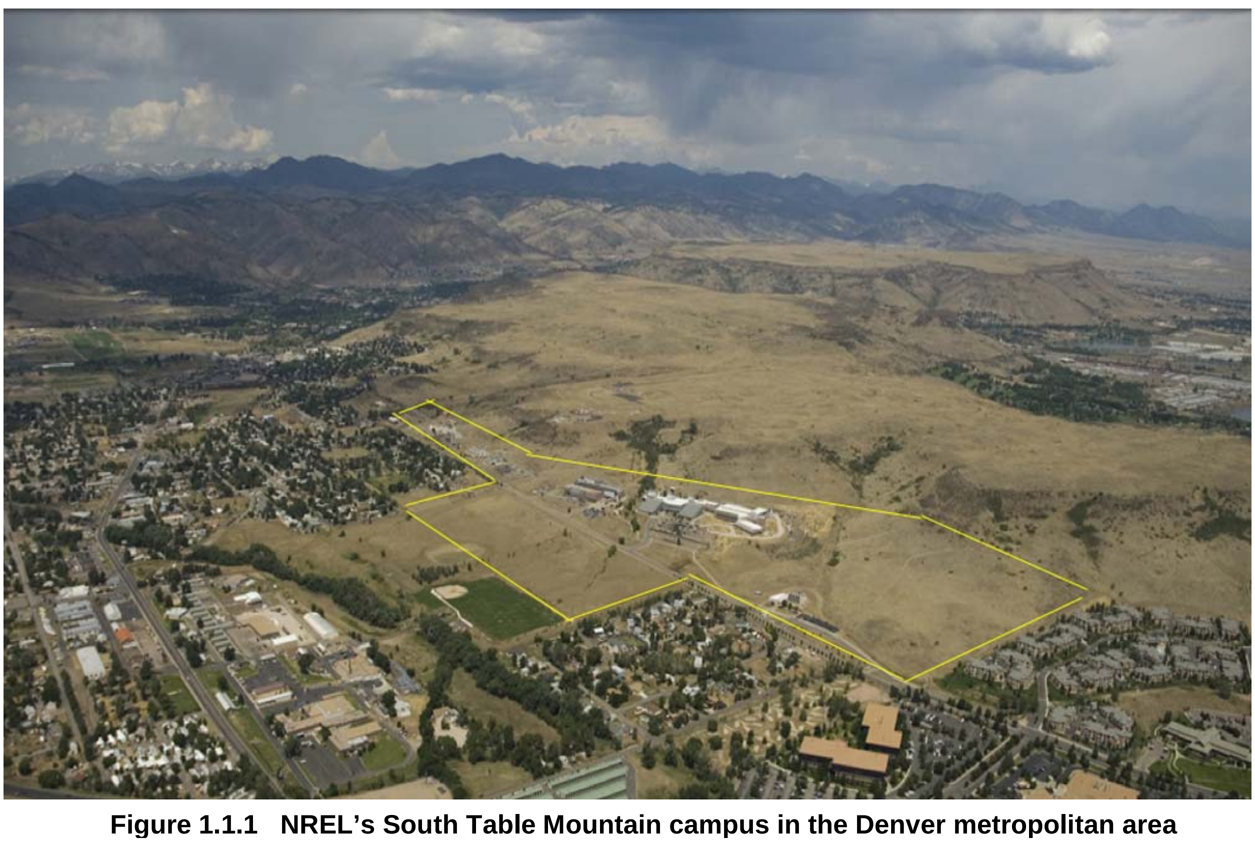

Figure 1.1.1 NREL's South Table Mountain campus in the Denver metropolitan area

Competitiveness Initiative that strives to increase investments in research and development, strengthen education, and encourage entrepreneurship. These initiatives, along with Congressional appropriations, places added emphasis on many of the research areas of the National Renewable Energy Laboratory (NREL), including solar and wind energy, hydrogen, biomass-derived alternative vehicle fuels, vehicle efficiency technologies, and net-zero-energy buildings, along with the foundational science that will fuel breakthrough innovations in these areas.

Transforming the nation's energy system is an enormously challenging task, and the trajectory of change will be steep. Meeting this challenge will require a range of technical capabilities and solutions, mobilizing our talent in government, national laboratories, universities, and the private sector. NREL, with its uniquely focused mission and experience in renewable energy and energy efficiency, is poised to provide strong leadership, integrating and mobilizing talent that will yield the innovations required to change the nation's energy use trajectory.

1.2 Strategy Highlights

NREL's current business and strategic thrusts for the future are described in the *Draft DOE Business Plan for the Office of Energy Efficiency and Renewable Energy FY2008 - FY2012 National Renewable Energy Laboratory (December 2006)*. The leadership of the Midwest Research Institute (MRI) and Battelle, who manage NREL for DOE, has established a distinctive vision and roadmap for NREL that will enhance the laboratory's unique competencies and the value that they bring through two flagship research directions: renewable electricity production and use and renewable fuels formulation and use. These two research flagship efforts directly support the President's Advanced Energy Initiative.

Figure 1.2.1 President Bush greeted NREL Director Dan Arvizu at the Laboratory following his State of the Union address, Feb 2006.

To accelerate progress in these two key flagship research areas, NREL will place significant emphasis on managing the interface between basic science and applied research and development (R&D), as well as the interface between applied R&D and the commercial marketplace. NREL will also augment its foundational science areas that strengthen our mission and influence the energy science agenda in areas that have the potential to significantly advance the applied R&D agenda.

1.3 Grand Buildout Vision for the NREL Campus

Accomplishing these goals for the future will require strengthening NREL's capabilities in several areas. NREL's current campus is the national focal point for renewable energy development through science and technology and provides a strong foundation for future growth (Figure 1.1.1). NREL's facilities meet national needs for renewable energy R&D in many areas, but gaps remain. NREL has a visionary plan to build out its campus in a way that will fill these gaps and accomplish many goals for our partners and the nation. With its focused mission in energy, NREL must provide a visible leadership example by using the energy efficiency and renewable technologies it works to develop within its own operations.

NREL's planned campus expansion is an investment in the energy future of the nation. The expanded campus will encourage innovation through interdisciplinary research. By actively enhancing the technology development interfaces between basic and applied research and between engineering and the marketplace, we will accelerate the impact of these technologies on the marketplace. Integration will be stressed from science to systems, including energy for entire communities.   Figure 1.3.1 shows how the campus will enhance these interfaces.

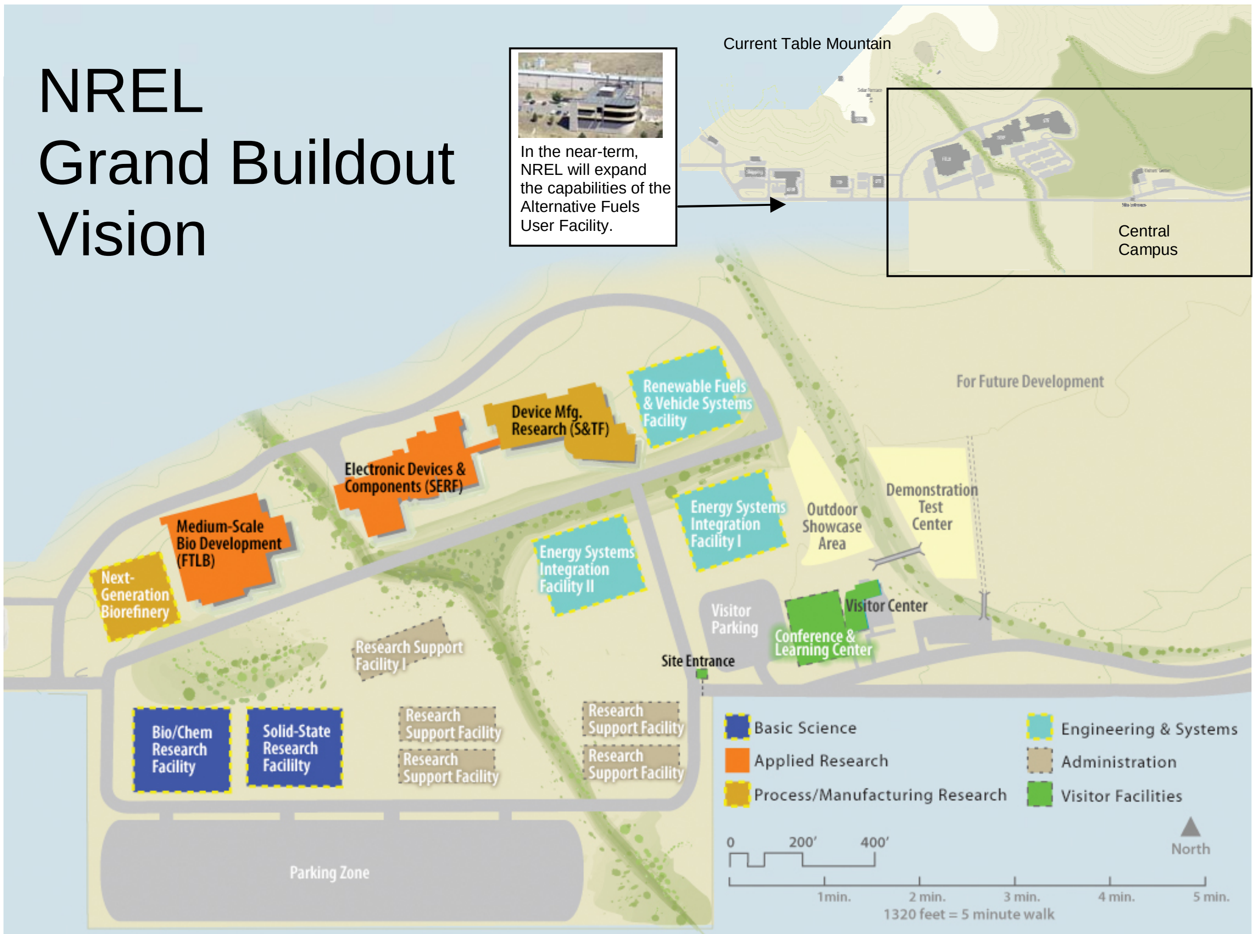

Figure 1.3.1   NREL's Grand Buildout Vision for the South Table Mountain Campus – Planned to enhance the interfaces between basic and applied science, and engineering and the marketplace

The campus design integrates as effectively as possible the interconnected processes of research and development. Foundational research and scientific computing will be supported by two new laboratories: the Biological and Chemical Research Facility, and the Solid-State Research Facility. Located next to each other to encourage interdisciplinary innovation, these new laboratories will accommodate extended research collaborations and visiting scientists. The Biological and Chemical Research Facility will include a dedicated portion for scientific computing. The energy intensive nature of large data centers offers an opportunity for NREL to use the design of the computing portion of this new facility to demonstrate energy efficient technologies that would serve as a model for similar centers.

The addition of these foundational research laboratory facilities will allow NREL to focus the existing facilities—Field Test Laboratory Building and Solar Energy Research Facility—on more applied research activities. Continuing the R&D progression, facilities dedicated to process research and scale-up (the Science and Technology Facility completed in 2006 and the new Next-Generation Biorefinery) are positioned immediately adjacent to the applied research facilities, which maximizes synergism between applied and process research.

This campus design integrates foundational—applied—and process research while efficiently supporting research and development in flagship research directions: Renewable Fuels Formulation and Use, and Renewable Electricity Conversion and Use (Figure 1.3.2).

Renewable Fuels Formulation and Use. The new Biological and Chemical Research Facility will expand the capabilities for structural biologists and molecular geneticists to study the internal mechanisms of plants to improve their production of ethanol, biodiesel, hydrogen, and other fuels and products. NREL will support its enhanced foundational research capability with additional scientific computing capacity. In the future, the existing Field Test Laboratory Building will focus on mid-scale biodevelopment—prototype processes to convert biomass to liquid fuels, syngas, hydrogen, electricity, and biobased products to replace petroleum-based fuels and chemical intermediates. The existing Alternative Fuels User Facility and Process Development Unit (at the west end of the NREL campus) will be enlarged in the near-term to an Integrated Biorefinery Research Facility supporting ethanol development, to allow more flexibility for testing "plug and play" process equipment, more room for biomass storage and pretreatment, and expanded analytical laboratories. Long-term, a Next-Generation Biorefinery will be required adjacent to the Field Test Laboratory Building to test concepts of integrating biochemical conversion processes with thermochemical conversion processes for all types of liquid and gaseous fuels, for the ultimate in process efficiency and flexibility.

Renewable Electricity Conversion and Use. The new Solid-State Research Facility will expand the potential for scientists to conduct research in solar cells, quantum dots, third-generation and organic photovoltaics, creation of hydrogen from sunlight and water, and nano-based materials that store energy and hydrogen. In the future, the existing Solar Energy Research Facility will focus on applied research such as developing electronic devices and

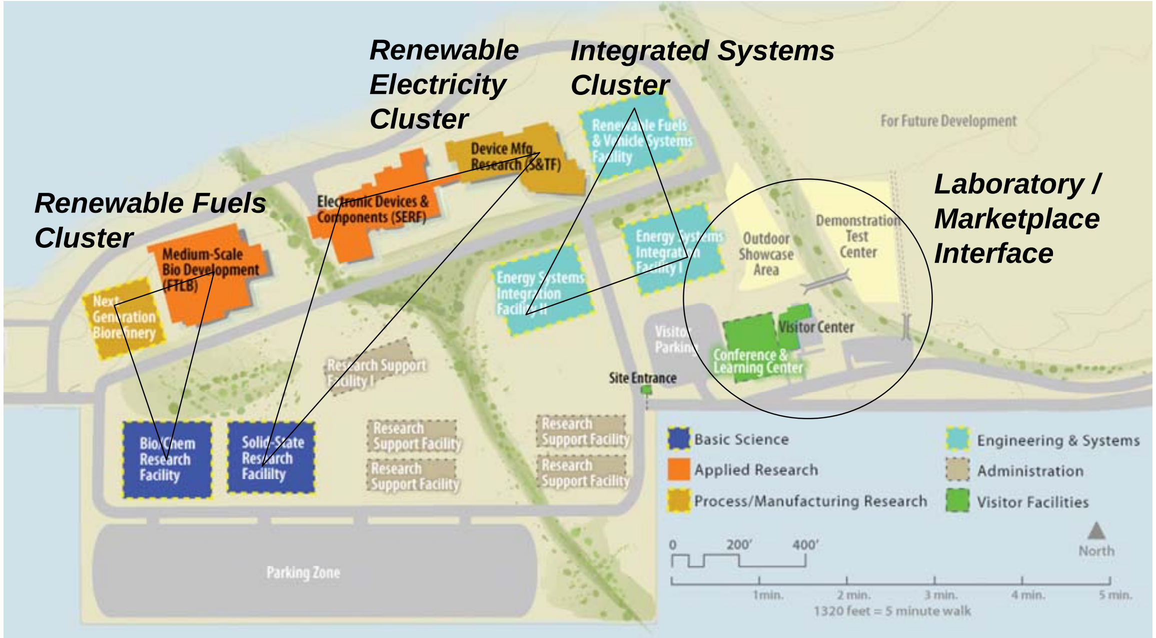

Figure 1.3.2 NREL's Grand Buildout Vision – Planned to support NREL's flagship research directions for EERE and help new systems penetrate the marketplace

components that incorporate innovations from core science areas. Immediately adjacent, NREL's recently complete—helping industry improve the complex processes related to manufacturing solar cells and other devices built of coatings or layers of electronic materials. This facility is providing much needed new space and equipment to support successful accomplishment of the DOE mission in areas such as photovoltaics, hydrogen, solar, buildings, solid-state lighting, thin-film energy coatings/devices, electrochromics, and nanotechnology.

Integrated Energy Systems Engineering and Testing. Foundational and applied research help "push" revolutionary technologies toward the marketplace; engineering and testing respond to needs as markets "pull" new technologies toward commercialization. To introduce these new technologies into markets more rapidly, the NREL campus vision includes the new Energy Systems Integration Facility I, which will provide the research, engineering, design, and testing of components and systems related to how energy efficiency and renewable energy systems work in integrated systems. The new facility will allow researchers to look at various types of integrated systems, from individual technologies such as a fuel cell or other hydrogen-based systems to energy use, electrical interconnections, and systems in a building or in a community. This research will also support improved and expanded capabilities in simulation and modeling of renewable energy and energy efficient systems, and related economic and financial impacts on communities and businesses. The Renewable Fuels & Vehicle Systems Facility will provide a similar set of activities for all types of advanced fuels and energy-efficient vehicles. Later, NREL anticipates a need for an additional engineering and testing laboratory, tentatively called Energy Systems Integration Facility II. These new engineering and testing laboratories will allow technology developers and potential users to engage in collaborative R&D, testing, and demonstrations.

Because this effort is closely associated with the marketplace where such systems are needed, integrated systems research and development is adjacent to the public area of the campus. The public area designated the ***Laboratory/Marketplace Interface*** will be greatly augmented by the addition of a new Conference & Learning Center to enable NREL to effectively meet the needs of the rapidly increasing number of people needing to know more about renewable energy and energy efficiency. The new public area will allow scientists, engineers, and analysts to share the results of research and modeling, and provide space for outdoor demonstration of a wide variety of technologies.

Research Support Facilities. To improve efficiency and reduce cost, NREL plans to consolidate its research support staff in new Research Support Facilities, which will end its occupancy of leased space and consolidate staff at the South Table Mountain site. This project also includes the construction of a Conference and Learning Center, which will help educate important energy users about the capabilities of renewable energy and energy efficiency technologies through virtual visualization of technology performance as well as the financial, environmental and security impacts through access to models and tools that enable examining alternative energy options.

Showcase Design. The campus itself will be a showcase of energy-efficient building design, sustainable transportation, and on-site renewable energy generation. One of the major changes is in the road/parking system, where employee parking is directed to collector parking structures at the southern edge of the campus. Providing a minimal number of parking spaces will encourage carpooling and public transportation. The compact campus maximizes functionality and encourages walking and the use of onsite alternatively fueled shuttles.

1.4 Management Framework for Facilities, Infrastructure, and Equipment at NREL

Planning facilities, infrastructure, and equipment requires a comprehensive strategy, shown diagrammatically as a pyramid in Figure 1.4.1. The most basic requirement, at the bottom of the pyramid, is to maintain the existing assets at NREL in excellent operating condition—to keep existing facilities viable and the equipment up-to-date. Other investments are needed, shown in the middle section of the pyramid, for modest changes or additions to support the research and development programs of today. The top-level investments represent the strategic new science and technology capabilities that will transform the way the nation uses energy. These investments are guided by NREL's strategic energy analyses.

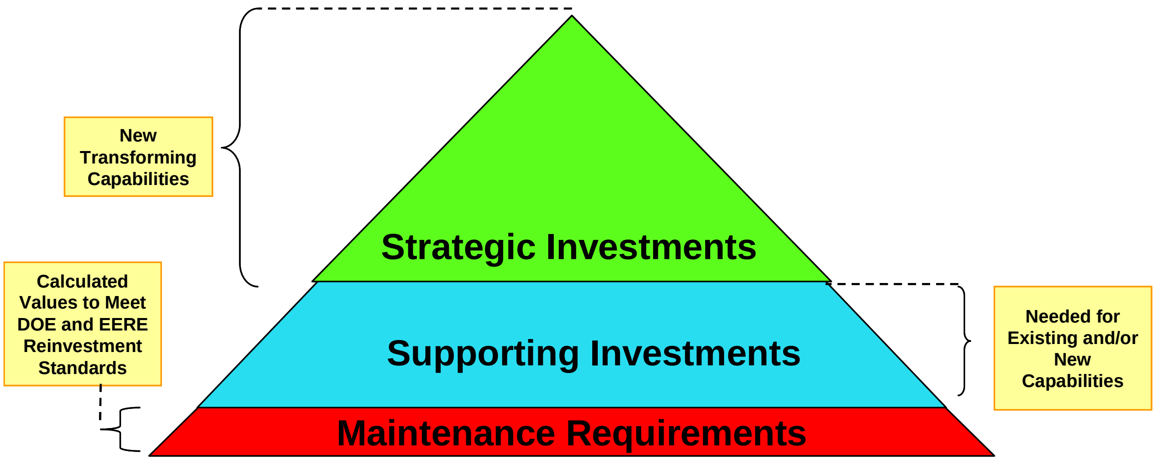

Figure 1.4.1 Planning framework for NREL facilities, infrastructure, and equipment

1.5 NREL's Priorities

Information included in this plan reflects NREL's proposals for its facilities and infrastructure. While the Ten-Year Site Plan attempts to align to the budget, it does not directly reflect the budget currently in development, but instead, it presents a vision that helps the DOE Office of Energy Efficiency and Renewable Energy (EERE) identify and make the best choices for its programs. This Ten-Year Site Plan is coordinated with EERE Program Managers. It reflects both known facility and equipment requirements (general purpose and program specific), and optional facility needs. Cost estimates generally require further development and validation.

Among the several projects described in this executive summary, NREL's highest level priorities for major projects in FY2009 are:

1. The ***STF Research Equipment Initiative*** (p. 1-7) will enhance the functionality of the latest strategic capital investment at NREL, the Science and Technology Facility.
2. The ***Integrated Biorefinery Research Facility*** (p. 1-8) will expand an existing facility to provide the capabilities needed to support process research for cellulosic ethanol and other products.
3. The ***Research Support Facilities Phase I and II*** (p. 1-12) will increase the amount of funds available for research, and improve efficiency, by moving all staff out of leased facilities into DOE-owned facilities.
4. The ***Energy Systems Integration Facility*** (p. 1-9) will provide critical capabilities to accelerate the market penetration of new energy technologies through integrated systems engineering and testing.

5. The ***South Table Mountain (STM) Site Infrastructure Development*** project (p. 1-15) will provide extension of roads, utilities, and other infrastructure into undeveloped portions of the STM site, and a decked parking structure at the southern edge of the STM site. This work is phased from FY2009-FY2013.
6. The ***Biological and Chemical Research Facility*** (p. 1-11) will provide new state-of-the-art laboratories for foundational science to support the development of biofuels and hydrogen, and space for expanded scientific computing for modeling and simulation.
7. The ***FTLB Expansion/Energy Efficiency Upgrade*** project (p. 1-13) will provide office and cubicle spaces for about 45 researchers, both NREL staff and industrial and university partners, to support biofuels and hydrogen development and related foundational research.
8. The ***Data Infrastructure Modernization*** project (p. 1-13) will prepare NREL to take advantage of better access to DOE's National Computing Leadership Facilities and improve its networking with other laboratories.

Table 1.5.1 lists NREL's entire set of capital budget requests for FY2009-FY2018 in strategic, supporting, and maintenance categories.

Table 1.5.1 Ten-Year Site Plan Summary FY2007-FY2018

National Renewable Energy Laboratory Ten-Year Site Plan FY2007-FY2018 (note a)

$ Thousands Current-Year Dollars

Investment Category	FY2006 Actual	FY2007 Estimate	FY2008 Estimate	FY2009 Request	FY2010 Request	FY2011 Request	FY2012 Request	FY2013 Request	FY14-18 Request	*Project Total*
Strategic Investments										
S&TF Research Equipment Initiative	$1,800	$12,800	$6,500	$7,800						*$28,900*
Integrated Biorefinery Research Facility			$16,500	$3,000						*$19,500*
Energy Systems Integration Facility (note b)				$6,600	$48,400	$22,000				*$77,000*
Biological and Chemical Research Facility (note b)				$11,400	$83,600	$39,700				*$134,700*
Renewable Fuels & Vehicle Systems Facility (note b)						$5,760	$42,240	$19,200		*$67,200*
Solid-State Research Facility (note b)							$8,160	$59,840	$40,800	*$108,800*
Energy Systems Integration Facility II									$84,000	*$84,000*
Next-Generation Biorefinery									$81,600	*$81,600*
Subtotal	**$1,800**	**$12,800**	**$23,000**	**$28,800**	**$132,000**	**$67,460**	**$50,400**	**$79,040**	**$206,400**	**$601,700**
Supporting Investments										
Research Support Facilities (Phase I)	$9,900									*$9,900*
Research Support Facilities (Phase II) (note c)			$7,800	$57,200						*$65,000*
Research Support Facilities (Phase III)					$26,000					*$26,000*
FTLB Expansion/Energy Efficiency Upgrade				$4,500						*$4,500*
Data Infrastructure Modernization				$2,100				$1,000	$3,000	*$6,100*
Research Support Facilities (Phase IV)									$204,000	*$204,000*
STM Site Infrastructure Development		$2,500	$0	$12,442	$3,000	$0	$27,029	$0	$0	*$44,971*
Institutional Facilities and Infrastructure -- New Capabilities	$1,646	$0	$1,138	$1,022	$1,083	$1,635	$1,748	$5,441	$27,207	*$40,920*
Institutional Capital Equipment -- New Capabilities	$1,492	$1,838	$2,353	$3,975	$5,000	$2,890	$2,828	$3,299	$16,493	*$40,167*
Program Capital Equipment -- New Capabilities	$1,772	$1,500	$1,500	$3,000	$3,000	$3,000	$3,000	$3,000	$15,000	*$34,772*
Subtotal	**$14,810**	**$5,838**	**$12,791**	**$84,239**	**$38,083**	**$7,525**	**$34,605**	**$12,740**	**$265,700**	**$476,331**
Maintenance Requirements										
Institutional Facilities and Infrastructure --Reinvestment	$2,144	$1,457	$2,704	$3,576	$3,791	$5,721	$6,117	$9,523	$47,613	*$82,645*
Institutional Capital Equipment -- Reinvestment	$1,459	$1,303	$2,126	$7,638	$6,427	$8,296	$8,008	$8,666	$43,329	*$87,251*
Program Capital Equipment -- Reinvestment	$1,182	$1,000	$1,000	$13,902	$6,302	$7,402	$7,902	$8,602	$43,010	*$90,302*
Subtotal	**$4,784**	**$3,760**	**$5,830**	**$25,116**	**$16,520**	**$21,419**	**$22,027**	**$26,790**	**$133,952**	**$260,199**

Notes:

(a) Information included in this plan reflects NREL's proposals for its facilities and infrastructure. While the Ten-Year Site Plan attempts to align to the budget, it does not directly reflect the budget currently in development, but instead, it presents a vision that helps the DOE Office of Energy Efficiency and Renewable Energy (EERE) identify and make the best choices for its programs. This Ten-Year Site Plan is coordinated with EERE Program Managers. It reflects both known facility and equipment requirements (general purpose and program specific), and optional facility needs. Cost estimates generally require further development and validation.
(b) Funding profile is project engineering and design in year 1, construction in year 2, and essential equipment in year 3.
(c) Funding profile is project engineering and design in year 1, and construction in year 2.

1.6 Providing Critical Equipment for Solar Process Integration

In his State of the Union Address in 2006, President Bush identified solar energy as one of the areas in which he wants to accelerate progress through the Solar America Initiative to help diversify the energy sources to power homes and businesses. In the Energy Policy Act of 2005, Congress passed legislation recommending $3.4 billion over ten years in tax incentives to encourage the production of electricity using photovoltaics and other renewable technologies, including the first-ever tax credit for residential solar energy systems. To meet these national goals for solar energy production, new lower-cost, high-performance solar technologies must be readied for the marketplace as quickly as possible. Accelerating the transfer of laboratory-developed technologies to manufacturing will require a new approach to research and development with an emphasis on issues related to process integration. Estimates are that an advanced process integration research capability for U.S. industry would reduce the time to market for new types of solar panels by up to 50%.

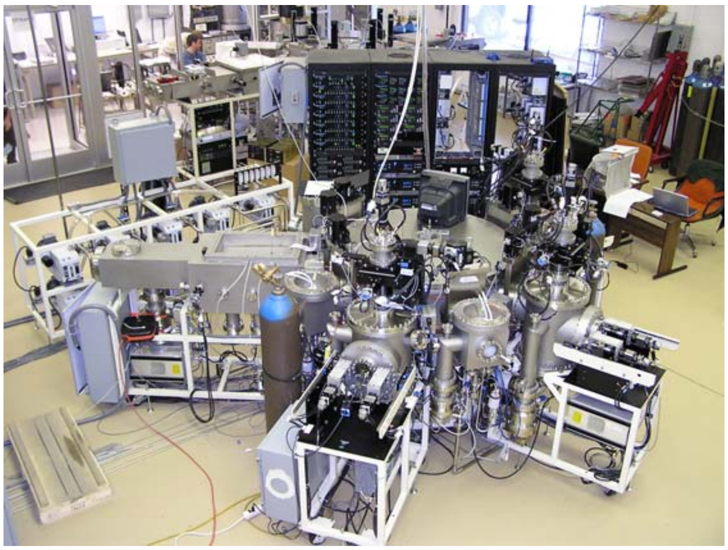

Figure 1.6.1 Silicon module process research tool, under construction. Such sophisticated tools are necessary to help meet national goals for solar energy production and cost.

Accomplishing these steps requires highly sophisticated, state-of-the-art chemical deposition, processing, and characterization tools specific to the material system under development (i.e., crystalline silicon, thin-film, polycrystalline, multi-junction; Figure 1.6.1). In the new Science and Technology Facility at NREL, six high-bay areas are designed such that key pieces of process and characterization equipment can be integrated, using robotic arms to transfer samples between chambers, allowing simulation of manufacturing processes in a controlled environment. Samples can be transferred between tools in special cassettes from one processing tool to another. However, the current and planned funding through FY2007 will only provide some equipment for three of the six large research bays, leaving the facility underutilized until FY2008 or beyond. The ***STF Research Equipment Initiative,*** requesting $10 million in FY07 (in addition to the $2.8 million already planned for FY2007), will complete four of the six bays and provide critically needed characterization equipment in adjacent laboratories. An additional $14 million would be needed in FY2008 and/or FY2009 to purchase all required equipment ($6.5 million in FY2008 and $7.8 million in FY2009).

1.7 Accelerating the Development of New Fuels from Biomass

Moving beyond a petroleum-based economy requires rapid development of domestic, renewable alternatives to gasoline and diesel fuels. Advanced technologies need to be perfected to make fuel ethanol from cellulosic (plant fiber) biomass, both from cellulosic biomass now discarded as waste and from crops grown especially for energy. Achieving rapid development of this technology will require expanding and accelerating research on ways to efficiently and cost-effectively convert the cellulosic materials into useful fuels and byproducts in a biorefinery, just as crude oil is today converted into gasoline, diesel, and other products in a petroleum refinery.

Figure 1.7.1 Integrated Biorefinery Research Facility Expansion. (*Proposed expansion indicated by blue arrows).*

NREL has two small pilot-scale biorefineries, one focused on biochemical conversion (using enzymes and microorganisms) and one focused on thermochemical conversion (using heat and chemical catalyst). However, the current biochemical facility's single pretreatment equipment train is too inflexible to support the accelerated research effort required by the President's Biofuels Initiative. NREL proposes expanding the existing biochemical facility to flexibly accommodate a wider variety of process equipment, to allow more than one pretreatment process to be studied in parallel, to enable large-volume residue production for thermochemical conversion testing, and to allow more rapid process sample analyses.

The proposed ***Integrated Biorefinery Research Facility*** project would expand NREL's existing biochemical process development facilities (Figure 1.7.1) to result in additional and reconfigured space, including high-bay space for process research, laboratories for analysis, storage space for biomass feedstocks, and a small amount of office support space. Assuming FY2008 funding, the total project cost (conceptual design, design/build, essential capital equipment, and equipment relocation) would be $19.5 million. With a design/build approach to project design and construction, and expedient approvals through the DOE construction management process, this expansion should be essentially complete by the fourth quarter FY2009.

1.8 Building a National Resource for Renewable Energy Systems Integration

Energy consumption in the United States is projected to increase by 34% by 2030 (Energy Information Administration, Annual Energy Outlook 2006). The Administration's goals is to change the way we power our homes, businesses, and automobiles—and renewable energy sources including solar, wind, and hydrogen should be a significant part of this increased demand for energy in 2030.

Surveys of energy experts indicate that one of the major barriers to renewable energy generation and use is effective and reliable integration—integrating renewable energy systems into existing grids, buildings of all types, and communities while reducing energy demand; developing hybridized systems of more than one technology; and developing net zero-energy buildings and communities. For example, even though wind resources offer a major opportunity to supply energy for electricity, their variability can make them challenging to integrate into energy production and delivery systems while ensuring low cost and high system reliability. As another example, integrating solar systems effectively into mass-produced housing will require extensive systems engineering and development of standards and protocols.

As noted above, to accelerate progress in renewable electricity and renewable fuels, NREL must place significant emphasis on managing the interface between applied R&D and the commercial marketplace. Managing that interface requires technical capabilities in designing renewable systems, new energy storage technologies, and the interconnection, control, and communication technologies needed to make these systems functional and reliable. Performance testing, standards development and protocols, and system modeling and simulation are needed for all renewable energy systems to be able to accelerate the entry of renewable systems into the commercial marketplace.

Capabilities are very limited, at NREL and elsewhere, for simulating, engineering and testing renewable electricity and hydrogen in energy systems, which includes fully integrated energy systems for buildings and communities of all types. In addition, energy decision makers have no place to observe actual working components and systems, and be informed on projections of performance and costs of specific energy options relevant to their situation.

The proposed ***Energy Systems Integration Facility*** would provide the required research space dedicated to the design and testing of renewable electricity and hydrogen systems, and fully integrated energy systems (Figure 1.8.1). The new facility will integrate NREL's capabilities in buildings research, distributed energy, electrolysis, power electronics, grid and micro-grid support applications, solar systems, hydrogen systems, renewable communities, and related modeling and simulation activities into one new state-of-the-art facility. The facility would also be designed to allow industrial users to bring in and test their own equipment and systems. The total cost for this proposal is $77 million, including essential equipment, over FY2009–FY2011. Construction would be completed in FY2012.

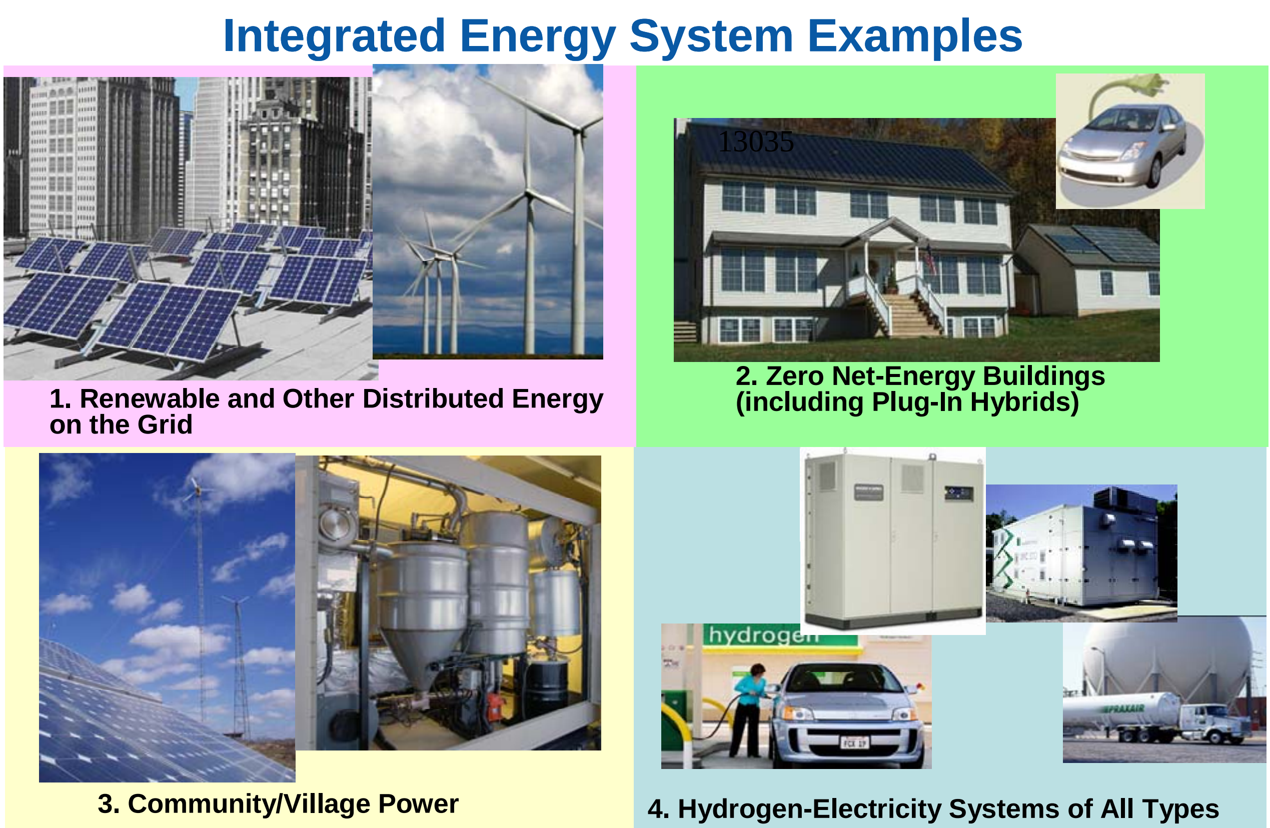

Figure 1.8.1 Examples of integrated systems that would benefit from the proposed Energy Systems Integration Facility

1.9 Strengthening the Interface of Basic and Applied Research

To accelerate progress in renewable fuels and renewable electricity, NREL must also place significant emphasis on managing the interface between basic science and applied research and development. The Grand Buildout Vision is designed specifically to strengthen NREL's capabilities to do just that. Today, one building (the Field Test Laboratory Building, NREL's oldest facility) provides space for both foundational science supporting renewable fuels development and the applied research needed for mid-scale development of renewable fuels. Similarly, one building today (the Solar Energy Research Facility) provides space for both the solid-state science underlying photovoltaics research and the applied research that supports the development of electronic materials, devices, and components. These two existing facilities are fully used, with no available space for additional work in either basic science or applied research. As emphasis continues to grow on the interface between basic and applied research, construction of additional laboratory facilities is critical.

NREL proposes two such facilities to strengthen this interface. The ***Biological and Chemical Research Facility*** is proposed for funding totaling $135 million, beginning in FY2009. This state-of-the-art laboratory building, housing 200 researchers, will provide space that will benefit Biomass and Hydrogen by conducting foundational science programs that will lead to breakthroughs in these areas; initially, it will also benefit DOE's Solar Program. This new facility will provide biology and chemistry laboratories for all areas of foundational research supporting Biomass and Hydrogen, including structural biology, genomics, enzymes and biological catalysts, biological materials, separations and membranes, bio-nanoscale materials, and biomimetic energy conversion processes, supporting the future development of all types of bio-based and hydrogen fuels. These activities will be moved out of the Field Test Laboratory Building, freeing up space for the expansion of related applied research in mid-scale bioprocess and hydrogen development. In addition, the new facility will help meet the needs of work in solid-state electronic materials until the Solid-State Research Facility (see below) is constructed.

The Biological and Chemical Research Facility will also provide dedicated space for NREL's scientific computing capabilities. Computer modeling and simulation is firmly established as an equal and indispensable partner, along with theory and experiment, in the advance of scientific knowledge and engineering practice. In fact, numerical simulation is the only viable way to advance knowledge and understanding in many areas of scientific and engineering pursuit. For example, the design of practical and efficient catalysts for biomass conversion requires the ability to predict, at the molecular level, the detailed behavior of the large, complex molecules and materials involved in catalytic processes. Because even the most sophisticated experimental techniques are unable to provide the details of the structures, processes, and chemical reactions occurring at the surface of a catalyst, the required understanding is only

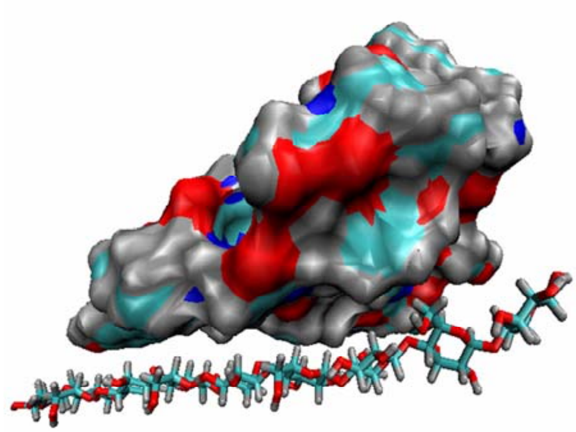

Figure 1.9.1 Understanding the function of enzymes that break down cellulose at the molecular level is very important to lowering the cost of biofuels. Computational modeling provides critical insights to guide research, such as this simulation of an experimental enzyme docking with the surface of cellulose.

possible by taking advantage of high performance computational hardware and software.

Scientific computing enables hypotheses to be modeled and validated quickly and cost effectively prior to experimental testing (Figure 1.9.1). Because of its importance, NREL has expanded its scientific computing capabilities and expertise over the past five years in support of the EERE mission. However, the current limit of one teraflop processing capability cannot meet the increasing demand for these resources, which means that not all EERE programs are fully benefiting from the accelerated development, reduced time to insight, and greater opportunities for breakthroughs enabled by scientific computing. Expanding our computing capability as a part of the Biological and Chemical Research Facility will provide necessary and sufficient modeling and simulation capabilities to be an appropriate "launching pad" for grand challenge applications in energy efficiency and renewable energy and efficiently utilize the Leadership Class Facilities being deployed at several Office of Science laboratories.

The ***Solid-State Research Facility*** is proposed for funding totaling $109 million starting in FY2011. This facility will be a companion to the Biological and Chemical Research Facility (except for the scientific computing capability, which will be located in the first laboratory constructed and serve both laboratory facilities). The Solid-State Research Facility will provide additional and updated laboratories for foundational research supporting solar, hydrogen, nanotechnology, buildings, and related programs. The foundational science necessary to sustain these programs into the future include optoelectronics, theoretical physics, carbon dioxide chemistry, catalysis, atomic-scale characterizations and measurements, smart materials, chemical kinetics, and optical and thermal properties of materials.

1.10 Reducing Cost of Research through Research Support Facilities at NREL

NREL and the DOE Golden Field Office have been in operation since 1977. EERE has fulfilled much of the space needs of these operations through long-term leases, paying over $150 million for the use of these facilities over this period. If EERE had acquired this space, EERE's investment in research and development at NREL could have been significantly higher. In 2006, 52% of NREL's staff of approximately 1100, and 100% of GO's staff of approximately 130, resided in 275,000 gross square feet of leased facilities, costing DOE about $5 million annually. Combined with the inevitable loss of productivity arising from fragmented operations at three distinct locations, the annual cost to EERE to house its NREL-affiliated operations far exceeds that of lease costs alone. EERE will spend in excess of $240 million in lease payments over the next 40 years to house its NREL-affiliated operations should it continue its current long-term leasing strategy, exclusive of productivity losses. The current leasing practice is the highest life-cycle cost option available to fulfill its space requirements.

The proposed ***Research Support Facilities Phase I and II*** will provide sufficient space to enable NREL and DOE staff in Golden to move from leased office space onto the primary NREL campus, satisfying administrative needs for several years. This project will reduce EERE's life-cycle operating costs at NREL, encourage higher productivity in research, and increase scientific collaborations.

These Research Support Facilities Phase I and II projects will also apply advanced design approaches and use market-validated renewable energy and energy efficiency technologies, with each successive module using the latest technologies. As showcase facilities, NREL's Research Support Facilities will be constructed to demonstrate the Laboratory's commitment to and leadership in cost-effectively pushing the envelope on efficiency and integration of renewables. Phase I and II are proposed as a set of individual buildings totaling approximately

$75 million funded over the period FY2006–FY2009. NREL has received $9.9 million in FY2006 to begin this series of projects.

1.11 FTLB Expansion/Energy Efficiency Upgrade

The Field Test Laboratory Building (FTLB) is the oldest laboratory at NREL. About 45 researchers occupy office and cubicle spaces that have no daylight or windows. These substandard spaces result in increased energy use compared to daylit spaces, and negatively affect researcher productivity and creativity. The FTLB Expansion/Energy Efficiency Upgrade project will create about 48 new daylit office and cubicle spaces in a second-floor space in the northeast corner of the second floor, to be constructed over the existing central utility plant. This project will benefit researchers in the EERE Biomass and Hydrogen programs, and related foundational research, as well as lower NREL's energy use. The cost is expected to be $4.5 million in FY2009.

1.12 Data Infrastructure Modernization

Networking provides NREL scientists with virtual proximity to collaborators, computers in the National Computing Leadership Facilities being established by DOE at multi-program laboratories, and data of all types. As research data files grow exponentially in size, sharing these data sets with other researchers requires a major increase in the bandwidth of NREL's information systems. NREL is preparing to improve this bandwidth from 1.5 gigabits per second to 622 gigabits per second through a combination of investments in FY2007. This will enable the Laboratory to take advantage of an important expansion in Denver of the DOE Office of Science Energy Sciences Network. However, NREL's current physical infrastructure of copper wire and some fiber optic cable presents a significant challenge to supporting the increased bandwidth needed for data transfer today and in the future. Today, all desktops, servers, and other network resources attach to NREL's information network using copper wire. However, major increases in bandwidth require replacement of copper with fiber optic cable and other wiring changes from the desktop out. Funding required for these infrastructure changes is estimated at $2.1 million in FY2009, and another upgrade of $1.0 million in FY2013, and $3.0 million in FY2014-FY2018.

1.13 Improving Marketplace Access to NREL Expertise

Managing the interface between applied R&D and the commercial marketplace requires the encouragement of effective and meaningful exchange of information between the Laboratory and energy stakeholders. ***Research Support Facility Phase III***, which will house the ***NREL Conference and Learning Center***, will provide critically needed space to interface effectively with the public and with energy stakeholders coming to NREL; improve the interchange of information between the Laboratory and the marketplace; and provide the nation with a "hub" for renewable energy and energy efficiency education.

As the nation's leading science and technology center for EERE, the numbers of visitors and high-level energy stakeholders—from the business, technical, finance, utility, and government communities—are increasing dramatically as interest in renewable energy and energy efficiency rises. This is creating important opportunities for the Laboratory and the Golden Field Office to significantly broaden the knowledge base about renewable energy in the United States, but is also creating unmanageable demands on existing, outdated visitor and conference facilities:

- In FY2006, almost 16,000 people visited NREL. The Laboratory's small (6,000-square foot) Visitor Center, built and donated by Midwest Research Institute in 1994, can no longer meet the demand of an increasing numbers of people who want to visit the Lab and/or learn about renewable energy.
- Many more business leaders and representatives from the other key communities cited above could be accommodated in discussing the technical and economic viability of renewable energy and energy efficiency technologies with NREL staff, if adequate public facilities were available on the NREL site.
- With increased attention on the interface between science and applied research, it is imperative to facilitate the exchange of technical information among researchers working in both fields. NREL has never been able to host major conferences pertinent to this DOE mission – to share its knowledge and gain new insights on a national scale – frustrating a central part of its mission. A conference facility would be highly beneficial to NREL's research and to the interests of many energy stakeholders by educating key decision makers about renewable energy in a facility co-located in the very place where the science and technology innovation is occurring.
- NREL currently processes its visitors (checks identification, issues badges) in a guardhouse of less than a thousand square feet. The small buildings results in groups of visitors, including high-level executives, foreign energy ministers and delegations, and similar guests, to sometimes by forced to wait outside in bad weather, sometimes for an extended period of time.
- NREL has a strong education program for K-12, but no onsite classroom space for demonstrating key scientific principles about energy to students, science teachers, and others. This lack of conference and classroom space results in lost opportunities to further science and technical education for many students, teachers, and school systems interested in renewable energy.
- Classroom space would also help accelerate the deployment of EERE technologies by allowing NREL to partner with community colleges and universities to develop curriculum and provide hands-on training in renewable energy and energy efficiency technology systems, installations, and energy business planning and management.

Figure 1.13.1   The addition of Research Support Facilities Phase III (NREL Conference and Learning Center) would provide space to interface effectively with the public and energy stakeholders coming to NREL.

The proposed Research Support Facility Phase III (NREL Conference and Learning Center, Figure 1.13.1), will provide auditoriums, large conference rooms convertible to classrooms, small conference rooms and data visualization facilities, a visitor receiving area, staff offices and other features similar to those available at other national laboratories. The Center will also incorporate state-of-the-art multi-media and web-connected technology to greatly enhance the learning experience presented at the Laboratory. Beyond the educational experience, the Center will be a unique place to study and collaborate—often as a shared space with academic institutions, industry partners and other national labs; in short, the Center would become a national learning "hub" for renewable energy.

1.14 Developing Site Infrastructure for the Grand Buildout Vision of the NREL Campus

With the addition of these facilities, new areas of the NREL campus will need to be developed that currently do not have utilities, roads, walkways, and parking. The proposed ***South Table Mountain Site Infrastructure Expansion*** set of projects will extend the roads and utilities into the undeveloped south central and northeast portions of NREL's primary site (Figure 1.14.1), develop stormwater management features necessary to meet environmental requirements, and develop parking structures. Because of the limited space for development, and the desire to demonstrate the most sustainable campus design, NREL will require double-decked parking structures in the parking zone on the southern edge of campus. Employees will walk, bicycle, or take a regular shuttle to get to their workplaces. All buildings whose occupants will use the parking structures are within a five-minute walk of the parking structures. NREL expects that additional funding of $4 million in FY2009 and $3 million in FY2010 will be required for roads, utilities, and related extensions. Estimates are that $8.5 million will be required in FY2009 for the lower deck of the major parking lot at the southern edge of the campus, and an additional $27 million in FY2012 for the upper deck.

Figure 1.14.1 Major areas of NREL's primary campus have no roads or utilities.

1.15 Supporting EERE with Small Institutional Facilities and Infrastructure

Supporting the current mission of NREL regularly requires the addition of new facilities and infrastructure assets that are relatively small, $5 million or less per project. Examples include refurbishment of laboratories for new or changing research opportunities, new safety or security capabilities, additions of fencing or walkways, new concrete pads for outdoor experiments, etc. For these small projects, a level of 0.5% of replacement plant value ($1 million to $5 million per year from FY2009 to FY2013) is estimated based on current needs ***(Institutional Facilities and Infrastructure—New Capabilities).***

1.16 Supporting EERE with New Institutional and Program Capital Equipment

The frontiers of scientific instrumentation, scientific computing, and information processing are always expanding, providing more precise and faster measurements, with ever-greater sensitivities. EERE programs will increase the likelihood of research breakthroughs and more rapid research progress by taking advantage of these advances in scientific instrumentation. For example, advances in nanotechnology alone have spawned several new instruments to enable isolation and manipulation of nanoscale particles, such as the focused ion beam milling machine that NREL purchased in FY2005 and an advanced X-ray diffractometer purchased in FY2006. A funding level of about $3 million to $5 million per year for institutional (administrative and shared) equipment, and about $3 million per year for program-specific capital equipment, allows the purchase of new equipment to take advantage of technical improvements in laboratory instrumentation (***Institutional Capital Equipment—New Capabilities***).

1.17 Reinvesting in Facilities and Infrastructure

Since NREL opened its doors in 1977, the Department of Energy has invested in facility and infrastructure assets at the Laboratory that were worth $170 million at the end of FY2006. Maintenance, replacement, and refurbishment (collectively, "reinvestment") are necessary to maintain these buildings, roads, and utilities in good condition; maintain the interiors of buildings including laboratories; configure research spaces to respond to modest changes in research direction; and respond to requirements for safety and security. As a relatively young institution in the DOE system, with no environmental legacies, NREL's facilities are in comparatively good condition, with an overall facility condition index[1] today of 1.8% ("Excellent"). However, NREL's oldest facilities are now beginning to require extensive reinvestments. NREL currently has $3.0-million worth of reinvestment projects where roofs, HVAC systems, and roads are beyond their expected service lives (deferred reinvestment).

The proposed level of funding for ***Institutional Facilities and Infrastructure—Reinvestment*** is based on DOE's minimum required annual reinvestment level of 2% of current replacement plant value, and an additional 0.5% of replacement plant value for deferred maintenance. Not including the amount that is projected to be covered by operating funds from NREL overhead, an annual investment ranging from $3.6 million in FY2009 to $9.5 million in FY2013 is required. The value increases each year because the replacement value increases both with inflation and with additional construction.

1.18 Reinvesting in Institutional and Program Capital Equipment

In addition to its facilities and infrastructure, NREL has capital equipment that is today worth $89 million. Of that total, $13 million represents equipment that, when purchased, was general purpose (institutional, shared, or multi-program in nature), as opposed to specifically serving only one DOE program. The equipment includes:

- scientific research instruments with a ten-year service life (e.g., scanning tunneling microscopes that examine individual atoms of solar cell layers and plant cells);
- scientific computing equipment with a three-year service life (e.g., to enable modeling of the release and transfer of hydrogen atoms in algal hydrogenase, or complex building energy simulations);
- administrative information systems with a four-year service life (e.g., network, voicemail, finance); and
- other equipment related to safety, security, or facilities operation with an average 12-year service life.

Extensive business analysis has shown that this equipment is, on average, 45% depreciated today, with 55% remaining value. About 26% ($3.3 million) of the institutional equipment is now beyond its expected service life. Reinvestment funds consist of three categories: funds to replace the equipment beyond its expected service life; funds to replace equipment when it reaches its expected service life; and funds for maintenance contracts that help extend the life of the asset in optimal condition. Given today's portfolio of equipment at varying ages, the required funding to replace equipment that will be beyond its service life after FY2008, to replace equipment reaching its service life and maintain an average remaining value of the

[1] The Facility Condition Index is the value of the deferred maintenance backlog (facility and infrastructure components not replaced at the end of the optimal period of use) as a percent of the total replacement plant value.

portfolio at 50%, and cover the increasing costs of maintenance contracts, results in a funding profile for ***Institutional Capital Equipment—Reinvestment*** of $8 million to $9 million per year from FY2009 through FY2013.

The balance of NREL's current capital equipment, worth $76 million today, was purchased by individual EERE programs ($70 million) and Office of Science programs ($6 million). Using a similar analysis and projection methodology as for institutional capital equipment, this program capital equipment is about 74% depreciated, with only 26% remaining value. About 29% ($22 million) of the program capital equipment is now beyond its expected service life. Reinvestment funds (not including maintenance contracts, for which data is not yet available) to reduce the deferred replacement backlog and to replace equipment at such a rate as to achieve and maintain a 50% remaining value will require funding of $6 million to $14 million per year for the combination of EERE and Office of Science (***Program Capital Equipment—Reinvestment***).

1.19 Conclusion

Meeting national objectives to transform the use of energy in the United States will require the best technologies that researchers can devise. The National Renewable Energy Laboratory, in partnership with hundreds of universities, private companies, and state and local governments, is the nation's focal point for all research to develop these new energy systems to a point of viable market acceptance. Without the facilities and equipment required to pursue new avenues of research in these areas, progress will be limited by today's capabilities. Without adequate stewardship to maintain today's capabilities, even today's research will falter. Capital investments must be made thoughtfully if we are to transform our energy future, a transformation that is critical to the United States and the world.

2.0 Strategic Investments

2.1 Science and Technology Facility (S&TF) Research Equipment Initiative

In his State of the Union Address in 2006, President Bush identified solar energy as one of the areas he wanted to support with the Solar America Initiative to help diversify the energy sources to power homes and businesses. In the Energy Policy Act of 2005, Congress passed legislation recommending $3.4 billion over ten years in tax incentives to encourage the production of electricity using solar photovoltaics and other renewable technologies, including the first-ever tax credit for residential solar energy systems. To meet these national goals for solar energy production, new lower-cost, higher-performance solar technologies must be readied for the marketplace as quickly as possible.

The solar industry has shown that resolving problems with process development is the most critical challenge to accelerating the scale-up of laboratory technologies towards commercial scale (Figure 2.1.1). Estimates are that an advanced process research capability for U.S. industry would shorten the time to market for new types of solar panels from 5-10 years to less than 3 years. In the new Science and Technology Facility at NREL, six high-bay areas are designed such that key pieces of process and characterization equipment can be integrated, using robotic arms to transfer samples between chambers, allowing simulation of manufacturing processes in a controlled environment. Samples can be transferred between tools in special cassettes from one processing tool to another.

This sophisticated equipment is necessary because solar cells and modules are complex devices consisting of many layers of different materials (Figure 2.1.2). To understand how to scale-up laboratory technologies, researchers must:

- prepare a wide variety of layers using various types of equipment
- examine these layers with a variety of atomic- and nano-scale instruments for surface characteristics, chemical composition, electrical and optical properties, morphology, and more
- modify the surfaces under different conditions of temperature and pressure
- develop diagnostic probes that tell researchers what is happening in real-time during processing
- test the completed photovoltaic prototypes for performance and reliability.

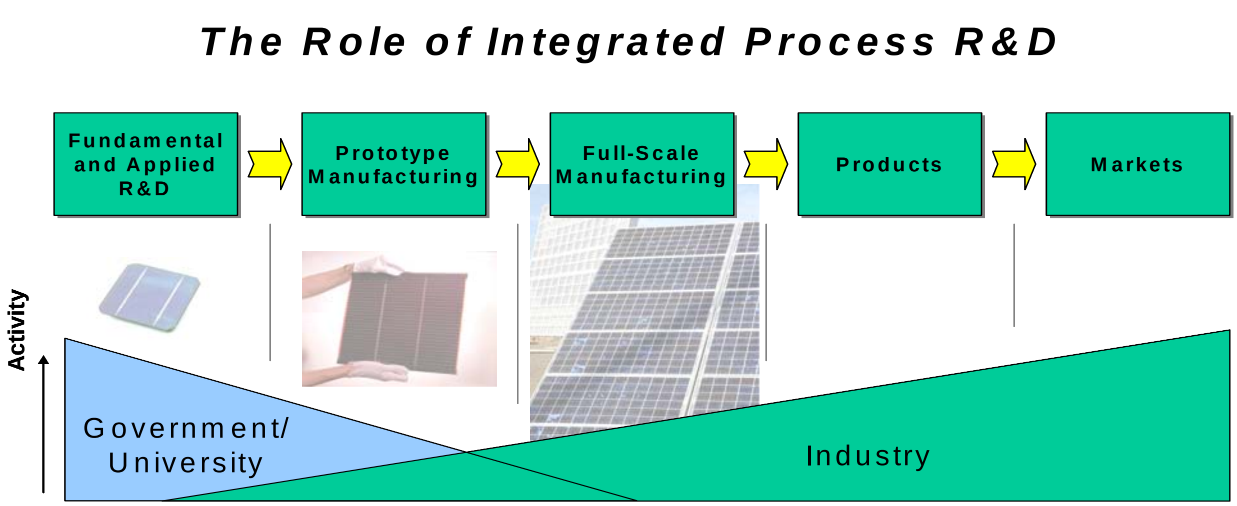

Figure 2.1.1

Accomplishing these steps requires highly sophisticated, state-of-the-art equipment and instruments, appropriate to the material system being studied (crystalline silicon, polycrystalline materials and thin films, high-efficiency cells). In the new S&TF at the National Renewable Energy Laboratory, six high-bay areas will be available where key pieces of equipment will be integrated, using robotic arms to transfer samples in special air-tight cassettes from one processing or testing step to another.

The remainder of the planned FY2007 funding for equipment in the S&TF will only provide some equipment for three of the six large research bays, leaving the facility underutilized until FY2008 or beyond. An additional $10 million in FY2007, beyond the $2.8 million already planned, will complete four of the six bays and provide critically needed characterization equipment in adjacent laboratories. The items urgently needed include:

Integrated processing equipment

- Thin-Film Vapor Deposition and Sputtering Cluster Tools ($4,294,000) – Portions of the tools necessary to prepare, characterize, and modify layers for copper indium diselenide and crystalline silicon material systems will be provided through FY05, FY06, and planned FY07 funds. Additional funds are needed to complete these tools and to provide similar capabilities for the cadmium telluride material system. Tool breakdown is as follows:
    - o Si Cluster Tool Extension - $1,530,000
    - o CIGS Cluster Tool Extension - $1,090,000
    - o CdTe Cluster Tool - $1,674,000

Solar Cells Are Complex to Manufacture

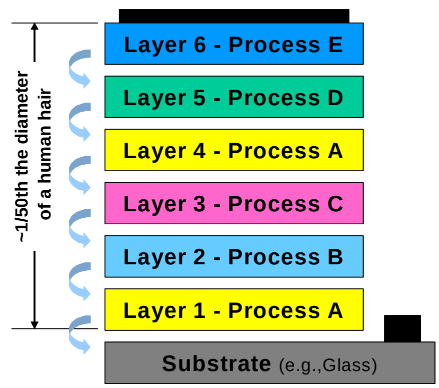

Figure 2.1.2

- Process Support Tools ($757,000) – Tools in this category are necessary to prepare substrates for deposition and modify semiconductor layers once deposited. These tools will also be used to deposit and process organic PV materials as well as atmospheric deposition of precursors by ink-jet printing techniques. Tool breakdown is as follows:
    - o Organic Electronic Materials Processing System - $290,000
    - o Multi-jet Ink Jet Printing System - $100,000
    - o Ozone Wafer Clean System - $182,000
    - o Rapid Thermal Annealing Pod - $185,000

- Substrate Transport Cassettes ($495,000) – The process integration concept uses a standard sample transfer interface that allows transfer of a sample under controlled conditions from one instrument to another, simulating manufacturing processes. The specialized cassettes and adaptors should be purchased in bulk for efficiency in research start-up and quantity discounts.

Instruments to characterize all types of photovoltaic cells at any step in a process

- Dynamic Secondary Ion Mass Spectrometer ($2,100,000) – This laboratory instrument will provide trace level analysis of all elements in the periodic table, to improve the characterization of all photovoltaic materials and cells. This will replace the current 26-year-old instrument.

- In-Lens Field Emission Scanning Electron Microscope ($875,000) – This laboratory instrument will allow researchers to study the morphology, chemistry, structure, and electro-optical properties of photovoltaic materials and devices on a nanoscale.

- Large-area Mobile Photoemission System ($797,000) – This laboratory instrument will provide researchers with the elemental, molecular, chemical state and electronic structure of the surface of solid materials. This information provides a quantitative picture of the chemical and electronic properties of surfaces and interfaces.

- Characterization Support Workstations ($1,000,000) – Provides critical characterization support capabilities. Specifically, the scanning probe microscope tool provides high-resolution sample topography information coupled with high spatial resolution electrical measurements on deposited materials and devices. The microwave reflectance lifetime scanner is a non-contact non-destructive method of mapping carrier lifetime, sheet resistivity, spectral response, and diffusion length. The photoluminescence/dispersive µRaman mapping system allows us to map compositional and electronic state related properties of materials. Tool breakdown is as follows:
    - Large Sample Scanning Probe Microscope - $375,000
    - Microwave Reflectance Lifetime Scanner - $275,000
    - PL/Dispersive µRaman Mapping System - $350,000

Equipment to test the performance of completed module prototypes
NREL is currently in the process of expanding the Outdoor Test Facility (OTF) to accommodate an expanded test and evaluation activity in support of the Solar America Initiative (SAI). The new characterization tools listed below will reside in the expanded OTF and are critical if we are to meet the anticipated added SAI test and evaluation workload.

- Multi-source Solar Simulators ($1,400,000) – Three new simulators are needed to measure the performance of photovoltaic research cells under normal sunlight conditions and concentrated sunlight conditions, and the performance of large-area photovoltaic modules sized for commercial use. The two types of simulators NREL already has are 25 and 20 years old, and NREL does not have a concentrated sunlight simulator.

- Environmental Test Chambers ($560,000) – These test chambers provide programmable environmental conditions for temperature, humidity and light for accelerated testing of durability and reliability of photovoltaic modules. NREL's current environmental test chambers were purchased in 1989 and need to be replaced.

2.2 Integrated Biorefinery Research Facility (IBRF)

Developing and deploying robust biomass refining (biorefining) technologies will be a key to realizing the full potential of biofuels to improve U.S. energy security by displacing up to 30% of the nation's current fuel use. Recognizing this potential, the Energy Policy Act of 2005 includes numerous provisions to spur research, development and deployment of biorefining technologies for the production of liquid transportation fuels like ethanol. With petroleum supply security concerns continuing to mount, President George W. Bush's announced in 2006 an Advanced Energy Initiative that includes a "Biorefinery Initiative" component to further accelerate research to develop cost competitive cellulosic ethanol technology. The proposed integrated biorefinery research facility is needed to support and enable success with these efforts.

Motivation – Energy security. Our national security relies on being "energy secure" and "environmentally secure." The importance of decreasing the United States' reliance on foreign sources of energy to improve our energy security has long been recognized. The National Energy Policy of 2001 specifically recommended supporting the research and development of new technologies that will help reduce our nation's dependence upon imported petroleum. Both the Energy Policy Act of 2005 and the Advanced Energy Initiative of 2006 include sections focused on diversifying transportation fuel options through the acceleration of cellulosic ethanol RD&D. Increased funding for research, development and demonstration activities related to biomass conversion to biofuels and bioproducts in integrated biorefineries, which would directly benefit from the proposed integrated biorefinery research facility (IBRF), is authorized in EPACT 2005 Sections 210, 931 and 932. Beyond this, Section 977 of EPACT 2005 authorizes funding for science to advance integrated bioenergy research, which would indirectly also benefit from the proposed facility. While the Advanced Energy Initiative has not yet been authorized, its accelerated "Biorefinery Initiative" would also greatly benefit from the proposed IBRF.

In support of this legislation and new initiative, and in accordance with our nation's energy and environmental security objectives, the U.S. Department of Energy's (DOE) 2006 Strategic Plan (Strategic Theme 1, Energy Security) directs the federal enterprise to:

- "Increase our energy options and reduce dependence on foreign fuel supplies, thereby reducing vulnerability to disruption and increasing the flexibility of the market to meet U.S. needs." (Goal 1.1 Energy Diversity)
- "Reduce greenhouse gas emissions and other environmental impacts (water use, land use, criteria pollutants) from our energy production and use." (Goal 1.2 Environmental Impacts of Energy)
- "Create a more flexible, secure, reliable, efficient, and higher capacity U.S. energy infrastructure by improving energy services throughout the economy and enabling the use of diverse sources." (Goal 1.3 Energy Infrastructure)

As discussed in the President's Advanced Energy Initiative, first revealed during his State of the Union Address on January 31, 2006, bio-based transportation fuels like cellulosic ethanol are recognized to have the potential to displace up to 30% of the nation's current fuel use and thereby dramatically contribute to improved U.S. energy and environmental security. Accordingly, the President's Advanced Energy Initiative includes a request for increased future funding to spur cellulosic ethanol technology development.

The proposed IBRF expansion is key to successfully conducting an accelerated cellulosic ethanol technology development effort. Such a facility is critically needed to be able to efficiently develop and validate cellulosic ethanol biorefining technology to the point where large-scale deployment can occur, an outcome that is critical to the U.S. Department of Energy being able to successfully meet its Energy Security strategic goals.

Motivation – Scientific Discovery. Developing and deploying robust biomass refining (biorefining) technologies will be a key to realizing the full potential of biofuels to improve U.S. energy security. Recognizing this, the Advanced Energy Initiative includes a "Biorefinery Initiative" component to accelerate cellulosic ethanol research.

A biorefinery is analogous to a petroleum refinery that refines crude oil into a broad range of industrial and energy products. Examples of existing biorefineries include paper mills and grain (predominantly corn) processing plants that produce ethanol and various food and feed coproducts. The DOE's Office of Energy Efficiency and Renewable Energy (EERE) is partnering with these industries to develop the next generation of biorefineries that will produce fuel, chemical, feed, material, and/or power products from non-conventional, lower-cost fibrous feedstocks such as residues resulting from agricultural and forestry operations and their allied industries. Since beginning pilot-scale research on biomass-to-ethanol in the early 1990s, it has become clear that biorefineries utilizing a combination of biochemical and thermochemical conversion technologies offer the best opportunity to capture the value in biomass in a commercially viable fashion.

The development of biorefineries will logically follow a progression moving from the lowest cost feedstock with the least technology and market risk, through a series of steps where research will be needed to bring an increasing breadth of feedstocks and products under the biorefinery umbrella. This progression is expected to develop along two principle conversion pathways – biochemical and thermochemical. The biochemical pathway will use the carbohydrate portion of biomass to produce intermediate sugars that can then be converted to fuel ethanol and other products. The thermochemical pathway will use intact (raw) biomass or just the non-carbohydrate portion to produce synthesis gas (analogous to natural gas for electricity and heating) and/or heavy oils (analogous to heating oil used for space heating), either of which then can be converted into a wide range of fuels and chemicals products. In time it is likely that a biorefinery will emerge that combines elements of both these pathways in one integrated facility.

The current EERE Biomass Program goal for biochemical and thermochemical conversion is to reduce the estimated cost for biomass-derived ethanol from an estimated $2.75/gal of ethanol today to $1.07/gal by 2020, and the President's Advanced Energy Initiative proposes to accelerate this cost reduction goal to 2012. Reaching these cost goals requires an overall systems-level approach to research and development on both biochemical and thermochemical production pathways, and will necessitate both bench-scale and pilot-scale research. At the pilot-scale, the research goal is to reduce cost through process intensification and integration within each pathway, and ultimately to couple the synergies afforded by combining elements of both pathways in one biorefining facility. Breakthroughs in fundamental science understanding and capabilities will also be needed in the longer term to be able to achieve these cost targets on higher cost biomass feedstocks such as so-called energy crops grown specifically for bioenergy applications.

In terms of advancing science and technology knowledge, capabilities and infrastructure, the U.S. DOE's 2006 Strategic Plan (Strategic Theme 3, Scientific Discovery) directs the federal research enterprise to:

- "Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy." (Goal 3.2, Foundations of Science)
- "Integrate basic and applied research to accelerate innovation and to create transformational solutions for energy and other U.S. needs."(Goal 3.3 Research Integration)

Developing new biorefining technologies for the value-added conversion of cellulosic biomass feedstocks is a transformational energy solution offering tremendous opportunities for science and technology innovation and continuation of U.S. scientific and engineering primacy.

Analysis to Support Mission Need. The Department works towards the biomass conversion cost reduction goals outlined above through the Office of the Biomass Program (OBP) within the EERE. The following analysis describes the shortfall in current capabilities to reach these program goals, identifies the range of alternatives to address this shortfall, and quantifies the approximate cost of each.

The Office of the Biomass Program carries out its R&D through competitive solicitations for industrial partnerships with appropriate cost sharing to attract innovation and ensure investment value for industry and university contracts. In addition, the Program relies on several national laboratories for research expertise and strategic guidance.

To conduct pilot scale research, the Program currently relies on the Biochemical Process Development Unit (BCPDU) located within the Alternative Fuels User Facility (AFUF) at the

National Renewable Energy Laboratory (NREL), and also the Thermochemical Process Development Unit within the Field Test Laboratory Building also at NREL. Industry partners working with NREL and the Program also share in the research conducted at these facilities. The experience with these two facilities has been invaluable in allowing the Program to envision the types of research, and the research facilities, that will be necessary to meet the Department's goals for displacing petroleum through the development of fully integrated biorefineries.

The current BCPDU was constructed in 1994 to research biomass-to-ethanol technologies at the pilot scale. Constructed in a space created by combining two metal shed-like buildings initially erected in 1984, the BCPDU consists of 6500 square feet (sf) of pilot-scale high-bay research space and 2150 sf of support space and associated laboratories. The process research equipment housed in the BCPDU represents an investment by DOE that is today worth approximately $12,000,000. The high-bay research space in the BCPDU is now fully occupied by existing equipment. As a consequence, the flexibility for conducting new research in this facility is highly constrained and there is no free space available for installation and testing of new equipment or systems. Moreover, the supporting analytical laboratories are the oldest at the NREL and scattered changes over the years have resulted in a labyrinth of poorly utilized space.

While the existing facility provides some of the equipment and capabilities required to pilot a biomass-to-ethanol process, it is not equipped with the range of necessary unit operations nor does it contain sufficient physical space to be able to pilot integrated biorefinery operations. Extensive additional processing, separations, and material handling equipment are required to be able to pilot integrated biorefining processes or test alternative biorefining concepts. For example, to separate non-carbohydrate residues resulting from biochemical conversion processing for subsequent thermochemical conversion requires installing additional processing equipment for which there is currently no space.

A suitably sized and flexible pilot-scale facility is critical to enable rapid progress in biorefining process research to occur. As different process development activities are designed and tested (e.g., equipment and systems for carrying out biomass pretreatment, enzymatic hydrolysis, ethanol fermentation, and related separations, etc.), researchers must have the ability and space to add or remove equipment, reconfigure biomass conversion process trains, etc. In addition, efficient laboratory facilities need to be coincident with the process development unit to enable efficient sample analysis across the breadth of processing stages.

Alternatives Considered to Meet Program Requirements. The following alternative courses of action have been considered in this preliminary analysis:

1. *Expand the existing pilot-scale facilities at the National Renewable Energy Laboratory.* This project consists of two separate but related activities to expand capabilities at the AFUF. The first activity is an expansion of existing AFUF high-bay area that houses the BCPDU to create additional space to accommodate the wider range of processing equipment needed to pilot and simulate biochemical conversion processes. Additionally, it supports related thermochemical operations as they would be performed in an integrated biorefinery. The expanded facility will provide better research space for the Biochemical Platform, the interface to the Thermochemical Platform, and Biorefinery RD&D projects and initiatives. The new structure will be connected to the existing AFUF high bay space and use the existing AFUF utility infrastructure for electricity, steam, water, space heat, and sewer.

When completed, the project will result in 4,800 sf of combined finished laboratory, storage and office space, 6,400 sf of basement space for feedstock storage and staging, and 5,200 sf of flexibly configurable open concrete floor industrial high bay space for process equipment. We propose to add during initial construction 5,000 sf of mezzanine space to the high bay to support state-of-the-art feeding and pretreatment equipment. The remaining 5,000 sf of potential mezzanine space would be built out as needs evolve to support future core research efforts likely to involve new and as of yet unknown processes and/or processing equipment.

The second activity is to add new space to the east side of the existing northern section of the AFUF structure to create a biomass sample analysis laboratory. Thirty linear feet of the existing metal building would be removed and replaced by a 50 ft by 60 ft addition of new building. This new construction would result in approximately 2750 sf on 2 levels to provide a total of 5500 sf of higher quality building space; the lower level would be a research laboratory and the upper level supporting office space. By providing increased laboratory space, this expansion will enable existing analytical equipment to be consolidated into one area. This will also permit rededication of existing laboratory space to bench-scale process development and integration research. The consolidated biomass sample analysis laboratory will include approximately 1200 sq. ft. of wet chemical lab, 1050 sq. ft. of instrument lab, and 500 sq. ft. of biomass processing space.

This option is recommended because it provides the most economical and expedient approach to establishing a pilot scale integrated biorefining research facility. Expanding the current AFUF high-bay research space and associated supporting analytical laboratory space is the lowest cost option because it effectively leverages the Department's substantial past investment in the existing AFUF facility, particularly in the BCPDU. Major portions of the existing BCPDU, including significant capital equipment and systems, are already in place and will not need to be modified. This includes pilot scale fermentation, distillation, ethanol collection equipment and utilities systems, as to a lesser extent biomass handling and solid-liquid separation equipment. This option has the unique advantage of requiring a minimum amount of new construction and capital equipment; it provides the quickest route to project completion.

2. *Build a new pilot-scale biorefinery facility at the National Renewable Energy Laboratory.*
The needs of OBP could be achieved by building a new facility at NREL that would provide 40,000 sf of flexible high bay space to house both biochemical and thermochemical pilot-scale processing equipment. This facility would also include 10,000 sf of space for pilot plant support and biomass analysis laboratories, as well as 5,000 sf of office space. This option has the advantage of allowing the latest thinking and options for biomass processing to be incorporated into a single state-of-the-art design that would effectively support OBP needs through 2025. This option improves overall efficiency and minimizes cost through centralized and consolidated electrical, utility and data acquisition and controls systems. It would also enable operating and support personnel to be shared, which would help ensure efficient utilization of OBP's resources. This option offers the advantage of providing a seamless transition from biochemical to thermochemical unit operations.

3. Build a new pilot-scale facility at another federal facility.
No federal facilities exist to meet this need. The USDA-sponsored National Corn-to-Ethanol Research Center pilot plant located at Southern Illinois University in Edwardsville, Illinois (http://www.ethanolresearch.com/) is specially constructed to investigate conversion of grain (starch) feedstocks; it is not designed to or capable of piloting biorefining operations on cellulosic feedstocks. The acid hydrolysis-based pilot plant constructed at the Tennessee Valley Authority (TVA) is no longer functional; equipment associated with this facility is antiquated and poorly instrumented – far removed from the current state of the art – and was put up for auction in 2004. Moreover, it is unlikely that another existing infrastructure could be used unless an empty building meeting the general requirements for this type of facility is available. Building at another federal facility would require the same level of funding as building a facility at NREL. A major disadvantage of this option is that it would not fully utilize and leverage the substantial scientific expertise and operating experience that has been developed and is available at NREL. Building at another federal facility would result in lower research productivity due to the inability

to effectively integrate with other important on-site NREL laboratories including the Biomass Surface Characterization Laboratory and the Nuclear Magnetic Resonance Facility. Because these laboratories as well as the requisite technical expertise to effectively use them would need to be developed at another institution, this option would result in higher operating cost and require a longer time to achieve OBP's goals. This outcome is undesirable and therefore this option is not recommended.

4. Conduct the research at a private sector or public university facility.
There are no pilot-scale biorefineries in the United States. Iogen has a pilot scale cellulosic ethanol demonstration plant in Ottawa, Canada, and Abengoa Bioenergy is in the early stages of constructing a cellulosic ethanol pilot plant in York, Nebraska. (Pilot facilities for testing various cellulose conversion technology options are also in existence or under construction in Brazil, Denmark, Japan, Spain and Sweden.) In addition, some U.S. companies have pilot-scale facilities for testing traditional petroleum refining or corn (grain/starch) ethanol production that could be modified and enhanced to permit piloting of biorefinery operations. However, there are several important challenges to using such privately owned facilities being able to successfully and efficiently meet OBP's technology development and demonstration objectives. First, the remoteness of the work from the established expertise base at NREL would increase costs and delay the achievement of milestones, similar to the issues noted above for the option to build the facility and conduct the work at a different federal facility. Second, establishing this capability somewhere in the private sector would not ensure that DOE has this capability in the future, since cooperative agreements and grants are limited to a few years' duration and industry partners can terminate agreements at any time. Third, an existing facility in the private sector would already be highly customized, and not have the flexibility represented by the IBRF, which will be needed to achieve OBP's mission goals. Fourth, a facility at a private company site would also not likely benefit the entire industry due to intellectual property considerations and would delay efforts to deploy cost effective technology to meet EERE's oil displacement goals.

While no comparably sophisticated pilot facilities to those currently existing in the industrial sector yet exist at U.S. public (or private) universities, many universities are interested in and actively pursuing development of such facilities, including Iowa State, Mississippi State, and the State University of New York (SUNY) at Syracuse. Similar concerns to those described above argue against the ability of such facilities being able to help OBP successfully achieve its objectives as well as locating at NREL.

Impact if not approved. In the United States there are currently no operational pilot-scale facilities for integrating lignocellulosic biomass conversion technologies. As mentioned above, a roughly 5 ton/d pilot plant is being operated in Canada by a private firm (Iogen Corp.) and another facility of unknown size being developed by a private firm in Nebraska (Abengoa Bioenergy). Neither of these facilities are likely to be available to other private entities attempting to commercialize biomass conversion technology that would be in direct competition with Iogen or Abengoa. There is also a smaller scale pilot being constructed in Sweden, but it has no additional capabilities beyond what is currently available in the AFUF's BCPDU. Besides Abengoa's facility under early construction in Spain, the other foreign pilot plants are based on alternative cellulose conversion concepts, i.e, different than enzymatic hydrolysis which represents the strategic emphasis of OBP's technology research, development and deployment (RD&D) program. Without the additional capabilities afforded by the this build-out of the existing BCPDU facility, or a new facility, U.S. industry will be at a distinct disadvantage compared to foreign competition, which is showing rapidly growing interest in fuels and products from biomass.

If the IBRF is not available to industry, individual companies will be forced to build their own exclusive testing facilities at much greater expense. This would put small and mid-sized companies at a distinct competitive disadvantage, thereby limiting competition and the innovation such competition fosters. Most would not be able to compete, as their access to the privately funded testing facilities would not be guaranteed and the financial risks associated with deploying untested technology would be too great.

One of the roles of the Federal government in energy research and development is to lower the risk associated with developing new technology and thereby encourage private industry will be encouraged to invest the significant capital that will be necessary to produce cleaner, more reliable, more secure electricity and fuel supplies for the Nation. Because of the large variety of potential process options and the complexity of getting the best options to efficiently work together, pilot-scale research for an integrated biorefinery fits well within the scope of Federal R&D.

The United States is facing major challenges with the cost-effective, reliable supply of clean, secure transportation fuels. Biomass represents one critical solution to this problem, along with a proven ability and great potential as a feedstock for a wide variety of industrial chemicals and products. The realization of the biorefinery concept – converting biomass into multiple fuels and chemicals products in a single well-integrated process facility – forms the heart of the Department's Biomass Program. The lack of integrated pilot-scale process performance information is a critical technical barrier increasing usage of biomass as a national resource for fuels, products, and energy. The lack of a suitable facility for Federal pilot-scale research is a key barrier to being able to meet Federal R&D goals. The researchers, equipment and existing but limited facilities at NREL already play a key role in defining, understanding, and advancing the state of technology for biomass conversion processes. Without this new facility, space limitations will continue to severely restrict the scope of R&D that can be accomplished, which in turn will impose delays on the DOE's biofuels and biorefinery deployment objectives that our nation can ill afford.

The AFUF must be significantly expanded and upgraded to allow NREL to fully support OBP's goals, especially its planned future solicitations to create successful DOE-industry partnerships for commercializing production of fuels and chemicals from lignocellulosic biomass. This expansion ensures that DOE will have the necessary facilities to catalyze and support its outyear biorefinery deployment objectives.

Stakeholder Opportunities. Funds-in CRADAs and WFOs will help to partially offset the operating cost of this facility, benefiting companies by eliminating their need to individually purchase and install such equipment and systems. These types of cost-shared projects with industry and other government agencies will leverage DOE resources. The addition of the IBRF would be expected to significantly increase industry's interest in the facility and thereby foster an even greater number of these types of agreements.

Stakeholders regard the IBRF pilot facility as essential to the development, testing, and validation of integrated biomass conversion technology. CRADA partners like Dupont are using the current facility to test various unit operations, but recognize the limitations of the existing facility because of its inability to house new equipment to enable additional process integration and testing. Future pilot-scale testing will be severely constrained by the inability to add new equipment and/or reconfigure process operations to test new process concepts. Stakeholder companies also recognize the unique capabilities offered by NREL and the current pilot facility, as well as the merits of the proposed expansion of the facility. The IBRF facility is necessary to satisfy stakeholder and DOE needs.

Interest in biomass conversion technology is at an all time high. Building upon this momentum, OBP is moving forward with a major solicitation to industry in FY08 to develop technology deployable in demonstration stage projects. The proposed completion date of the IBRF aligns with the pilot-scale testing that will be necessary to support the new and follow on projects that result from funding obtained through the FY08 and future solicitations. Investing in the IBRF now will shorten development time as this will enable a pilot-scale facility to be available when it is needed. Beyond this, it will be significantly less costly to construct the IBRF now than at a later date.

Resource Requirements and Schedule. The project funding profile for the expansion project is given below. The cost estimates have a 25% uncertainty and the subsequent ranges for the estimates are $13.4MM to $22.3MM for expanding the existing facility.

Proposed Funding Profile for Expansion of Existing Pilot-Scale Facility ($ million)*

		FY06	FY07	FY08	FY09	FY10	Total
Conceptual Design Report	Operating		0.3				0.3
Construction	Capital			5.4§	6.9		12.3
Essential Capital Equipment	Capital			6.9			6.9
Total Estimated Cost (excl. CDR)	**Capital**		**0.3**	**12.3**	**6.9**		**19.5**

**All numbers represent mid-point with uncertainty of ± 25%*
§Includes $0.28MM for equipment relocation

Proposed Project Schedule

	Start Date
• CD-0 Approve Mission Need (authorizes the CDR start)	Nov 2006
• CD-1 Approve Preliminary Baseline Cost Range (requires completion of CDR and Cost Estimate)	Jul 2007
• CD-2 Approve Performance Baseline (requires completion of Preliminary Design and Cost Estimate)	Apr 2008
• CD-3 Approve Start of Construction (requires completion of Final Design and Cost Estimate)	Apr 2008
• CD-4 Approve Start of Operations (requires beneficial occupancy, completion of construction and commissioning)	Jul 2009

2.3 Energy Systems Integration Facility

In 2002, President Bush and the U.S. Council for Automotive Research announced the cooperative FreedomCAR partnership to develop the technologies that will enable petroleum-free cars and light trucks. In 2003, President Bush launched the nation toward a new hydrogen infrastructure and transportation future with a sweeping initiative to develop hydrogen fuel cell vehicles. In response, the U.S. Department of Energy (DOE) established the International Partnership for the Hydrogen Economy, involving 15 nations and the European Union, to pursue hydrogen as a transportation system reality by 2020. The Advanced Energy Initiative, announced in February 2006, continues progress toward achieving the President's vision of changing the way we fuel our vehicles and the way we power our homes and businesses.

Energy consumption in the United States is projected, by the Energy Information Administration, Annual Energy Outlook 2006, to increase by 34% by 2030. The energy infrastructure and energy demand will not be replaced by a single production source. Renewable energy sources including solar, wind, and hydrogen should be part of the energy supply for this increased demand. In the United States, solar and wind resources offer a major opportunity to supply energy for electricity and hydrogen production; however, their variability and intermittency can make them challenging to integrate into energy production and delivery systems while ensuring low cost and high system reliability. These systems need substantial back-up from the existing utility grid or significant storage capacity.

Improved systems design will help lower energy use in buildings and other applications, and help renewable energy to penetrate the marketplace more rapidly. This will only be made possible through integration and testing renewable energy components. Developing integrated energy systems and testing technologies that include energy generation, storage, distribution, and utilization will be critical to maximize the potential benefits of renewable and hydrogen technologies.

As part of the Energy Policy Act (EPACT) of 2005, the government has a stated goal of developing a long-range national policy to achieve North American energy freedom by 2025. To meet the goal of energy independence the United States will need to develop cost-effective renewable technologies and hydrogen-based energy systems that can provide electricity and fuels. EPACT 2005 also directs the DOE to fund renewable energy and energy efficiency technologies. These technologies include electricity and fuels generation and utilization in transportation and buildings applications including hydrogen-related demonstration programs. The following EPACT Sections are directly relevant to renewable energy and energy efficiency technologies:

- EPACT Sec 203 Renewable Energy - Federal Purchase Requirement
- EPACT Sec 206 Renewable Energy Security – District Heating and Cooling
- EPACT Section 711 Hybrid Vehicles – “The Secretary shall accelerate efforts directed toward the improvement of batteries and other rechargeable energy storage systems, power electronics, hybrid systems integration, and other technologies for use in hybrid vehicles.”
- EPACT Sec 911 Energy Efficient Buildings (and related sections 913-915)– “Programs under this subtitle shall include research, development, demonstration, and commercial application of— (A) advanced, cost-effective technologies to improve the energy efficiency and environmental performance of vehicles, including—(i) hybrid and electric propulsion systems; (ii) plug-in hybrid systems; (iii) advanced combustion engines; (iv) weight and drag reduction technologies; (v) whole-vehicle design optimization; and (vi) advanced drive trains; (B) cost-effective technologies, for new construction and retrofit, to improve the energy efficiency and environmental performance of buildings, using a whole-buildings approach, including onsite renewable energy generation”
- EPACT Sec 921 Distributed Energy and Electrical Energy (and related sections) –“The Secretary shall carry out programs of research, development, demonstration, and commercial application on distributed energy resources and systems reliability and efficiency, to improve the reliability and efficiency of distributed energy resources and systems, integrating advanced energy technologies with grid connectivity, including activities described in this subtitle. The programs shall address advanced energy technologies and systems and advanced grid reliability technologies.”
- Energy Policy Act of 2005 (Public Law 109-58) Title VIII *Hydrogen,* “1. To enable and promote comprehensive development, demonstration, and commercialization of hydrogen and fuel cell technology in partnership with industry. 2. To make critical public investments in building strong links to private industry, institutions of higher education, National Laboratories, and research institutions to expand innovation and industrial growth.”

As DOE’s Strategic Plan (Fall 2006) notes: “The United States is heavily dependent upon oil, especially in the transportation sector. Rapid increases in U.S. and world energy demand, combined with regional resource and production constraints, have led to large increases in oil and natural gas prices, changing the industrial and commercial business environment. The

Nation's energy infrastructure is not keeping pace with the growth in energy demand, thereby endangering the reliability of the energy system. Finally, there is a need to reduce the environmental impacts associated with energy use."

DOE Strategic Plan goals for Energy Security include:

- ***Energy Diversity*** - ***Increase our energy options and reduce dependence on foreign oil supplies, thereby reducing vulnerability to disruption and increasing the flexibility of the market to meet U.S. needs.*** – Studies on the barriers to market penetration of renewable energy, an obvious choice for energy diversification, indicate that some of the most common issues are unfamiliarity and uncertainty about renewable energy systems, whether the potential purchaser is a home or business owner, a utility executive, a community developer, a state public utilities commission, or a federal agency. Research, design, testing, technoeconomic analyses, modeling and simulation, and demonstration of near-commercial renewable energy systems are necessary to overcome these barriers and reduce the technical risk perceived by financial markets and energy developers.
- ***Environmental Impacts of Energy – Improve the quality of the environment by reducing greenhouse gas emissions and environmental impacts to land, water, and air from energy production and use.*** – Reducing the use of energy is the first step toward reducing the environmental impacts of energy. The logical second step is to use renewable energy sources, which are generally more environmentally friendly than fossil fuel sources, at least until carbon sequestration and other mitigation technologies are commercially available. However, the practical application of energy efficient building designs and renewable energy sources, whether for one building or for a community, requires modeling, simulation, and testing of the entire system for which energy is needed. Only a systems approach can determine the optimal component choices, design reliable and efficient interconnections, and predict overall system performance.
- ***Energy Infrastructure - Create a more flexible, more reliable, and higher capacity U.S. energy infrastructure.*** – Greater diversity in energy generation sources provides flexibility and improves reliability of the energy infrastructure of any community, state, or nation. However, having multiple energy sources can also complicate safely and reliably interconnecting generating sources to loads and to the grid, at all scales of energy use. Research and testing of integrated renewable energy generating systems, interconnection hardware and software, energy management systems, "smart" buildings, codes and standards are all necessary to accelerate the market adoption of renewable electricity.

- ***Energy Productivity – Cost-effectively improve the energy efficiency of the U.S. economy.*** The Department works towards these goals through the integrated efforts of Solar, Wind, Hydrogen, Fuel Cells and Infrastructure Technologies, Buildings, and FreedomCAR and Vehicle Technologies offices within the Office of Energy Efficiency and Renewable Energy (EERE). Research on energy use in buildings has shown that collaboration with energy generating technologies is necessary, with research in a systems context, to lower the demand for energy in buildings.

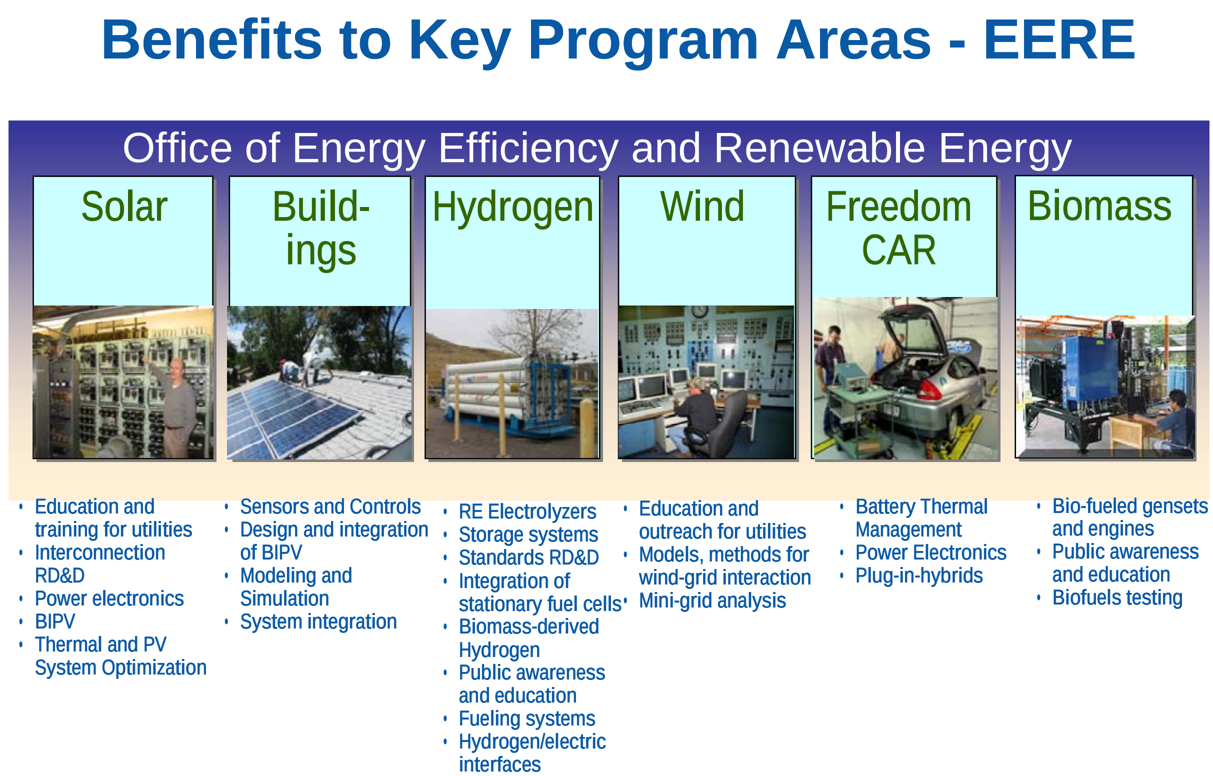

Figure 2.3.1. Benefits of new capabilities in energy systems integration

DOE's visionary initiatives and programs are designed to accelerate the development of technologies to meet milestones for each individual technology. Developing a new electric and fuel infrastructure for the nation is a complex task requiring a systems-level approach, and many paths can lead to a successful electric and hydrogen future. Today, scientists and engineers are developing more efficient and lower-cost fuel cells; advanced vehicle designs; new methods to produce hydrogen from solar, wind, and biomass resources; gasoline and diesel alternatives from biomass.

To fully realize the benefits of EERE's technology programs and improve the market impact of renewable energy, DOE will also need to strengthen its engineering, design, modeling, simulation, and testing capabilities. Currently, the DOE research, development, and demonstration environment has little capability to accomplish the following critical activities:

1. Integrate components into optimized systems from power generation through end use at a building-scale, community-scale, or utility-scale system.
2. Test systems using flexible platforms for mixing and matching power generation and use.
3. Provide technical and economic data/analyses to foster successful business opportunities.

Analysis to Support Mission Need. EERE needs to increase the ability to characterize and test pre-commercial-scale integrated renewable energy and hydrogen systems to maximize the benefit of individual program funding, which is directed at individual technology development. The ability to test and evaluate integrated systems will help maximize the benefit to each technology program to accomplish the EERE mission in support of the Department's Energy Strategic Goals. This scale of testing can be done quicker and for less cost than commercial-scale demonstrations and will allow industry to try a variety of new and advanced component and system combinations quickly before deciding on which paths forward make the best economic sense to commercialize (Figure 2.3.1).

The Federal system currently lacks a facility for designing and testing engineering optimized systems, testing integrated energy technologies, and simulating and or emulating new infrastructure scenarios under the control of DOE and available to all of DOE industry partners. The lack of such a facility represents a key barrier to being able to meet DOE's solar, wind, and hydrogen goals. A new facility would allow DOE to optimize these technologies as part of a total energy system collecting both technical and economic data for business analysis will encourage their integration into energy production and delivery systems at minimum cost and high system reliability.

In addition to supporting EERE Program requirements for the Solar; Wind; Hydrogen, Fuel Cells, and Infrastructure; FreedomCAR and Vehicle Technologies; and Building Technologies, the capabilities of a new facility would also support the interconnection requirements of the Office of Electricity program for distributed power from renewable energy technologies and the integration of EERE technologies into the electrical grid. Table 2.3.2 indicates the areas of research, development, and testing envisioned in a new facility, and the benefits such a new facility will bring to meet EERE and national energy goals.

Industry partnership is vital to the success of new energy and transportation technologies. U.S. utilities and private sector companies are interested in partnering with DOE to achieve a successful electric and hydrogen future. However, there is currently no facility in the country that supports cooperative public-private, laboratory-controlled research at the pre-commercial engineering scale, including testing and verification of a wide variety of concepts for advanced hydrogen technologies and integrated energy systems. Also, private facilities are not equally available to all researchers involved in a national effort.

One of the goals of NREL, for which EERE is the principal secretarial office, is to manage the interface between applied R&D and the commercial marketplace to encourage the market penetration of renewable and energy efficiency technologies. Many of the existing individual engineering and testing activities supporting the goals of the Solar, Wind, Hydrogen, Buildings and FreedomCAR programs described above are conducted at NREL. Hydrogen systems development and advanced fuels technology development activities are effectively leveraged to take advantage of NREL's core expertise and capabilities in integrating clean energy technologies such as solar, wind, and biofuels. These activities at NREL, however, have no dedicated facility.

Table 2.3.2. Examples of Areas of Research and Benefit for the Energy System Integration Facility

Application	Component or System	Technical Benefits	Benefits
Renewable Electrolysis	– Wind Turbine – Power Electronics interface, Electrolyzer, H2 Compressor, H2 Storage, H2 Engine	– Optimization of performance and of wind turbine to electrolyzer	– Benefits distributed energy manufacturers, electrolyzer manufacturers, utilities, end-use customers – Allows hydrogen production via clean, renewable resource in the most optimized maner – Allows utilities to see benefit of production and use of hydrogen
Interconnection of Distributed Energy to Grid	– Interconnection equipment (Inverters, protective relays, switch gear) – Distributed Energy (PV, Wind, Fuel Cell, Microturbine, Engine)	– Optimization of interconnection and performance for various grid configurations – Verify whether the equipment meets applicable standards (IEEE 1547, UL 1741)	– Benefits distributed energy manufacturers, utilities, end-use customers – Allows utilities to understand impacts of DE on electric power system – Allows distributed energy manufacturers to only need to design and test equipment to one standard – Allows end-use customers to interconnect DE equipment easily
Integration of Distributed Energy into Buildings	– Distributed Generation (PV, Fuel Cell, Engine, Microturbine) – Building Thermal systems: air conditioning units, dessicant cooling units, domestic hot water systems, absorption chillers	– Use and optimization of heat and electricity from distributed power generation sources – Development of controls and communication systems for distributed power generation sources	– Benefits distributed energy manufacturers, utilities, end-use customers
Community/Village Power Systems	– Hybrid Community or Village Power System (Wind, Diesel Engine, Inverter/Controller, Battery)	– Optimize design of community systems – Verify whether equipment can supply the load based on various resource profiles	– Benefits distributed energy manufacturers, utilities, end-use customers

Alternatives. The following alternative courses of action have been considered in this preliminary analysis:

1. Build a new facility at NREL. Creating a facility to test the integrated renewables system concept (energy system technology and system design, testing and performance optimization in the context of the larger energy supply, delivery, and end use systems for deployment) forms the center of DOE's energy efficiency renewable energy capability. The Energy Systems Integration Facility (ESIF) will enable DOE and its industrial partners to assess the potential of solar, wind, and hydrogen technology options for buildings, transportation, community, and utility utilization and develop a validated engineering-scale collection and analysis of performance data for the most promising technologies and integrated energy systems. The ESIF will allow U.S. industry members to insert their individual technologies into a controlled integrated energy system platform to test and optimize the technologies for earlier market penetration. It will also help to enable the success of the Hydrogen, Fuel Cell & Infrastructure Technologies Program effort to meet the technology readiness milestones.

The ESIF consists of a new 130,000-gross-square-foot facility specially designed to accommodate the critical engineering, testing, optimization, and verification research needed for integrated engineering systems development for EERE programs. It is proposed as the "first of its kind" integrated test and validation facility for new technologies being developed by the EERE programs and industry research partners nationwide, including engineering performance and testing of renewable hydrogen systems. Developing engineering-scale integrated energy system capability is critical to optimizing technology penetration into the energy market. The availability of an engineering scale integrated energy systems test facility for renewable energy technologies power production and stationary and transportation use will immediately benefit the U.S. renewable energy solar, wind, buildings, and hydrogen industries, and in a limited sense, transportation industries.

As envisioned at NREL, this new facility will leverage technology developments from EERE's Solar Energy and Wind Technologies programs for renewable hydrogen generation. With multidisciplinary engineering experts (mechanical, electrical, thermal) working together in one location, the facility will encourage the development of enabling technologies such as advanced power electronics, electrical interfaces and connections, fuels and emissions systems, grid-connected hybrid propulsion systems, and environmental testing.

The ESIF will also be designed for industry collaboration through cost-shared partnerships. This will allow industry researchers to conduct full-scale testing of components and systems. Experience has shown that validating and correcting problems in a laboratory environment enables technologies to go from concept to production more quickly, reduces overall cost, and avoids discovering key performance issues after market introduction. Establishing this capability at NREL will foster information exchanges to help growth in these new emerging industries.

The facility will provide support space for about 160 researchers, effectively consolidating activities currently in several different locations at NREL, some of which is currently in leased facilities. In addition, outdoor pads will be available for testing larger equipment and systems up to the multi-megawatt scale. The facility itself will be designed to merit at least a "Silver" rating from the U.S. Green Building Council, in support of EERE's goal to demonstrate energy efficient buildings with a lower impact on the environment.

Cost and schedule ranges for building design and construction were prepared in accordance with DOE Order 413.3 Program and Project Management for the Acquisition of Capital Assets. Tables 2.3.3 and 2.3.4 indicate the anticipated funding profile and schedule.

Table 2.3.3 Proposed Funding Profile ($ Millions)*

		FY07	FY08	FY09	FY10 & Beyond	Total
Conceptual Design Report (CDR)	Operating	$1.5				$1.5
Project Engineering & Design	Capital		$6.6			$6.6
Construction	Capital			$48.4		$48.4
Facility Capital Equipment	Capital				$22.0	$22.0
Total Estimated Cost (Excluding CDR)	Capital					$77.0

** All numbers represent mid-point with an uncertainty of +/- 25%.*

Table 2.3.4 Proposed Project Schedule

• CD-0 Approve Mission Need (authorizes the CDR start)	May 2007
• CD-1 Approve Preliminary Baseline Cost Range (requires completion of CDR and Cost Estimate)	Dec 2007
• CD-2 Approve Performance Baseline (requires completion of Preliminary Design and Cost Estimate)	Jul 2008
• CD-3 Approve Start of Construction (requires completion of Final Design and Cost Estimate)	Jan 2009
• CD-4 Approve Start of Operations (requires beneficial occupancy, completion of construction, and commissioning)	Jun 2011

2. Conduct Research at a Different Federal Facility with Existing Space. EERE already conducts related research at a number of federal facilities; however EERE has developed unique capabilities at NREL in renewable electricity production, renewable hydrogen production and storage research, buildings energy research, distributed electrical systems research, and testing and analysis for transportation and stationary fuel cell applications. The concentration of research staff with the required expertise in these areas presents a distinct advantage to locating a dedicated engineering and testing facility at NREL compared to other federal facilities.

3. Conduct Research at Private Sector Facilities. U.S. industries (power generators and electrolyzer manufacturers, for example) do not have the facilities or capability to conduct the integrated engineering and testing to meet program needs. Establishing this capability somewhere in the private sector would not ensure that DOE has this capability in the future, since cooperative agreements and grants are limited to a few years' duration and industry partners can terminate agreements at any time. In addition, establishing this capability somewhere in the private sector would not foster the information exchanges vital to helping grow this emerging industry in the United States.

There are existing facilities that conduct demonstrations on commercially available distributed generation, but these facilities focus on understanding the impact of commercial-grade DER on the utility grid, not on the integration of the variety of renewable and hydrogen technologies with each other for total system optimization. These facilities also do not have the staff to understand the performance and optimization of all the diverse technologies that NREL has.

Impact If Not Approved. The EERE programs support the R&D needed to bring critical new technologies to a point where the private sector can make business decisions about commercializing renewable energy-based total energy systems, hydrogen infrastructure, and plug-in hybrid vehicles. The United States needs an effective research facility to reduce the development time of cost-effective technologies that meet the technology readiness milestones.

An integrated and coordinated effort dedicated to developing cost-effective technologies for renewable energy systems, hydrogen systems, and buildings, utility, and some transportation applications is critical to meeting the goal of the administration, DOE, and EERE of establishing energy independence for the United States. To meet this goal, DOE needs a facility designed and dedicated to this purpose. The ESIF has been conceived to meet this vital goal.

- Without an appropriate research facility, solar, wind, hydrogen, and related buildings systems cannot be effectively designed with the optimal integration, engineering, testing, and verification necessary for commercial success of integrated energy systems. Achieving the goals of the President's initiatives and the DOE in renewable energy, hydrogen systems, and energy efficiency will take longer than planned or may not be achieved at all.
- Without well-designed and tested technology systems, the technical and financial risks for U.S. industry will remain high, and technology readiness will be more difficult, more costly, and take significantly more time.
- Without an appropriate research facility that can benefit U.S. industry supporting this mission, U.S. industry will be at a disadvantage compared to foreign companies in Europe and Asia.
- Without timely determination of technology readiness, the United States will remain vulnerable to all the problems inherent in dependence on foreign oil, and achieving the objectives of energy security will take significantly longer than necessary.

Project Constraints and Assumptions

Operational Limitations*.* The ability to test and validate megawatt-scale renewable energy systems, electrolyzers, and other hydrogen-generating systems, advanced power electronics, advanced interconnection technologies, and entire energy generating and energy use systems is critical to developing and deploying practical systems for real-world applications that will help achieve the nation's energy goals. The current infrastructure and facilities at NREL, other federal facilities, and in the private sector are inadequate to support this development effort.

Standards Requirements. Integrating renewable and hydrogen energy resources with the existing electrical grid and in distributed energy applications requires testing and certification as well as uniform standards to ensure these systems perform safely and reliably. Buildings codes must continually be updated for new technologies. Numerous model codes and standards are now being developed for renewable, distributed energy, and hydrogen systems. In the future, independent testing facilities will become increasingly important for validating new designs and certifying safety and performance.

Goals for Limitations on Operating Costs. Public-private partnerships will help validate designs and perform third-party testing. The fees collected for this work can offset operational expenses. Partnering with renewable energy and electrolyzer companies to test and validate equipment will eliminate the need to purchase these products and will be beneficial to both parties. Cost-shared projects with industry and other government agencies will also be used to leverage DOE resources.

Stakeholder Issues*.* Stakeholders regard the ESIF as essential to the development, testing, and validation of integrated renewable, hydrogen and related systems. Companies such as General Electric, Proton Energy, Teledyne, and Avalance, and Xcel Energy have expressed interest in testing renewable electrolysis systems at NREL. Companies such as General Electric, ASCO Power Technologies, Encorp, and Northern Power Systems have used NREL facilities to develop advanced interconnection products for distributed energy applications. These companies recognize the unique capabilities that NREL has and are in favor of NREL expanding its capabilities. By leveraging its previous successes with these stakeholders, DOE will use its contractual relationships and these new facilities to test larger-scale (megawatt-size) systems and accelerate their deployment in support of EERE missions.

Successful adoption of EERE technologies depends on optimizing system performance, proving the technologies' value and performance through engineering optimized systems, testing integrated energy technologies, developing new infrastructure scenarios, providing world-class technical and economic data for business analysis, showcasing advanced systems, and educating key stakeholders. The Energy Systems Integration Facility will provide EERE and the nation with these critical capabilities.

2.4 Biological and Chemical Research Facility

Analysis of Mission Need. With strong emphases on both Science Discovery and Innovation and Energy Security, one of DOE's challenges is to ensure these areas work together synergistically, to maximize the impact of research dollars. As stated in the DOE Strategic Plan (Fall 2006): "Through recent deliberate and highly disciplined assessments, several critical areas of technology barriers have been identified, that if overcome through basic research, could create paradigm-shifting developments for the U.S. energy sector. They are, in a sense, a select set of grand challenges for the science and technology communities…. Additionally, there are significant opportunities for crosscutting science 'push,' that is to say, areas where fields of science hold seemingly broad potential to accelerate innovation in many areas of energy supply and demand. Significant science opportunities include the design and synthesis of materials exploiting nanoscale understanding; advanced computation and predictive modeling of complex materials, technologies, and systems; catalysis and control of chemical transformations; and systems and synthetic biology for energy applications. While these are not exhaustive lists, they represent an initial and ambitious set that offer high potential payoff, thus motivating the science and technology communities to work together in the years ahead."

DOE conducts both foundational and applied research at all of its multi-program laboratories. However, NREL is the only laboratory that focuses its entire mission on renewable energy and energy efficient technology development, utilizing both foundational and applied research capabilities. To accelerate progress in its two key research directions, Renewable Electricity Conversion and Use, and Renewable Fuels Formulation and Use, NREL is placing significant emphasis on managing the interface between basic science and applied research and development in both these areas. NREL is developing stronger roles in the foundational science areas that underpin its applied research agenda.

Today, one building at NREL (the Field Test Laboratory Building, NREL's oldest facility) provides space for both foundational science supporting renewable fuels development and the applied research needed for mid-scale development of renewable fuels. Similarly, one building (the Solar Energy Research Facility) provides space for both the solid-state science underlying photovoltaics research and the applied research that supports the development of electronic materials, devices, and components. These two primary laboratory buildings are not only fully utilized, but additional research must be conducted in leased facilities in a nearby office park. Current research is challenged by this lack of facilities, with little flexibility to respond to changing research needs or new research proposals. The crowded conditions work against the Laboratory's goal to attract and retain the brightest scientific minds to help pursue this national vision. The Laboratory regularly must turn away students and visiting professionals because of lack of research space, missing key opportunities to encourage the brightest students in higher education and the interlaboratory collaborations that are so fruitful to good science. Leased research facilities are used, and will continue to be used, but splitting research groups miles apart is not conducive to the synergy and creativity that are the success factors of scientific breakthroughs.

Alternatives.

1. Build a new facility at NREL. NREL proposes to strengthen this foundational science – applied research interface, and expand its capabilities to conduct foundational science, beginning in FY2009 with the Biological and Chemical Research Facility. This state-of-the-art laboratory building will provide space that will benefit Biomass and Hydrogen by conducting foundational science programs that will lead to breakthroughs in these areas; initially, it will also benefit DOE's Solar Program. This new facility will provide biology and chemistry laboratories for all areas of foundational research supporting Biomass and Hydrogen, including structural biology, genomics, enzymes and biological catalysts, biological materials, separations and membranes, bio-nanoscale materials, and biomimetic energy conversion processes, supporting the future development of all types of bio-based and hydrogen fuels. These activities will be moved out of the Field Test Laboratory Building, freeing up space for the expansion of related applied research in mid-scale bioprocess and hydrogen development. In addition, the new facility will help meet the needs of work in solid-state electronic materials until the Solid-State Research Facility, proposed for initial funding in FY2012, is constructed.

The Biological and Chemical Research Facility will also provide dedicated space for NREL's scientific computing capabilities. Computer modeling and simulation is firmly established as an equal and indispensable partner, along with theory and experiment, in the advance of scientific knowledge and engineering practice. In fact, numerical simulation is the only viable way to advance knowledge and understanding in many areas of scientific and engineering pursuit. For example, the design of practical and efficient catalysts for biomass conversion requires the ability to predict, at the molecular level, the detailed behavior of the large, complex molecules and materials involved in catalytic processes. Because even the most sophisticated experimental techniques are unable to provide the details of the structures, processes, and chemical reactions occurring at the surface of a catalyst, the required understanding is only possible by taking advantage of high performance computational hardware and software.

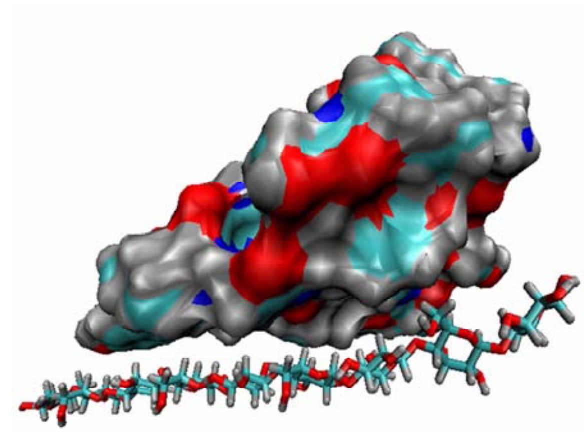

Figure 2.4.1 Understanding the function of enzymes that break down cellulose at the molecular level is very important to lowering the cost of biofuels. Computational modeling provides critical insights to guide research, such as this simulation of an experimental enzyme docking with the surface of cellulose.

Scientific computing enables hypotheses to be modeled and validated quickly and cost effectively prior to experimental testing (Figure 2.4.1). Because of its importance, NREL has expanded its scientific computing capabilities and expertise over the past five years in support of the EERE mission. However, the current limit of one teraflop processing capability cannot meet the increasing demand for these resources, which means that not all EERE programs are fully benefiting from the accelerated development, reduced time to insight, and greater opportunities for breakthroughs enabled by scientific computing. Expanding our computing capability as a part of the Biological and Chemical Research Facility will provide necessary and sufficient modeling and simulation capabilities to be an appropriate "launching pad" for grand challenge applications in energy efficiency and renewable energy and efficiently utilize the Leadership Class Facilities being deployed at several Office of Science laboratories.

The Biological and Chemical Research Facility will be a new, 165,000-gsf research building with bench-scale laboratories for biological, chemical, and related research, including scientific computing support. About 135,000 gsf are planned for science laboratories; about 30,000 gsf are planned for scientific computing support (machine space and support staff). The building is planned to accommodate about 200 occupants total, with appropriate support capabilities and interaction spaces to spur creativity. It is planned to be located on the southern portion of the South Table Mountain campus, close to the existing Field Test Laboratory Building.

Data center facilities have unique energy needs, in both electrical supply and space conditioning. The design of the data center portion of this facility to support scientific computing will be assisted by the building design and energy engineering experts at NREL to minimize energy demand, in ways that can be replicated at other federal and non-federal sites.

Table 2.4.2. Current Proposed Funding Profile ($ millions)*

		FY2007	FY2008	FY2009	FY2010	Total
Conceptual Design	Operating	$2.5				$2.5
Project Engineering & Design	Capital		$11.4			$11.4
Construction	Capital			$83.6		$83.6
Program Capital Equipment	Capital				$39.7	$39.7
Total Estimated Cost (excluding Conceptual Design)	Capital					$134.7

Table 2.4.3 Current Proposed (or Actual) Project Schedule

	Month-Year
CD-0 Approve Mission Need (authorizes the CDR start)	May 2007
CD-1 Approve Preliminary Baseline Cost Range (requires completion of CDR and Cost Estimate)	Dec 2007
CD-2 Approve Performance Baseline (requires completion of Preliminary Design and Cost Estimate)	Jul 2008
CD-3 Approve Start of Construction (requires completion of Final Design and Cost Estimate)	Jan 2009
CD-4 Approve Start of Operations (requires beneficial occupancy, completion of construction and commissioning)	Jun 2011

2. Conduct Research at a Different Federal Facility with Existing Space. EERE already conducts foundational science research at a number other laboratories; however EERE has developed unique capabilities at NREL in renewable energy production technologies. The concentration of research staff with the required expertise in these areas presents a distinct advantage to locating an expansion of foundational science related to this area of research at NREL compared to other federal facilities.

3. Conduct Research at Private Sector Facilities. DOE conducts major research efforts at a wide variety of U.S. universities. However, no single university has the depth and breadth of knowledge and expertise in all areas of renewable energy that exists after three decades of investment in people and equipment at NREL. University scientists are already, and will continue to be, extremely valuable research partners with NREL in the new Biological and Chemical Research Facility at NREL

Impact If Not Approved. To achieve the objective of the DOE Strategic Plan, and provide the maximum benefit to the nation of federal and private energy-related research investments, federal research investments must foster the closest possible synergies between science and technology, i.e., between foundational science and applied research. Without this close synergy, the nation risks delays in the impact that scientific advances should have on technological challenges in energy production and use. Also, the problems faced by those developing components and systems for energy-related applications won't have the benefit of the insights from genomics, structural biology, kinetics, catalysis, chemical physics, and other sciences.

3.0 Supporting Investments

3.1 Research Support Facilities (Phases 1 & 2)

Mission Need

Early in his administration President George W. Bush publicly recognized the critical linkage between national energy security and economic prosperity. Accordingly, the President chartered the National Energy Policy Development Group (NEPDG) to develop the nation's energy policy. In its Report of May 2001,[1] the NEPDG detailed a national energy policy based on three principles:

- The Policy [must be] a long-term, comprehensive strategy, recognizing that [the nation's] energy crisis has been years in the making and will take years to put fully behind us;
- The Policy advances new, environmentally friendly technologies to increase energy supplies and encourage cleaner, more efficient energy use; and
- The Policy seeks to raise the living standard of the American people, recognizing that to do so our country must fully integrate its energy, environmental, and economic policies.

The resultant National Energy Policy (NEP) identified five specific national goals. These goals are to:

- Modernize conservation;
- Modernize our energy infrastructure;
- Increase energy supplies;
- Accelerate the protection and improvement of the environment; and
- Increase our nation's energy security.

The strategic plans of both the Department of Energy (DOE) and the Office of Energy Efficiency and Renewable Energy (EERE) reflect these foundational principles and NEP goals. DOE's Strategic Plan directs the federal enterprise to: *"Improve energy security by developing technologies that foster a diverse supply of reliable, affordable, and environmentally sound energy...and improve energy efficiency."*

DOE's mandate is reflected in EERE's Strategic Plan. EERE's mission is to: *"Strengthen America's energy security, environmental quality, and economic vitality through public-private partnerships that enhance energy efficiency and productivity; bring clean, reliable and affordable energy technologies to the marketplace; and make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life."*

EERE's strategic goals include:

- Dramatically reduce, or even end, dependence on foreign oil;
- Increase the viability and deployment of renewable energy technologies;
- Increase the energy efficiency of buildings and appliances; and
- Lead the nation by example through the government's own actions.

DOE has developed world-class science and technology programs to fulfill its national mandate. DOE relies on its national laboratories to conduct the high-risk, high-value research and development (R&D) activities necessary to achieve our national goals; activities that the private sector, on its own, cannot undertake. EERE conducts the majority of its research and development in these laboratories. These institutions are critically important to EERE's long-term success, and it is EERE's responsibility to ensure that they operate as efficiently and effectively as possible.

[1] Report of the National Energy Policy Development Group, May 2001.

It is in DOE's strategic interest to direct as much of every dollar provided to the national laboratories to the research and development mission. Therefore, reducing the operating costs of these laboratories to the lowest level achievable commensurate with risk allows more of each dollar provided to be invested in research and development, thereby accelerating the accomplishment of DOE's mission. Similarly, it is EERE's interest to ensure that its federal field entities achieve similar operating efficiencies.

The National Renewable Energy Laboratory (NREL) is EERE's primary provider of renewable energy research and development. EERE provided NREL in excess of 90% of its annual funding, and sponsors NREL's designation as a Federal Funded Research and Development Center (FFRDC). The Golden Field Office (GO), responsible for oversight and administration of the management and operating contract for NREL, is wholly-owned by EERE. NREL, along with the Golden Field Office, are critical and growing components of EERE's Project Management Center.

Since the inception of NREL and GO in 1978, EERE has paid in excess of $150M in lease receipts to provide space for its Golden-based NREL and GO operations. NREL leases approximately 50% of its existing space requirements at multiple locations, and GO leases 100% of its requirements in a single location. Occupancy at NREL and GO is 100%, and future staff growth must be accommodated through leasing of additional space. Lease payments, an operating cost paid for at the expense of the research and project management missions, are the largest discretionary costs at NREL, and are a significant cost at GO.

EERE needs to increase the available office/work space for the existing and expanding Golden-based federal and contractor staff. In order to ensure that the maximum amount of program funding is directed towards accomplishment of the EERE mission in support of the Department's Energy Strategic Goal rather than overhead costs, EERE needs to ensure a cost effective balance between upfront acquisition costs and life-cycle operational costs for both the additional space requirements and the current space requirements.

Analysis to Support Mission Need

The following analysis describes the current and growing capability shortfall, identifies the range of alternatives to address this shortfall, and quantifies the cost of this range.

EERE's Growing Need in Golden. As stated above, EERE houses most of its Golden-based employees in leased space, and has done so since NREL's inception in 1978. This space is 100% occupied, and future growth must be satisfied by leasing additional space. Since 1978, this strategy has cost EERE in excess of $150M with no option for ownership of the underlying asset. If EERE continues this strategy, similar or higher costs will be paid by EERE in the future to the detriment of the mission-direct activities.

In FY2002, EERE developed a transformational business model and, as a result, reorganized EERE in its entirety to implement this model. EERE's new model reduced the historic fragmentation of EERE's delivery network; segregated program management, an executive function best executed at the corporate level, from project management, an implementation function best executed in the field; standardized EERE's business methodology among its implementers; and allowed for a more efficient alignment of resources in service of EERE's strategic goals. EERE's Project Management Center (PMC), a coalition of field implementation entities, was created as a mechanism through which EERE could most efficiently implement its program and deliver its mission. NREL and GO are critical and growing components of the PMC, and are discussed more fully below.

GO is wholly-owned and operated by EERE. Historically, GO was established as a site office to oversee the management and operation of NREL. Accordingly, GO's federal employee level was limited to eight from 1978 to 1992. In 1992, EERE consolidated a portion of its field portfolio at GO, and GO's federal contingent grew to 32 to accommodate the additional workload. EERE created the PMC in 2003 and began consolidating the substantial amount of work remaining at other DOE operations offices into the PMC. In response, GO's federal workforce increased to 130 in FY2006.

Due to the nation's economic need for clean, reliable, and inexpensive energy sources, and NREL's role as EERE's primary national laboratory, EERE's reliance on NREL continues to grow. EERE sponsors NREL's FFRDC designation, and relies on NREL for primary research, development, and strategic counsel. Recognizing the unique and growing role of NREL in its delivery network, EERE designated NREL a critical contributor to EERE's PMC. Recently, EERE assigned NREL the strategically important "integrator" role for the Hydrogen, Fuel Cells, and Infrastructure Technologies Program. Additionally, NREL was named as a Hydrogen Storage Center of Excellence, and NREL operates EERE's National Biomass Center, the National Center for Photovoltaics, and the National Wind Technology Center, all mainstays of EERE's mission portfolio. These assignments, combined with NREL's historic role as a provider of world-class research and development, will drive expansion of NREL's existing staffing levels over the next decade.

The cost of housing EERE's current Golden-based contractor and federal employee contingent impinges on accomplishment of EERE's mission. NREL and GO continue to grow, and under the historic leasing schema, the impact of this cost on EERE's mission-direct funding will continue to grow. EERE is compelled to reduce these costs to the lowest level feasible, thereby directing more funding to EERE's mission. The following range of alternatives has been developed to address EERE's need.

Range of Alternatives. Three basic categories of alternatives have been developed to address EERE's need. They are:

1. *Standard Leasing Without Ownership (Base Case):* This alternative represents a continuation of EERE's historic practice of leasing from the private sector at a location proximate to DOE's STM site without the option for ownership of the asset;
2. *Acquire the Capability Using Appropriated Funds:* This alternative involves collocating a facility on DOE's STM site using appropriated funds; and
3. *Acquire the Capability Using Private Sector Funds:* This alternative involves collocating a facility on or adjacent to DOE's STM site using private sector funds in a project finance arrangement.

Analyzing the Cost of the Range of Alternatives. The cost of the range of alternatives was analyzed using a discounted, life-cycle cost model as prescribed by OMB Circular A-94.[2] Assumptions used in this analysis include:

- A 40-year project period to match asset life;
- A discount rate of 5.5% as required by OMB for CY 2004;
- All cases were treated equivalently and include:
  - i. Furniture, fixtures, and general equipment;
  - ii. Utilities;
  - iii. Janitorial costs;
  - iv. Land;
  - v. Maintenance;
  - vi. Taxes;
  - vii. Insurance; and
  - viii. Major repairs.

[2] OMB A-94 requires a discounted cash flow analysis of project life-cycle costs be completed to determine the true costs of the various options for comparison purposes. "Present Value" in this case means the value of a dollar at the end of CY 2003.

- Rental rates were conservatively increased by historic Consumer Price Index (CPI) inflation (3.1%) applied cumulatively every 5 years;[3]
- Facility comparisons are based on a theoretical 300K usable square foot requirement;[4,5,6]
- New construction will be designed to the LEED Platinum rating; [7]
- One-year of overlap rent was included in the construction cases to accommodate the transfer of people and equipment;[8]
- Construction using appropriated dollars includes all costs associated with bond financing (the federal government must borrow money even if it were to appropriate funding for the project);
- Construction using private sector funding includes all costs associated with standard amortization of a debt. The cost of private sector money is 8.0%;
- The financial analysis compares only lease costs, and claims no credit for productivity gains;
- The government retains an option to take title to any land deeded to a developer in the alternative financing scenario; and
- Lease cost for the alternative financed option is level and fixed over the project life.

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[3] The financial analysis assumes that real property valuations reflect Consumer Price Index (CPI) inflation. From 1993 through 2003, CPI increased at an annualized rate of ~2.7%. During that same period real property valuations in Denver increased at an annualized rate of ~6.8%. At the end of the period Denver real property valuations increased in excess of six times that of the CPI. As true market rents reflect both CPI and real property valuations, and real property valuations over CPI were assumed to be zero in this financial analysis, the projected lease cost over the period is understated, all other factors unchanged.

[4] Actual usable square footage required will be determined in the Conceptual Design phase. This requirement will determine the ultimate size and cost for the project.

[5] The primary and most significant factor in determining the estimated TPC is the size of the project. As noted, 300K gsf was conservatively used to identify the upper bound of the cost range. Upon completion of the conceptual design, the total size of the project is likely to be less than 300K gsf, and the cost estimate will decline in proportion. Whatever the final size of the project, the estimated cost is likely to vary +/- 20% at the conclusion of the conceptual design given that this is not a complex project.

[6] The cost of the project is driven primarily by the project's size, which will be unknown until a conceptual design is completed. To prepare the financial comparisons, however, we conservatively projected a 300K square foot need, an upper bound on the project's size. If the project's size is decreased by 25%, the project's cost decreases by 25%. Using project size to establish a range is probably best. Therefore, assuming the post-conceptual design need is 225K square foot (vs. 300K), then the costs will range from $173M to continue leasing as we are to $68M for an appropriated project, with an alternative financed project at $98M.

[7] LEED is a building design and operation standard developed by the U.S. Green Building Council. The standard uses an "Olympic" rating system of certified, silver, gold, and platinum to rate a building design. The LEED standard measures factors such as building energy use, use of renewable technologies, transportation access, intensity of water use, and use of environmentally benign construction materials. The General Accounting Office in GAO-03-609T, General Services Administration: Factors Affecting the Construction and Operating Costs of Federal Buildings, reports that GSA and other agencies have adopted LEED to guide design efforts for new facilities, stating that "By using LEED, agencies can gauge the impact of design decisions on energy efficiency and other sustainable factors". The report goes on to say that adopting sustainable design principles can reduce annual operating costs. LEED Platinum is EERE's goal. A design charrette for this project was conducted by the U.S. Green Building Council, and the results of the charrette indicated that LEED Platinum was achievable at a competitive cost. Regardless, the cost and benefit of achieving this will be assessed through the conceptual design process.

[8] The additional 3 years (minimal) required to execute this project in the federal sector will cost ~$15M in additional lease cost. These costs are (conservatively) ignored in the financial analysis. Therefore, actual cost gap between private and public financing is smaller than shown, subject to incentives applied, if any.

Cost of the Range. The cost of the alternatives ranges from a high of $231M to a low of $91M using OMB's A-94 model and the assumptions (above). The cost of each category of alternative is:

1. *Standard Leasing Without Ownership (Base Case):* $231M
2. *Acquire the Capability Using Appropriated Funds:* $ 75M
3. *Acquire the Capability Using Private Sector Funds:* $130M

The analysis shows that the life-cycle cost of EERE's historic leasing practice is substantially more expensive than either option to acquire the capability. Therefore, pursuing either of the alternatives in-lieu-of the Base Case is programmatically and financially prudent.

Impact if not Approved. If not approved, EERE will continue to lease its current and future real property needs from multiple private sector sources to house its Golden-based staff, without the option of ownership. As shown in the preceding financial analysis, adopting any of the other alternatives in the range over the Base Case will result in a savings to the EERE ranging from $101M to $140M. These savings would be applied to EERE's mission-direct activities. If EERE continues its historic leasing practice, these savings will not occur, and the opportunity to accelerate EERE's investment in its mission-direct activities will be lost. Costs associated with productivity losses will continue to accrue due to the inherent inefficiencies associated with the current leasing practice. Moreover, EERE will continue to be exposed to real property inflationary rates that far exceed the general consumer price index, diverting even more of EERE's future funding flow from mission-direct uses. Finally, an opportunity to develop and transfer the advanced design, construction, and operating approaches necessary to reduce the energy intensity of the nation's building sector envisioned in EERE's Strategic Plan will have been forfeited.

Constraints and Assumptions. The following constraints and assumptions apply to the range of alternatives in support of the mission need.

- **Operational Limitations in Effectiveness, Capacity, Technology, Organizations or Other Special Considerations.** EERE's Golden-based operations are physically separated into three distinct sites. The Department of Energy currently owns 325 acres of land on South Table Mountain in Golden, Colorado. The South Table Mountain (STM) site is the home of NREL. EERE has invested over $200M in site improvements, including buildings, roads, and so on, in support of the NREL mission. The Denver West Office Park facilities are leased through the commercial real estate market, and are located near the STM.[9]

  EERE's investments at NREL on the STM have been dedicated exclusively to establishing the scientific infrastructure necessary to accomplish NREL's mission. Approximately 430 NREL scientists, engineers, and immediate support staff (payrolled employees) occupy these improvements. The balance of EERE's Golden-based staff of approximately 1000 employees is located in these leased facilities.

  EERE incurs three productivity penalties arising from is current operational approach. 1) First, the cross-fertilizing collaborations critical to creating a vibrant scientific environment is significantly inhibited due to the compartmentalization of NREL scientific staff at and within the STM site. All of EERE's investment at NREL has been directed at developing specific and geographically discrete scientific capabilities, and NREL's research staffs are effectively insulated from regular interaction with their peers. No common area currently exists to facilitate staff interaction. 2) Second, the physical separation of its science and general support staff at three separate locations reduces operational efficiency and increases operational risk. 3) Lastly, studies have found that significant productivity gains are associated with energy-efficient "green" buildings, designed to meet the Leadership in

[9] NREL has initiated a year-long effort to consolidate its operations in three buildings at Denver West.

Energy and Environmental Design (LEED) standard.[10] The leased facilities currently housing the majority of EERE's Golden-based staff do not meet even the lowest LEED design standard.

Productivity penalties, like long-term leases, divert funding from mission to indirect use. Quantifying productivity penalties are difficult at best: No credit for productivity improvements has been claimed in the financial analysis performed in support of the Mission Need Statement. Nonetheless, a 1% productivity change at NREL is valued at approximately $635K annually[11] which represents in excess of $24M over the 40-year analysis period.

- **Limitations Associated with the Organizational, Geographic, or Environmental Location.** Approximately 18% (25 acres) of the buildable acreage on the STM site carries an option that, if exercised, would transfer ownership of this acreage to Jefferson County, Colorado. Exercise of this option would severely limit EERE's ability to expand NREL in the future, thereby impacting EERE's ability to accomplish its mission. All alternatives that involve collocation on the STM site will extinguish this option. This option can be exercised by the County in 2018 if not extinguished prior to this date.

Development Plan. Preconceptual planning activities for a collocated capability have been completed. These activities include:

- In 1993, a conceptual design for a research support facility was completed. EERE was unsuccessful in its attempts to secure appropriated funding for this project numerous times given the nation's fiscal challenges and competing national priorities.
- In 1996, a private-sector financed alternative was briefed to the DOE, OMB, and Congressional Authorization and Appropriations committee staff through the DOE CFO and DOE's Office of Field Management. Following these briefings, this project was offered to the private sector. This effort was curtailed due to DOE's decision to compete the management and operating contract for NREL. The deterioration of the financial markets discouraged long-term private sector investment in the post-competition period.
- In 1999, DOE obtained additional developable land at its STM site on which to collocate this capability.
- In 2000, a design charrette for this capability was conducted by the U.S. Green Building Council. As a result, the charrette validated the project's potential to achieve the LEED Platinum rating.
- In 2004, DOE exercised its option to extend the Midwest Research Institute's (MRI) contract for the management and operation of NREL. As part of this extension, DOE added contract language that obligated MRI to pursue this project due to the overwhelming value MRI identified to the government.
- In 2004, EERE Executive Management transmitted the CD-0 package to the Office of Planning, Analysis and Evaluation for review, which approved the project in December 2004.
- In 2006, Congress appropriated $9.9M for construction of the first phase of the Research Support Facilities. Because this amount is not sufficient for the entire project, which has a goal to provide space for 780 people and supporting functions, optional design solutions will be examined for an incremental approach to the entire project.

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[10] The Costs and Financial Benefits of Green Buildings, October 2003, Report to California's Sustainable Building Task Force.

[11] 1% of NREL's labor and fringe costs.

3.2 South Table Mountain Site Infrastructure Expansion

As outlined in the discussion of NREL's campus development plans in the Executive Summary of this Ten-Year Site Plan, NREL has planned several major new facilities to meet the needs of renewable energy and energy efficiency research in the next twenty-five years. Two major areas of the campus, south and east of the existing research core of buildings, currently have no roads, electricity, data/telecomm, water, or sewer. (Figure 3.2.1) Developing this infrastructure will require approximately $4 million in FY2009 and $3 million in FY2010.

Figure 3.2.1. NREL's South Table Mountain campus buildout requires roads and utility

In addition, the campus of the future will require the most efficient use of the limited land available to NREL. There is not enough land to accommodate surface parking of any and all employee and institutional vehicles. As shown on the future site maps in the Executive Summary, all parking (except for disabled, deliveries, and visitors) will be in structured parking collector lots at the southern edge of the South Table Mountain campus. Parking studies are currently underway to better understand what types of parking structures will best serve NREL's needs. Options include double-deck structures utilizing the existing topography for parking lot entrances, lowering the cost and footprint by eliminating ramps, and structures of 3 or more levels to lower the land footprint even further. Initial costs appear to be in the range of $20-$30 million for parking structures for 2,100 vehicles, and can be phased. This does not include parking for the future NREL Conference and Learning Center. Parking lot funding is included as $8.5 million in FY2009 for the lower deck of the major parking structure, and an additional $27 million in FY2012 for the upper deck.

3.3 FTLB Expansion/Energy Efficiency Upgrade

The Field Test Laboratory Building (FTLB) is the oldest laboratory at NREL. Originally constructed in 1984, it has been modified many times to serve various purposes. To consolidate all research activities focusing on biology and biomass into one facility, 45 researchers were moved from offices in the Denver West Office Park into interior spaces in the FTLB. While this created some efficiencies and synergies, it also required the use of space that does not meet NREL's standards for daylighting. The current offices and cubicles are totally interior, with no access to windows or skylights of any kind. This situation results in increased energy use compared to daylit spaces.

The FTLB Expansion/Energy Efficiency Upgrade project will create about 48 new office and cubicle spaces in a second-floor space in the northeast corner of the second floor, to be constructed over the existing central utility plant. (Figure 3.3.1). These spaces would be constructed with extensive daylighting, as was already done in a similar space in the northwest corner of the second floor. Daylighting is widely accepted as a fundamental design practice today in all buildings that strive for energy efficiency and sustainability. Daylighting not only saves energy, but has been shown to improve employee morale and productivity. In the highly competitive job market today for scientists and engineers experienced in biomass related technologies, such demotivating work spaces can mean the difference between retaining and losing valuable researchers.

This project will benefit researchers in the EERE Biomass and Hydrogen programs, and related foundational research. The cost is expected to be $4.5 million in FY2009.

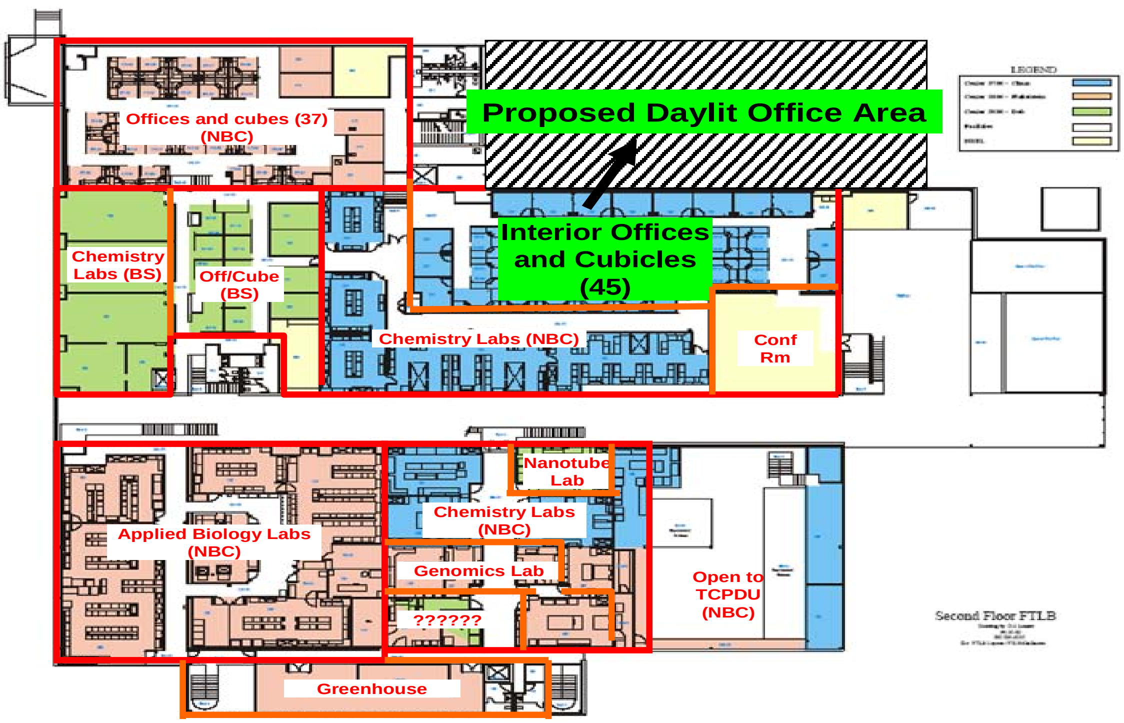


Figure 3.3.1 Proposal to improve energy efficiency and expand office/cubicle space in FTLB

3.4 Data Infrastructure Modernization

Networking provides NREL scientists with virtual proximity to collaborators, computers in the National Computing Leadership Facilities being established by DOE at multi-program laboratories, and data of all types. According to the National Science Foundation Blue Ribbon Advisory Panel Report on Cyberinfrastructure, "The capacity of this technology has crossed thresholds that now make possible a comprehensive cyberinfrastructure on which to build new types of scientific and engineering knowledge environments and organizations and to pursue research in new ways and with increased efficacy."

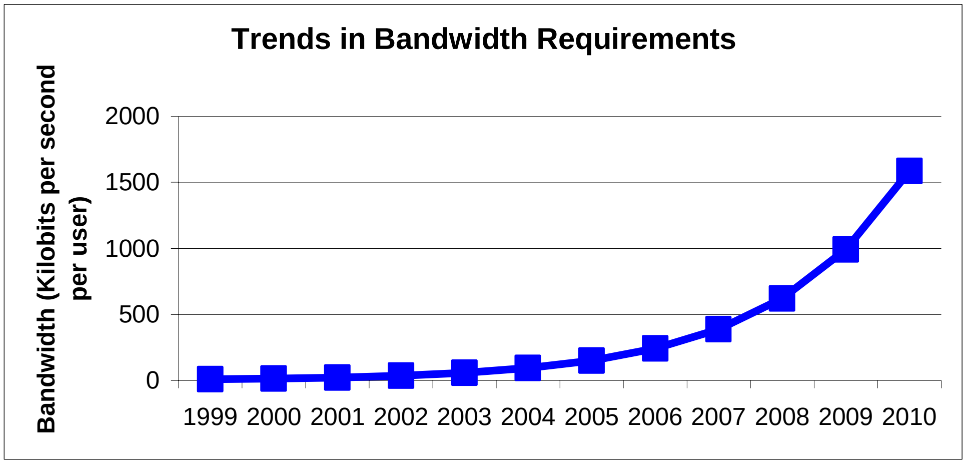


Figure 3.4.1 Trends in Bandwidth Requirements

Figure 3.4.1 shows one projection of bandwidth requirements in the world economy in general, and research data demands are among the highest of any type ("Updated Bandwidth Capacity Requirements," Gartner Systems, Jean-Claude Delcroix, 8/5/04).

Several general changes are driving NREL's requirement for data infrastructure modernization:

- All business transactions are becoming more data and information intensive, as noted throughout the information technology industry.
- Research is becoming more and more collaborative, with that collaboration dependent on data sharing over networks.
- NREL is rapidly developing its capabilities in scientific computing, which speeds up the understanding of natural phenomena and accelerates the pace of research. Scientific modeling and simulation requires the movement of massive amounts of data among researchers.
- NREL plans to add facilities in the buildout of its campus, requiring extensions of network connectivity throughout the campus.

In addition, one specific change will be occurring in 2007 that presents an excellent opportunity for NREL. The DOE-sponsored Energy Sciences Network (ESNet), a high-speed network serving thousands of DOE scientists and collaborators worldwide, will be completing a major change in its national configuration in July 2007, and including Denver as a major data hub for the first time (Figure 3.4.2). This DOE network enables researchers at national laboratories, universities, and other institutions to communicate with each other using the collaborative capabilities needed to address some of the world's most important scientific challenges. As of December 2006, NREL is considering upgrading its network bandwidth to allow file transfer speed to increase from 1.5 megabits/second (current status in December 2006) to 622 megabits/second to support the transfer of large scientific computing files, to allow the

Laboratory to take advantage of this new Denver hub for ESNet. This change in bandwidth will shorten the time to transfer a 5-gigabyte file from 22.2 hours to 3.2 minutes.

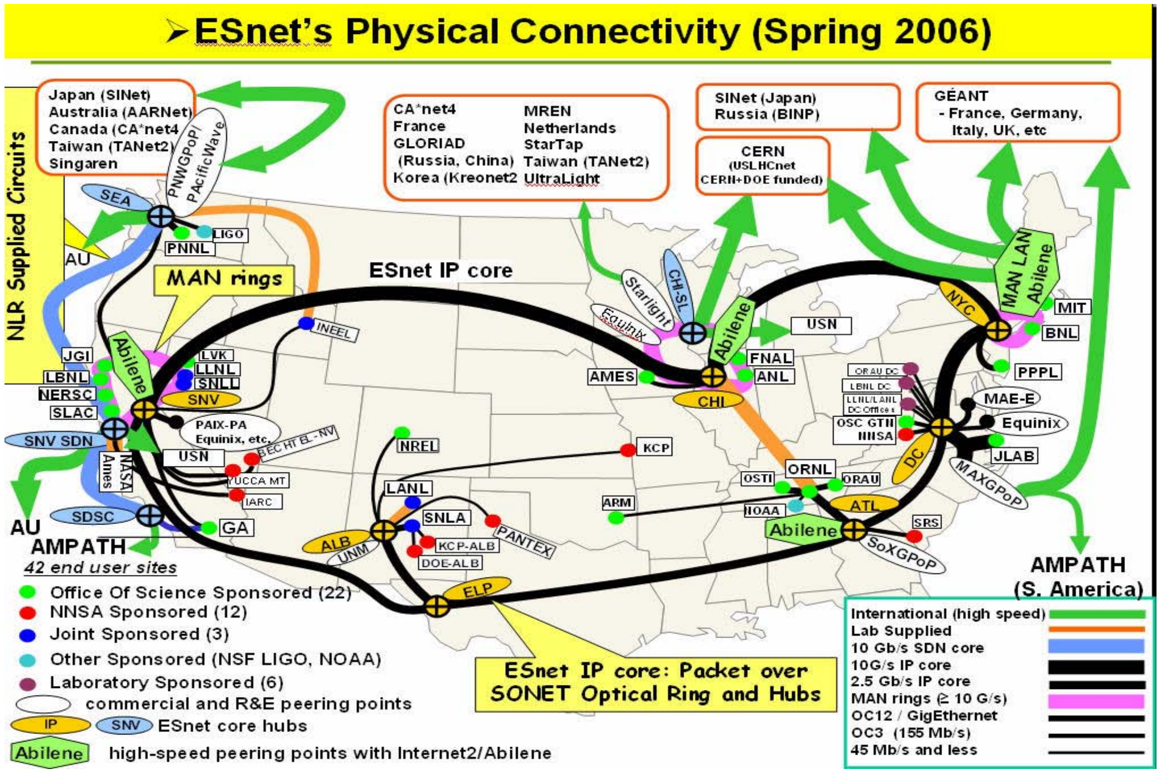
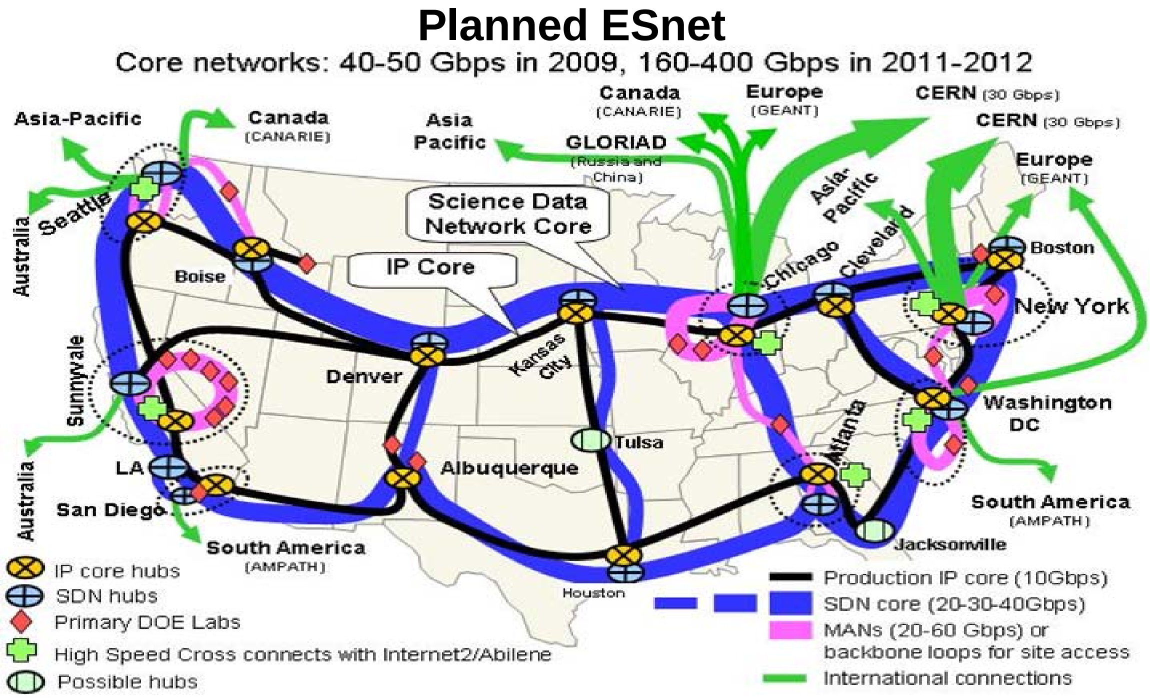


Figure 3.4.2 Comparison of 2006 (top) and future (bottom) configurations for DOE's Energy Sciences Network indicates that Denver will become a core hub, planned for July 2007, opening up new network connectivity opportunities for NREL.



NREL's current physical infrastructure of copper wire and some fiber optic cable presents a significant challenge to seizing the opportunities of the expanded ESNet and other information-based advances. Today, all desktops, servers, and other network resources attach to NREL's information network using copper wire. However, major increases in bandwidth require replacement of copper with fiber optic cable and other wiring changes from the desktop out. Funding required for these infrastructure changes is estimated at $2.1 million in FY2009, and another upgrade of $2.0 million in FY2013-FY2014, and $1.0 million in FY2016.

3.5 Research Support Facility Phase III (NREL Conference and Learning Center)

Managing the interface between applied R&D and the commercial marketplace requires the encouragement of effective and meaningful exchange of information between the Laboratory and energy stakeholders. ***Research Support Facility Phase III***, which will house the ***NREL Conference and Learning Center***, will provide critically needed space to interface effectively with the public and with energy stakeholders coming to NREL; improve the interchange of information between the Laboratory and the marketplace; and provide the nation with a "hub" for renewable energy and energy efficiency education.

As the nation's leading science and technology center for EERE, the numbers of visitors and high-level energy stakeholders—from the business, technical, finance, utility, and government communities—are increasing dramatically as interest in renewable energy and energy efficiency rises. This is creating important opportunities for the Laboratory and the Golden Field Office to significantly broaden the knowledge base about renewable energy in the United States, but is also creating unmanageable demands on existing, outdated visitor and conference facilities:

- In FY2006, almost 16,000 people visited NREL. The Laboratory's small (6,000-square foot) Visitor Center, built and donated by Midwest Research Institute in 1994, can no longer meet the demand of an increasing numbers of people who want to visit the Lab and/or learn about renewable energy.

- Many more business leaders and representatives from the other key communities cited above could be accommodated in discussing the technical and economic viability of renewable energy and energy efficiency technologies with NREL staff, if adequate public facilities were available on the NREL site.
- With increased attention on the interface between science and applied research, it is imperative to facilitate the exchange of technical information among researchers working in both fields. NREL has never been able to host major conferences pertinent to this DOE mission – to share its knowledge and gain new insights on a national scale – frustrating a central part of its mission. A conference facility would be highly beneficial to NREL's research and to the interests of many energy stakeholders by educating key decision makers about renewable energy in a facility co-located in the very place where the science and technology innovation is occurring.
- NREL currently processes its visitors (checks identification, issues badges) in a guardhouse of less than a thousand square feet. The small buildings results in groups of visitors, including high-level executives, foreign energy ministers and delegations, and similar guests, to sometimes by forced to wait outside in bad weather, sometimes for an extended period of time.
- NREL has a strong education program for K-12, but no onsite classroom space for demonstrating key scientific principles about energy to students, science teachers, and others. This lack of conference and classroom space results in lost opportunities to further science and technical education for many students, teachers, and school systems interested in renewable energy.
- Classroom space would also help accelerate the deployment of EERE technologies by allowing NREL to partner with community colleges and universities to develop curriculum and provide hands-on training in renewable energy and energy efficiency technology systems, installations, and energy business planning and management.

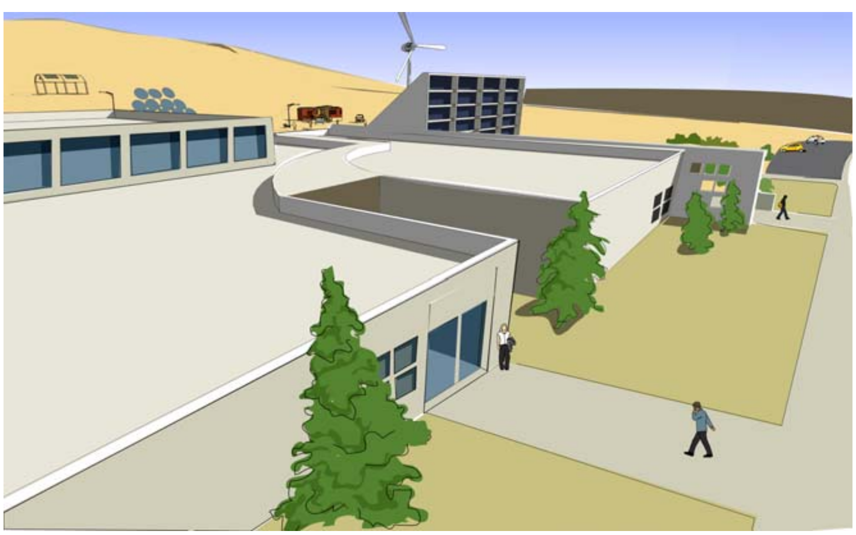


Figure 3.5.1 The addition of Research Support Facilities Phase III (NREL Conference and Learning Center) would provide space to interface effectively with the public and energy stakeholders coming to NREL.

The proposed Research Support Facility Phase III (NREL Conference and Learning Center, Figure 3.5.1), will provide auditoriums, large conference rooms convertible to classrooms, small conference rooms and data visualization facilities, a visitor receiving area, staff offices and other features similar to those available at other national laboratories. The Center will also incorporate state-of-the-art multi-media and web-connected technology to greatly enhance the learning experience presented at the Laboratory. Beyond the educational experience, the Center will be a unique place to study and collaborate—often as a shared space with academic institutions, industry partners and other national labs; in short, the Center would become a national learning "hub" for renewable energy.

3.5 Institutional Facilities and Infrastructure – New Capabilities

An analysis of historical requirements for facilities and infrastructure at NREL have shown that approximately 0.5% of replacement plant value is typically required per year to cover investments that do not pertain to existing assets, but represent new assets of small (<=$1 million) value per project. Examples include the additions for safety and security requirements; new small buildings to meet growing needs; walkways and outdoor seating; energy systems, water treatment facilities, and other features to meet sustainability goals. While this value of 0.5% of replacement plant value is expected to remain for the next five years, these needs are expected to increase in the longer term to 1.0% of replacement plant value as meeting energy and water needs becomes more challenging. (Table 3.6.1)

Table 3.6.1 Categorization of Annual Supporting Expenditures [as a % of Replacement Plant Value (RPV)]

Category	Source of Funds	Approx % of Current-Year RPV for FY08-FY12	Approx % of Current-Year RPV for FY13-FY17	Description
Annual Costs Related to New Assets				
Institutional F&I New Capabilities	GPP Capital or GPP Operating[2]	0.5%	1.0%	New assets required for small safety, security, sustainability, and mission needs, at $50,000 to $5,000,000 per project

Table 3.6.2 Projections of Institutional Facilities and Infrastructure New Capabilities, FY2007-FY2013

	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
RPV Projections at start of FY	$170.0	$180.2	$204.3	$216.6	$326.9	$349.6	$544.1
Institutional F&I New Capabilities	$2.500	$1.138	$1.022	$1.083	$1.635	$1.748	$5.441
Institutional F&I New Capabilities, % of Replacement Plant Value	***1.5%***	***0.6%***	***0.5%***	***0.5%***	***0.5%***	***0.5%***	***1.0%***

3.7 Institutional Capital Equipment – New Capabilities

Institutional capital equipment serves the entire laboratory or multiple programs, and includes scientific research equipment, scientific computing equipment, administrative information equipment, and other. The frontiers of scientific instrumentation, scientific computing, and information processing are always expanding, providing more precise and faster measurements, with ever-greater sensitivities. EERE programs will increase the likelihood of research breakthroughs and more rapid research progress by taking advantage of these advances in scientific instrumentation. For example, advances in nanotechnology alone have spawned several new instruments to enable isolation and manipulation of nanoscale particles, such as the focused ion beam milling machine that NREL purchased in FY2005. A level of about $1.8 million per year allows the purchase of new equipment similar to that required over the past six years, adjusted for inflation.

Table 3.7.1 Projections of Institutional Capital Equipment New Capabilities, FY2007-FY2013

	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
Scientific Research Equipment	$1.146	$1.655	$1.000	$1.200	$1.440	$1.728	$2.074
Scientific Computing Equipment	$0.108	$0.396	$2.500	$2.500	$0.000	$0.000	$0.000
Administrative Information Equipment	$0.421	$0.302	$0.475	$1.200	$1.350	$1.000	$1.125
Other Equipment	$0.162	$0.000	$0.000	$0.100	$0.100	$0.100	$0.100
Total Equipment	***$1.838***	***$2.353***	***$3.975***	***$5.000***	***$2.890***	***$2.828***	***$3.299***

Scientific Research Equipment. The strategic goals of NREL's institutional scientific research equipment program include:

- Provide state-of-the-art scientific instrumentation that can be used by multiple programs across the Laboratory
- Provide the metrology and calibration equipment necessary to maintain scientific excellence
- Assist programs to meet technical milestones
- Encourage new areas of scientific discovery

The challenge in managing institutional scientific instrumentation is to wisely invest in the new instruments, and major upgrades to existing instruments, that will most benefit NREL's programs today and for the next ten years. For example, the field of scientific instrumentation for micro-, nano-, and atomic-scale characterization has exploded in the last ten years. Instrumentation for genomics and biological science of all types has advanced rapidly as well. Miniaturization of computers and the geometric progression of their capabilities continue to increase the effectiveness of all instruments.

In the period FY2001-FY2006, NREL spent about $1 million/year, or roughly 50%, of its institutional equipment funding on new scientific research equipment capabilities. Examples of recent specific items include instrumentation to fabricate new nanostructured excitonic solar cells; a focused ion-beam milling device that manipulates and prepares all types of nanostructures for spectroscopic, chemical, and electrical analysis; a direct-current power processing system beneficial to all electricity-generating renewable technologies; a x-ray diffraction system that will provide structural and chemical information on biological materials benefiting biomass, biological science, and related research; and an elemental chemical analysis accessory for a scanning electron microscope that adds the latest resolution and sensitivity in chemical analysis for all solid samples.

Scientific Computing Equipment. Scientific computing is a rapidly growing multidisciplinary scientific field with connections to the physical and biological sciences, engineering, applied mathematics, numerical analysis, and computer science. Computational science focuses on the integration of knowledge and methodologies from all of these disciplines, and as such is a subject that is distinct from each of them. It focuses on developing and applying problem-solving methodologies and robust tools for the solution of scientific and engineering problems. Computational scientists are scientists in their own right. However, they often work with the discipline-specific scientists and engineers to apply scientific computing tools to real world problems.

The mission of NREL's Scientific Computing Program is to perform world-class computational research and provide high performance computing capabilities, leadership, and expertise enabling advances in the leading edge of renewable energy and energy efficiency technologies. Expected outcomes of this effort include:

- Bring simulation to a level of parity with experiment and theory at NREL in the scientific and engineering research enterprise.
- Improve the efficacy with which scientific research is conducted including expanding research options to more potential solutions, lowering cost of research, and reducing the time from concept to market.
- Produce breakthrough scientific results in materials research, molecular mechanical modeling, aeroacoustics research, biophysical modeling, and computational chemistry.
- Enable whole new areas of scientific discovery.

Based on the demand and success to date in several program areas for scientific computing, NREL needs to continue to support and grow this important area to be able to support DOE missions at the highest level of effectiveness.

The proposed Scientific Computing Equipment funding will significantly expand NREL's current one teraflop scientific computing capability over a two-year period, FY2009 and FY2010. As the Directors of the Office of Management and Budget, and Office of Science and Technology Policy, stated, "…high-end computing and cyberinfrastructure R&D should be given higher relative priority due to the potential of each in furthering progress across a broad range of scientific and technological application areas…..Agency requests should reflect these two program priorities by reallocating funds from low priority efforts." The funding profile for equipment for this initiative is $2.5 million in FY2009 and $2.5 million in FY2010. This would provide necessary and sufficient modeling and simulation capabilities to meet NREL needs and be an appropriate "launching pad" for grand challenge applications in energy efficiency and renewable energy that require even more computing capability, such as the National Leadership Computing Facilities being deployed at several DOE Office of Science laboratories.

NREL success in scientific breakthroughs and technical progress on DOE milestones depends heavily on having sufficient resources to meet the growing demand for high performance computing. Examples of applications with large compute requirements abound at NREL with relevance to such programs as Biomass, Photovoltaics, transportation (FreedomCAR), Buildings, Hydrogen production and storage and Fuel Cell technologies, and nanoscale material research:

- The Energy Bill of August 2005 requires nearly doubling the production of biofuels including ethanol and biodiesel from 4 billion to 7.5 billion gallons within the next 10 years. To help meet these goals, researchers at NREL are working to improve the production of ethanol from biomass. The current process of producing ethanol is relatively slow and expensive, paced by the slow rate at which the enzyme cellulase breaks down cellulose (the woody parts of plants). In order to make this process more efficient through bioengineering, researchers need a detailed molecular-level understanding of how the cellulase enzyme functions. However, the system is impossible to study experimentally at this level of detail because the reactions occur too quickly and at spatial scales to small to be observed directly. To explore the intricate molecular dynamics of cellulase, researchers are using molecular dynamics simulations on high performance computers to model the structure, movement and function of the enzyme at the atomic scale. The NREL simulations are the first to simultaneously model the cellulase enzyme, cellulose substrate, and surrounding water. The NREL cellulose model includes more than 800,000 atoms and is an enormous structure to model computationally. It is estimated that the full-scale simulation will take nearly one million CPU hours or about 40 days on a system with 1000 processors.

- The proposed Scientific Computing Equipment funding will greatly expand NREL's computational capabilities to permit highly detailed fluid dynamics and gas diffusion simulations and visualization necessary to predict hydrogen concentrations within enclosed structures (important for when hydrogen-fueled cars become available and are parked inside attached residential garages).
- In net-zero-energy building research, the Laboratory will be able to go beyond modeling the energy usage of a building and actually optimize the building design for most efficient energy use. The increased compute capability will be used for detailed modeling of thermocline storage tanks to improve the dispatchability of concentrating solar power.
- In the transportation area, increased compute capability will enable engineers to utilize finite element analysis and computational fluid dynamics modeling capabilities coupled with advanced design techniques such as optimization and probabilistic methods and all integrated with traditional analytical tools. These new state-of-the-art capabilities will be used by NREL engineers and scientists to search complex design spaces to determine the relative effects of changing multiple input parameters and variations. Powerful tools such as these dramatically reduce development time but require significantly increased computational power. Currently, detailed CFD models of hybrid electric and fuel cell vehicle energy storage, power electronics, and fuel cells are limited by the computational capability. Enhanced computation power will allow NREL researchers to take full advantage of the advances in modeling software technology and to work with industry partners that do not currently have the computing resources. Finally, this capability would enhance NREL's ability to run large-scale classical and quantum mechanical simulations needed to study electron transfer and protein dynamics in hydrogenase complexes that are part of photobiological hydrogen production.

Thus, the Laboratory anticipates that by FY2010 NREL would have a substantially expanded high performance computing capability to appropriately support the EERE mission. This investment would enable NREL to overcome hurdles the Laboratory now faces due to limited compute capability. It would provide necessary and sufficient computing capabilities to meet growing demand for modeling and simulation at NREL in support of EERE goals, and allow NREL to step up to the level necessary to utilize the National Leadership Computing Facilities being deployed at several Office of Science laboratories.

Administrative Information Equipment. Institutional information technology provides the backbone for scientific interchange, knowledge management, and all administrative computing needs for the Laboratory. Effective execution of NREL's mission requires information technology that supports all administrative functions including communications, and provides the architecture and networks necessary for analysis and communication of scientific information. Typical areas for capital investment include networks and storage, cyber security, telecommunications and hardware that supports core applications and services such as office productivity, email, and financial and human resources business systems, NREL must wisely invest in the new capabilities that will most benefit DOE's programs today and for the next ten years. Simply replacing existing information equipment will not satisfy the needs of a research organization in the rapidly changing world of 21^{st} -century information management. Investment goals for information technology include:

- Safeguard information and information technology assets
- Deliver cost-effective and reliable IT services
- Improve operational effectiveness
- Share NREL's research with the world
- Enable the creation of knowledge

These are some of the issues that must be considered in investing in new information equipment capabilities:

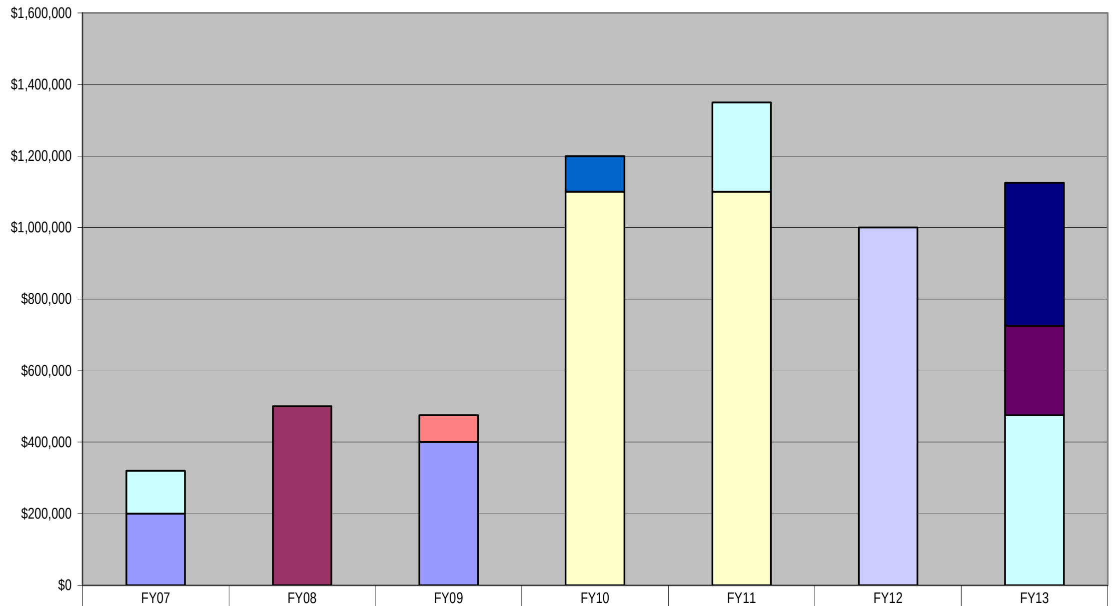
- Exponential increases are required in bandwidth due to increased external collaboration with industry partners, other Labs, and local high-tech and higher education organizations, transfers of large scientific datasets, as well as increasing use of web-delivered rich content that will drive 10x-100x growth in the requirement for network and Internet bandwidth. (See Section 3.4 above on the Data Infrastructure Modernization proposal.)
- Building and securing ubiquitous networks require an architecture that will allow access to the enterprise network from any place at any time. This will drive technologies such as wireless LAN's and virtual private networks.
- Enabling and expanding online collaboration is needed to provide the services that enable online collaboration – security, file storage, video conferencing, file sharing, etc.
- Meeting increased demand for data storage requires storing, archiving, indexing of digital content.
- Providing 24/7 access for key information technology services requires building a high-availability infrastructure that is accessible at any time.
- Increasing use of Web services will also increase requirements for bandwidth and 24/7 availability.
- Increasing cyber security in the face of growing threats requires securing NREL's information technology environment from internal and external threats

Investments in this category are driven by significant changes in the Laboratory's size and research directions. Additionally, they reflect the impact of advances in information technology and the resulting change in the workplace. Over the FY2007-FY2018 time period major trends include: improved data center efficiency, implementation of project management capabilities, increased emphasis on information security and management, support for internal and external workgroup collaboration, and continued emphasis on building anytime/anywhere IT availability. Major capital investments that support these trends include: virtual tape libraries, core routing failover and storage enhancements (FY2007,FY2008,FY2011,FY2013,FY2016), wireless expansion (FY2007,FY2009), collaboration and instant messaging (FY2009,FY2010,FY2014), and voice over internet protocol (VoIP) systems in FY2010 and FY2011. Major expenditures include:

- Disaster Recovery is a coordinated activity to enable the recovery of information technology-based business systems due to a disruption. Disaster recovery is achieved by restoring complete or partial IT/business operations at an alternate location, recovering business systems using alternate equipment, and/or performing some or all of the affected business processes using manual methods. Federal regulations and best business practices will likely require NREL to develop formal disaster recovery plans to recover information technology services and information critical to the operation of the Lab.

- Voice-over-internet-protocol (VoIP) systems use the internet to carry voice communications rather than a separate telephone system, as is the case today. VoIP technology provides many features not available using traditional voice communication technology—like the ability to read voice mail or listen to email. More importantly, VoIP will yield NREL long-term cost savings while providing the Lab with the opportunity to use state-of-the-art capabilities for voice and data communications. When a new facility is built today, a telecommunications network and a data network must be built to support the new facility. Once VoIP is implemented, only the data network will be required. Reduced costs for telecommunication services and reduced network maintenance (since only one network will need to be maintained) will also contribute to additional cost savings.
- Wireless infrastructure expansion will result in: 1) support of “anytime, anywhere access to information” which promotes collaboration with colleagues, business partners, and customers, 2) real-time access to instant messaging, e-mail, and network resources that increases productivity and improves business decision making and 3) mobility of services such as voice, guest access, security, and location will transform business operations.

Table 3.7.2. New Capabilities Required for Institutional Administrative Information Equipment



	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Document Management							$400,000
Disaster Recovery						$1,000,000	
Instant Messaging				$100,000			
Collaboration Infrastructure			$75,000				
Virtual Tape Library							$250,000
Storage Upgrades	$120,000				$250,000		$475,000
Voice Over Internet Protocol				$1,100,000	$1,100,000		
Core Routing Failover		$500,000					
Wireless Expansion	$200,000		$400,000				

4.0 Maintaining Requirements

4.1 Reinvesting in Facilities and Infrastructure

Since NREL opened its doors in 1977, the Department of Energy has invested in facility and infrastructure assets at the Laboratory that were worth $170 million at the end of FY2005. Regular infusions of funds are necessary to maintain these buildings, roads, and utilities in good condition; maintain the interiors of buildings including laboratories; reconfigure research spaces to respond to modest changes in research direction; add small additions to existing buildings as necessary; respond to requirements for safety and security; and other needs. Table 4.1 lists the terms from the Real Property Asset Management Order 430.1b that are collectively referred to in this report as "reinvestment."

Table 4.1 DOE Terminology Included in "Reinvestment" at NREL

Sustainment (DOE Order 430.1B pg 9)	Reinvestment (DOE Order 430.1B pg 11)
Maintenance (prevention, prediction) Repair/Component level replacement in kind	Alterations/Restorations Betterments/Modernization Renovations Reconstruction Replacements/Plant record level Conversion

The funds to pay for reinvestment in all its types and forms is categorized depending on the nature of the reinvestment, the timing compared to the need, and the value of the project (Table 4.2). DOE budget guidance (April 2006) recommends a level of 2%-4% for on-time reinvestments, and an additional 1%-2% of replacement plant value for deferred reinvestments, at DOE facilities.

At this time, NREL's oldest facilities (Field Test Laboratory Building, NWTC Administration Building 251, parts of the Alternative Fuels User Facility, some mesa top facilities) are reaching the end of the useful life of their important building systems, and for the next five years (FY2008-FY2012), a minimum of the combined rate of 2.25% for on-time reinvestments of various types will be required to maintain an excellent facility condition index rating. However, during the second five years of the plan, (FY2013-FY2017), that combined rate will need to be increased substantially, to an estimated 3.5%, to reinvest primarily in the facilities originally built in 1993-1997. These facilities include the Solar Energy Research Facility, Outdoor Test Facility, Thermal Test Facility, Shipping and Receiving Facility, Industrial User Facility, Dynamometer, Site Entrance Building, and some mesa top facilities.

Table 4.2 Categorization of Annual Real Property Reinvestment Expenditures
[as a % of Current-Year Replacement Plant Value (RPV)]

Category	Source of Funds	Approx % of Current-Year RPV for FY08-FY2012	Approx % of Current-Year RPV for FY2013-FY2017	Description
Annual Costs Related to Current Assets (all expenditures including small expansions to existing assets)				
Real Property In-house Maintenance	NREL Overhead Operating	1.0%	1.5%	Less than $2,000 of labor, performed in-house, less than $50,000 total per project
Real Property Contracted Maintenance	NREL Overhead Operating/GPP Operating[1]	0.25%	0.5%	Labor more than $2,000, contracted, less than $50,000 total per project
Real Property On-Time Reinvestment	GPP Capital or GPP Operating[2]	1.0%	1.5%	Total per project between $50,000 and $5,000,000, on-time
Real Property Deferred Reinvestment	GPP Capital or GPP Operating[2]	0.5%	0.5%	Total per project between $50,000 and $5,000,000, not performed when it should have been

The previous discussion referred to reinvestments made "on time," i.e., when the asset should be replaced because it has reached its useful life. However, not all reinvestments are made on time. Those investments that must be budgeted or corrected beyond the time when they should have been invested are deferred. Totally eliminating deferred reinvestment is expected to remain a challenge because of the uncertainty of funding. Optimistically, funding for deferred reinvestments is estimated to be 0.5% of replacement plant value from FY2008-FY2017.

Projecting the actual funding levels required for reinvestment depends on the projections for replacement plant value. Table 4.3 lists the specific new facilities expected to be placed into service during FY2006-FY2017. Table 4.4 shows the increase by year in replacement plant value from both the escalation in replacement value of existing facilities and the addition of new facilities.

[1] Currently (FY06-FY08) NREL Overhead Operating. Beginning in the FY09 budget cycle during FY07, this cost will be included in General Plant Projects
[2] Capital or operating according to DOE Accounting Handbook definitions

Table 4.3 NREL Facility Additions FY2007-FY2018*

NREL Facility and Infrastructure Additions FY2007-FY2018		
	Completion Year	Construction Cost
Integrated Biorefinery Res Facility	2010	$19,500,000
Energy Systems Integration Facility	2012	$54,563,884
Scientific Computing	2012	$37,874,309
Biological & Chemical Research Facility	2012	$57,095,521
Renewable Fuels & Vehicle Systems Facilit	2014	$47,520,390
Solid-state Research Facility	2015	$68,001,678
Energy Systems Integration Facility II	2016	$60,068,149
Next-Generation Biorefinery	2019	$50,874,401
RSF Phase I ($9M, funded)	2008	$10,800,000
RSF Phase 2	2010	$65,386,778
RSF Phase 3 conf/learning center	2012	$24,088,060
RSF Phase 4a	2016	$38,013,277
RSF Phase 4b	2017	$34,249,962
STM Site Infrastructure Development	2008	$2,500,000
STM Site Infrastructure Development	2010	$12,442,398
STM Site Infrastructure Development	2011	$3,000,000
STM Site Infrastructure Development	2013	$27,028,747

** Only construction costs are included in these asset calculations. Essential capital equipment and conceptual design are not included.*

Table 4.4 Projections of Replacement Plant Value FY2007-FY2013 (Buildings Only)

Projections of Replacement Plant Value FY2007-FY2013									
		9/30/2006	9/30/2007	9/30/2008	9/30/2009	9/30/2010	9/30/2011	9/30/2012	9/30/2013
Total RPV		$170.0	$180.2	$204.3	$216.6	$326.9	$349.6	$544.1	$603.8
Escalation factor			1.06	1.06	1.06	1.06	1.06	1.06	1.06

Table 4.5 indicates the specific amounts required in each category described above, applying the given percentages to the expected replacement plant value at the start of the fiscal year. Figures 4.6 and 4.7 shows this data graphically.

Table 4.5 Projections of Real Property Reinvestments Required, On-Time and Deferred, FY06-FY2012

Projections of Real Property Maintenance and Reinvestment Requirements FY2007-FY2013

	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
RPV Projections at start of FY	$170.0	$180.2	$204.3	$216.6	$326.9	$349.6	$544.1
Real Property Inhouse Maintenance (NREL Overhead Operating, 1% of RPV)	$1.700	$1.802	$2.043	$2.166	$3.269	$3.496	$5.441
Real Property Contracted Maintenance (NREL OH, 0.25% of RPV)	$0.300	$0.400	$0.000	$0.000	$0.000	$0.000	$0.000
Subtotal NREL On-Time Maintenance Overhead	$2.000	$2.202	$2.043	$2.166	$3.269	$3.496	$5.441
Real Property Contracted Maintenance (GPP Operating, 0.25% of RPV)	$0.000	$0.000	$0.511	$0.542	$0.817	$0.874	$1.360
Real Property On-Time Reinvestment (GPP Capital or GPP Operating, 1% of RPV)	$0.000	$1.802	$2.043	$2.166	$3.269	$3.496	$5.441
Subtotal On-Time Reinvestment GPP, 1% of RPV	$0.000	$1.802	$2.554	$2.708	$4.087	$4.369	$6.802
Total Real Property On-Time Reinvestment and Maintenance	$2.000	$4.005	$4.598	$4.874	$7.356	$7.865	$12.243
Real Property On-Time Reinvestment % of Replacement Plant Value	***1.2%***	***2.2%***	***2.3%***	***2.3%***	***2.3%***	***2.3%***	***2.3%***
Real Property Deferred Reinvestment (GPP Capital or GPP Operating, 0.5% of RPV)	$1.457	$0.901	$1.022	$1.083	$1.635	$1.748	$2.721
Real Property Deferred Reinvestment, % of Replacement Plant Value	***0.9%***	***0.5%***	***0.5%***	***0.5%***	***0.5%***	***0.5%***	***0.5%***

Figure 4.6 Real Property Reinvestments Required, FY2008 – FY2012 (NREL Overhead and General Plant Projects)

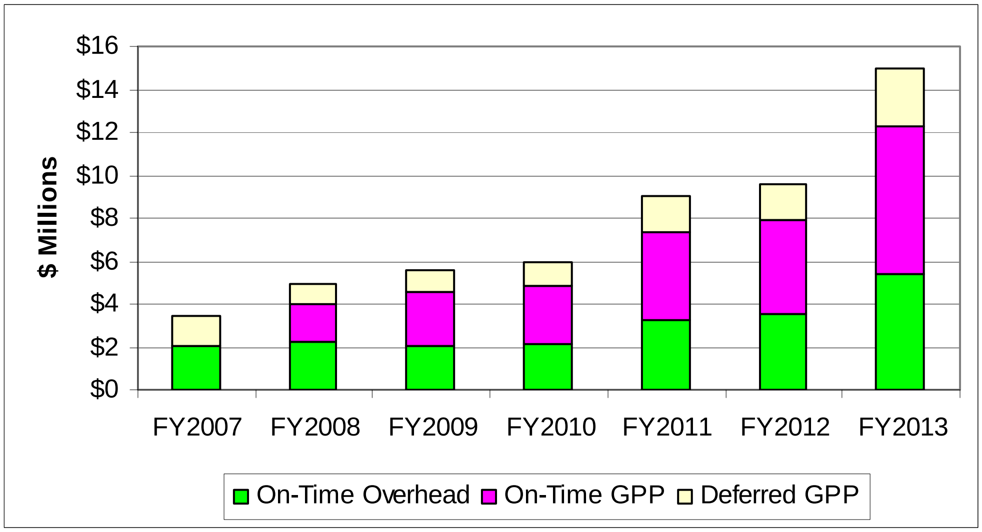
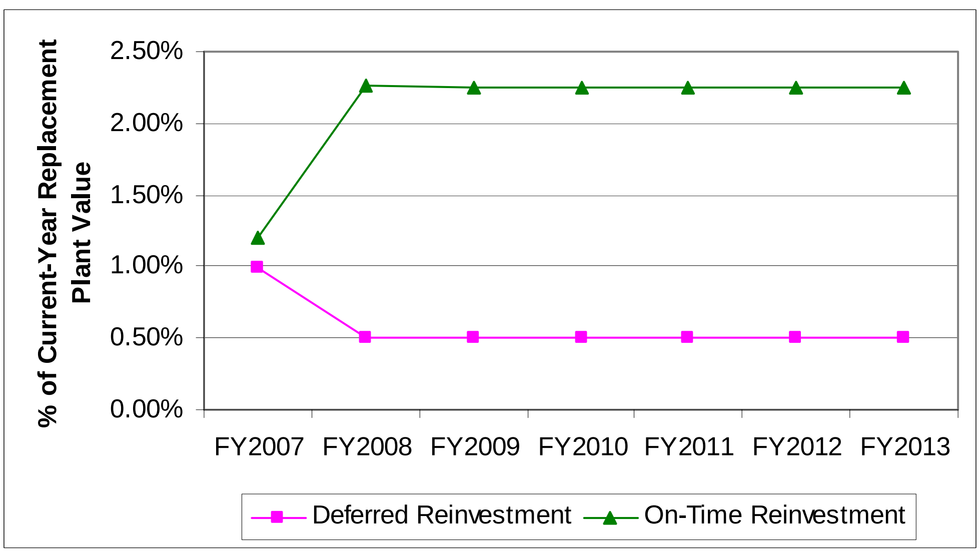


Figure 4.7 On-time and Deferred Reinvestments as a Percentage of Replacement Plant Value



Individual reinvestment projects are identified in the *Deferred and Regular Maintenance Report* and the *Ten-Year Maintenance Plan Report*, which are developed through on-site inspections of existing facilities and infrastructure, and managed through the Condition Assessment Information System. These full reports and descriptions of individual projects are available on request to NREL.

4.2 Reinvesting in Capital Equipment

Reinvestment Philosophy and Methodology

Since NREL opened its doors in 1977, the Department of Energy has invested in capital equipment assets at the Laboratory that were worth $89 million at the end of FY2006. Regular infusions of funds are necessary to replace this equipment as it reaches the end of its service life to maintain or improve productivity, to avoid obsolescence, and to maintain the scientific capabilities at the level of excellence needed for the mission of the laboratory.

Table 4.2.1 Summary of Opportunities and Issues for NREL Capital Equipment

Opportunities

- Greater resolution and other improvements in scientific instrumentation are permitting enhanced understanding of new nanostructured and organic materials, at ever-smaller scales.
- Rapid advances in deposition and manipulation equipment is broadening the possibilities for electronic materials.
- Greater speed, flexibility, and sophistication in genomic instrumentation is helping to advance analysis and understanding of proteins and biological molecules.
- New scientific computing capabilities at NREL are adding significant value to research programs.

Issues

- Overall NREL's capital equipment is 65% depreciated, with only 35% remaining value.
- Deferred backlog of items older than their service life is $25 million, or 29% of the current inventory.
- The average age of items in the current inventory (average 10.0 years) has reached the average useful life of this equipment.
- Program capital equipment is significantly older on average than institutional capital equipment, and funding has been decreasing, further exacerbating the problem of aging equipment.

In addition to replacing equipment at the end of its service life, NREL also needs to add new capabilities – new types of equipment -- on a regular basis as technological advances offer new types of scientific instrumentation, security equipment, and computer and telecommunication systems. These new capabilities are necessary to provide the best possible results for today's missions. These items of equipment also need to be maintained.

There are many methods to project what levels of funding will be required to maintain capital equipment in a suitable condition to allow the Laboratory to continue to accomplish its mission in the coming years. NREL has analyzed several of these methods, and has chosen to use a metric that is a valuable indicator of the overall "health" of the capital equipment portfolio, and is supported as a best business practice in the private sector. That metric is the total remaining value of the capital equipment portfolio as a percentage of the total original acquisition cost (i.e., 100 minus the percentage depreciated).

Effects of Flat Funding

Program capital equipment funding from EERE has declined significantly during the last four years, from $7.0 million in FY2003 to $2.5 million in FY2006. Institutional capital equipment funding has been flat during this period at about $2 million/year. (Figure 4.2.2 below and Figure B.4.1 in Appendix B). A flat level of funding has a persistent negative effect on the value of capital equipment assets, as shown in Figures 4.2.3 and 4.2.4. Flat funding results in a steady decrease in the value of the portfolio both because of the continuous aging of equipment (which is much more rapid than facilities and infrastructure) and because of the continuous rise in inflation (reference the set of five figures below). Declining funding has an even more dramatic negative effect.

Figure 4.2.2 Trends in Capital Equipment Funding at NREL

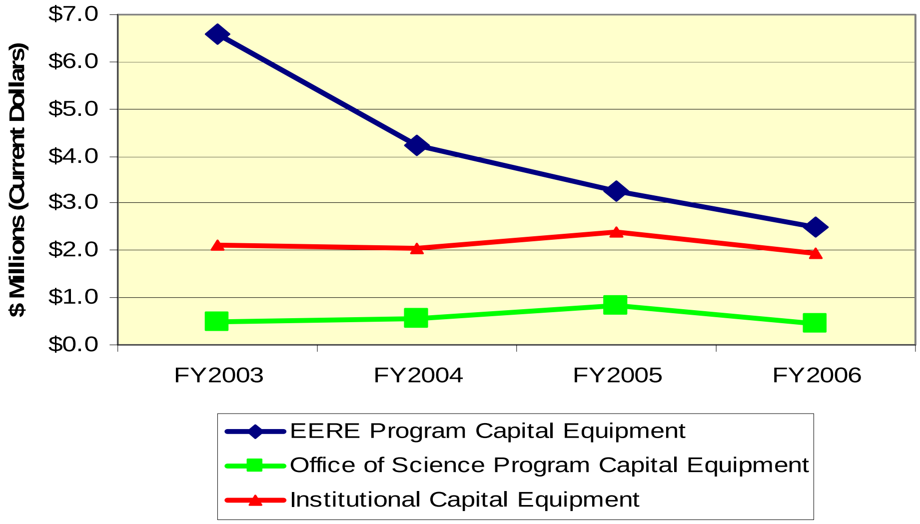
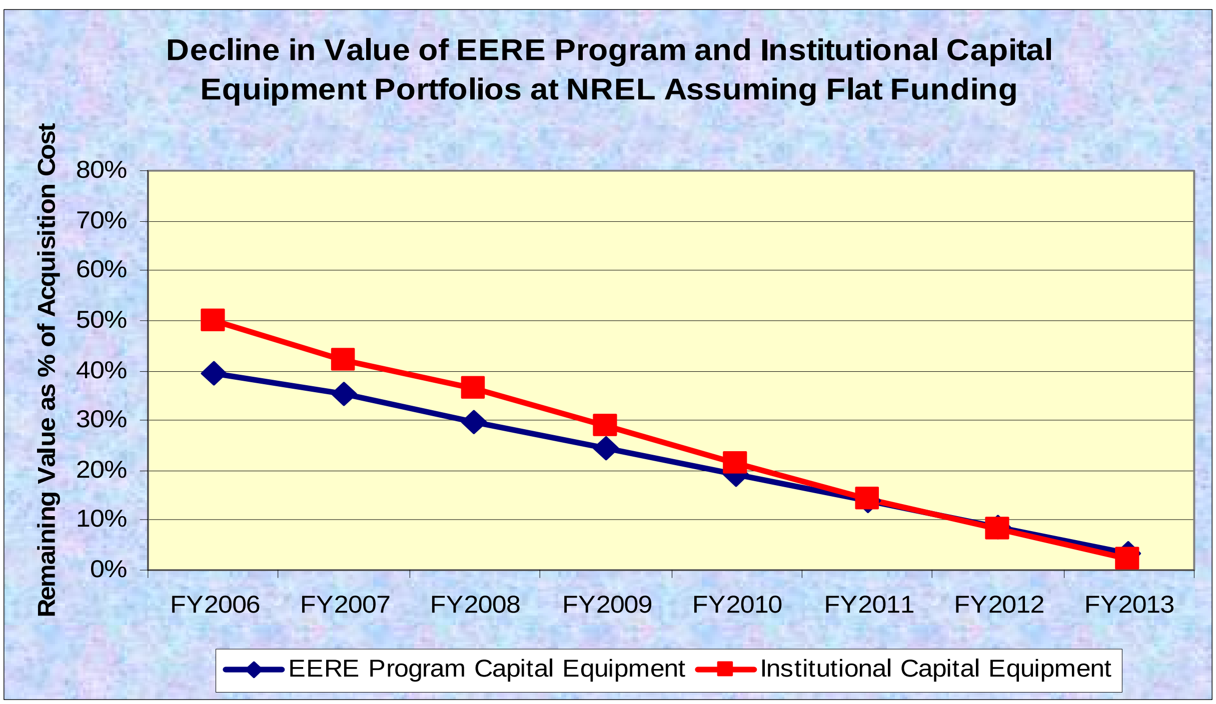
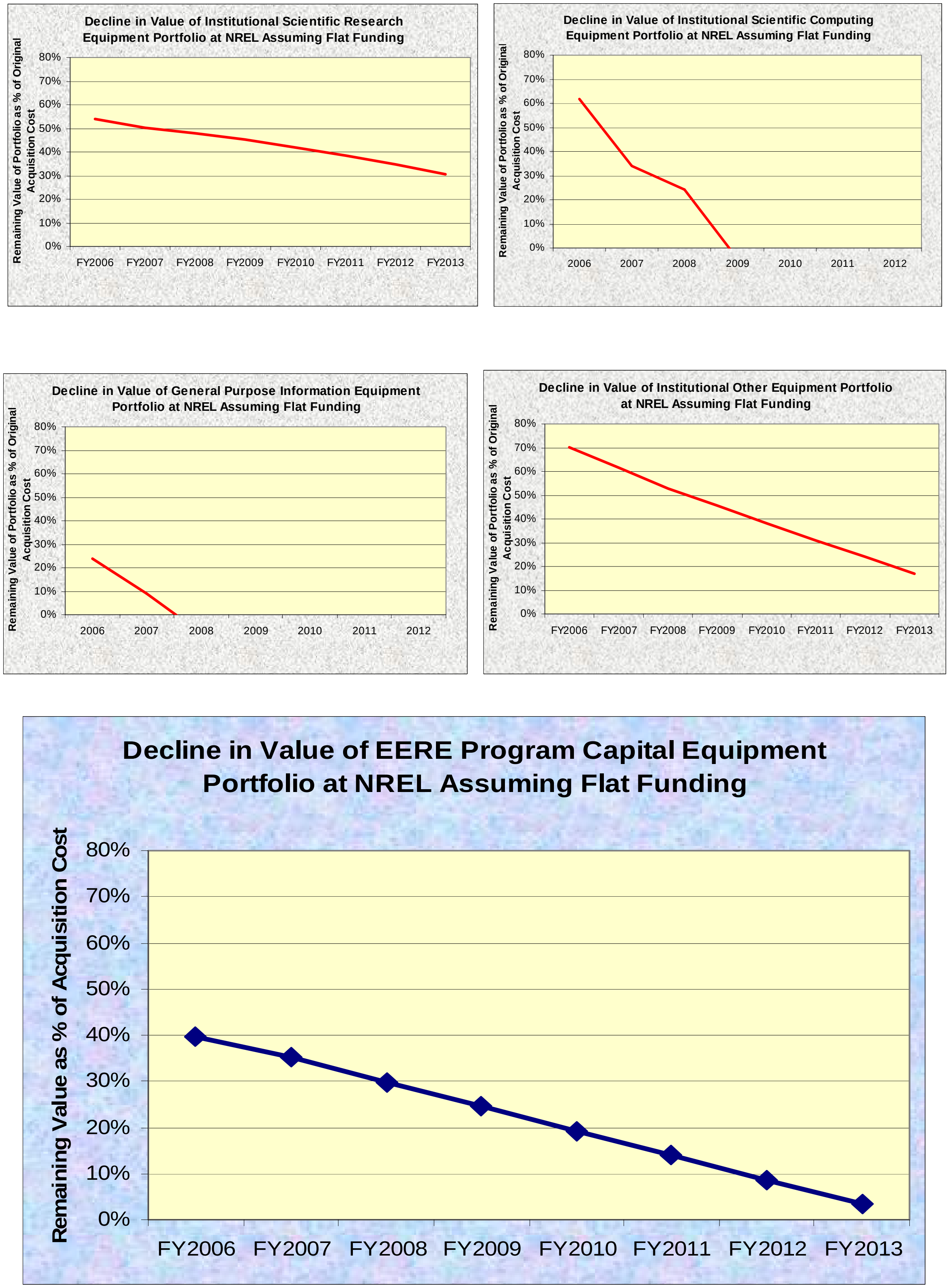


Figure 4.2.3 Effect of Flat Funding on Value of Institutional Equipment at NREL (*This data includes items intended to be replaced by institutional funding.)*



Note: This data reflects portfolios defined as the items that are intended *to be replaced by* either program funds or institutional funds, which can vary slightly from the portfolios defined as the items *originally purchased by* program or institutional funds.

Figure 4.2.4 Effect of Flat Funding on the Remaining Value of Four Types of Institutional Capital Equipment



To project the institutional capital equipment funds required, FY2007 and FY2008 funding requirements were estimated by specific item to match the level of the funding expected at the time of preparation of this Ten-Year Site Plan in December 2006. The projections of program capital equipment funds for FY2007 and FY2008 were best-guess estimates based on recent trends.

For both program and institutional capital equipment, funds required for FY2009-FY2013 reinvestment were estimated in three type-of-need categories as follows: deferred replacement, on-time replacement, and new capabilities.

- Funding for deferred replacement was calculated by estimating the funding needed to replace all specific items of equipment in the category that were expected to be beyond their service life at the beginning of FY2009. The assumption was made that this deferred backlog would be funded one-fifth per year from FY2009 to FY2013 in most circumstances (Information and Scientific Computing equipment was reduced more aggressively, over three years), reducing the deferred replacement backlog to zero by the beginning of FY2014.
- Funding for new capabilities was estimated as the same amount of annual investment for new capabilities as has been required over the last several years, with an assumption for inflation.
- Funding for on-time replacement was determined through an algorithm that used these assumptions for deferred replacement and new capabilities. The algorithm then calculated the % remaining value (and therefore the % depreciated) at various levels of potential future funding, given all the expected changes to the portfolio (retired items, new capability items, replaced deferred items, and replaced ontime items) and the calculated effects on original acquisition cost, accumulated depreciation, and replacement equipment value. (Replacement equipment value is the value of the institutional equipment portfolio at any point in time, analogous to the replacement plant value often used to describe facilities and infrastructure.) The required funding was chosen to achieve a level of 50% remaining value as quickly as possible within the FY2009-FY2013 timeframe, and then to maintain that level of 50% through FY2013.

4.2.1 Institutional Capital Equipment

Of the $89 million in total value of capital equipment today, $13 million represents the value today of equipment that was purchased with institutional capital equipment funds, and still serves a general or institutional purpose (including multiple research programs, as opposed to specifically serving only one DOE program) (Table 4.2.1.1).

Table 4.2.1.1

NREL Institutional Capital Equipment Condition Assessment (09/30/06)*

	Units	All Institutional Equipment	Institutional Scientific Instrumentation	Institutional Scientific Computing Equipment	Institutional Information Equipment	Institutional Other Equipment
Acquisition Cost (Full Use)	million	$11.652	$7.070	$0.604	$2.708	$1.270
Remaining Value Today (Full Use)	million	$6.426	$4.525	$0.372	$0.639	$0.890
Remaining Value (%)	%	55.2%	64.0%	61.7%	23.6%	70.1%
Estimated Value Today (Full Use)	million	$12.827	$8.083	$0.604	$2.708	$1.432
Deferred Replacement Backlog	million	$3.307	$1.493	$0.000	$1.659	$0.155
Deferred Backlog (%)	%	25.8%	18.5%	0.0%	61.3%	10.8%
Average Useful Life	yrs	8.8	10.0	3.0	4.0	13.7
Average Age	yrs	5.2	5.5	0.1	5.2	4.9

** This data includes only items originally purchased with institutional funds.*

NREL's portfolio of institutional capital equipment at the end of FY2006 had a remaining value of 55% of original acquisition cost for items intended to be replaced by institutional funding, and 40% for items intended to be replaced by program funding. However, the flat levels of funding expected in FY2007 and FY2008 result in a continuing drop in remaining value through the end of FY2008. To reach the target level of 50% remaining value requires an immediate and substantial increase in FY2009. After that time, maintaining a level of 50% remaining value will require from $5 million to $6 million per year. Figures 4.2.1.2 and 4.2.1.3 indicate the projected funding requirements and the resulting value of the equipment portfolio that achieves the 50% target. Table 4.2.1.4 describes the important characteristics for the institutional equipment portfolio required to meet the NREL mission, and Table 4.2.1.5 gives details of the funding required to achieve these characteristics.

Figure 4.2.1.2 Institutional Equipment Funding Required to Meet Mission Needs and Maintain Remaining Value at 50% of Acquisition Cost

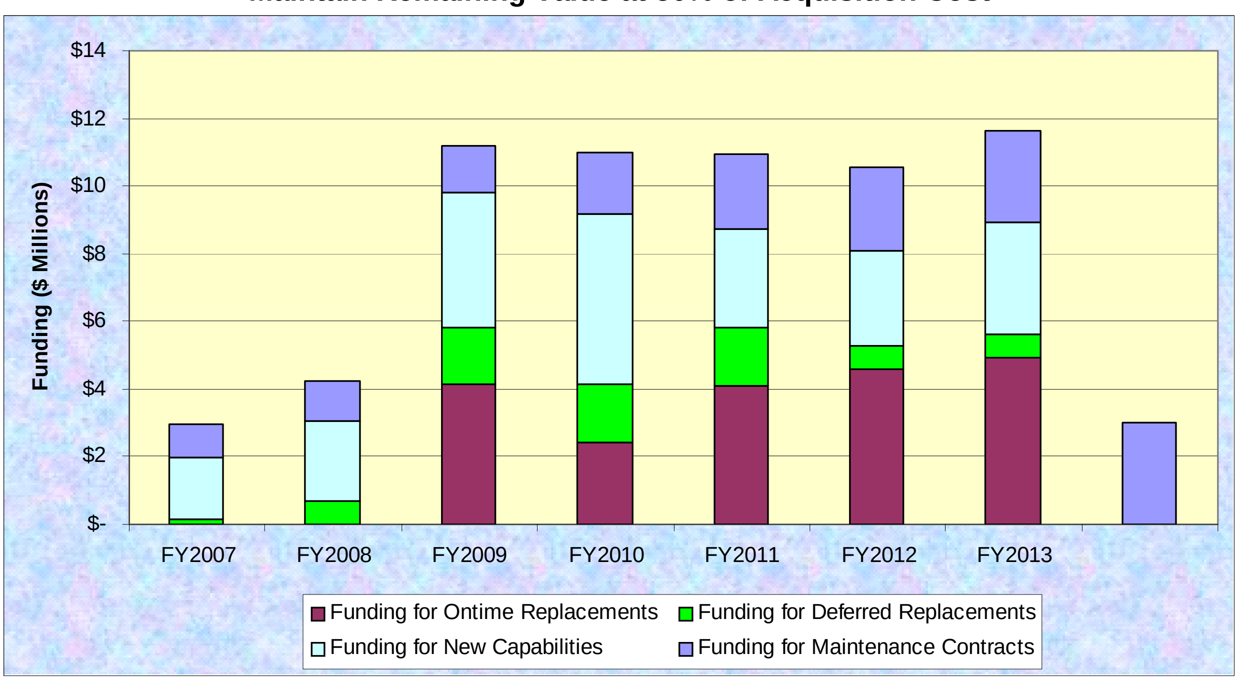


Figure 4.2.1.3 Achievement of 50% Remaining Value for Institutional Equipment with the Funding Portfolio Above

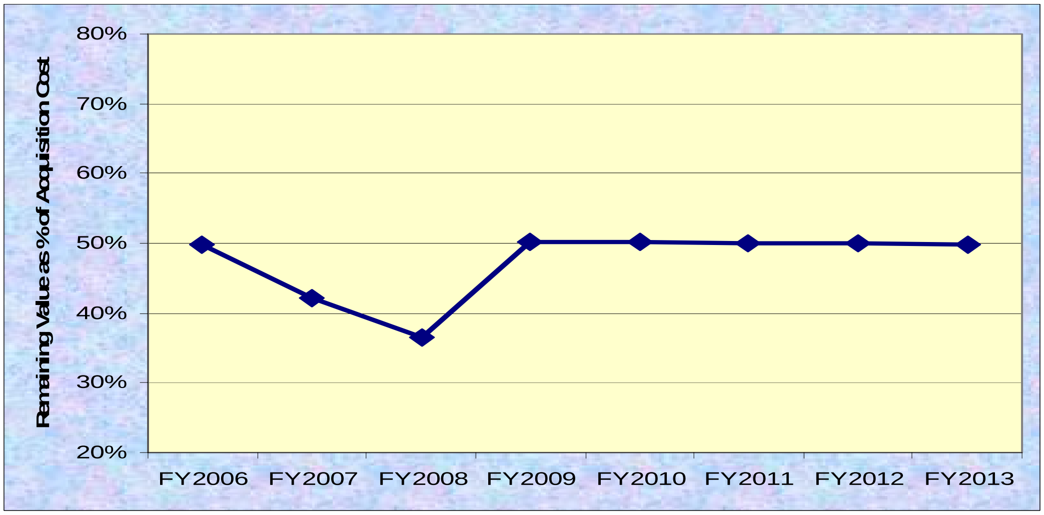


Table 4.2.1.4 Current and Required Characteristics of Institutional Equipment Portfolio *(This data reflects equipment intended to be replaced with institutional capital equipment funds.)*

	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
Original Acquisition Cost								
Scientific Research Equipment	$ 9,213,685	$ 10,413,208	$ 12,335,625	$ 13,878,213	$ 15,569,619	$ 17,516,379	$ 19,763,935	$ 22,408,272
Scientific Computing Equipment	$ 603,753	$ 711,753	$ 1,107,753	$ 3,607,753	$ 6,107,753	$ 6,107,753	$ 6,107,753	$ 6,107,753
Administrative Information Equipment	$ 2,708,421	$ 3,129,621	$ 3,432,021	$ 6,332,021	$ 8,232,021	$ 9,832,021	$ 11,132,021	$ 12,432,021
Other Equipment	$ 1,269,531	$ 1,431,531	$ 1,431,531	$ 1,431,531	$ 1,563,556	$ 1,702,221	$ 1,847,526	$ 1,992,831
Total Equipment	$ 13,795,390	$ 15,686,113	$ 18,306,931	$ 25,249,518	$ 31,472,948	$ 35,158,374	$ 38,851,235	$ 42,940,877
Accumulated Depreciation								
Scientific Research Equipment	$ 4,245,715	$ 5,199,758	$ 6,406,555	$ 6,921,024	$ 7,753,452	$ 8,735,911	$ 9,905,920	$ 11,191,545
Scientific Computing Equipment	$ 231,439	$ 468,690	$ 837,941	$ 1,790,525	$ 3,056,443	$ 3,042,361	$ 3,058,278	$ 3,064,196
Administrative Information Equipment	$ 2,069,224	$ 2,851,629	$ 3,709,635	$ 3,172,640	$ 4,120,645	$ 4,928,650	$ 5,561,655	$ 6,169,660
Other Equipment	$ 379,637	$ 484,503	$ 589,369	$ 694,236	$ 774,245	$ 851,053	$ 925,145	$ 1,009,882
Total Equipment	$ 6,926,015	$ 9,004,581	$ 11,543,500	$ 12,578,425	$ 15,704,785	$ 17,557,974	$ 19,450,999	$ 21,435,283
Remaining Value								
Scientific Research Equipment	$ 4,967,970	$ 5,213,449	$ 5,929,070	$ 6,957,189	$ 7,816,167	$ 8,780,469	$ 9,858,015	$ 11,216,727
Scientific Computing Equipment	$ 372,315	$ 243,063	$ 269,812	$ 1,817,228	$ 3,051,310	$ 3,065,393	$ 3,049,475	$ 3,043,557
Administrative Information Equipment	$ 639,197	$ 277,991	$ (277,614)	$ 3,159,381	$ 4,111,376	$ 4,903,371	$ 5,570,365	$ 6,262,360
Other Equipment	$ 889,894	$ 947,028	$ 842,162	$ 737,296	$ 789,311	$ 851,168	$ 922,381	$ 982,950
Total Equipment	$ 6,869,375	$ 6,681,532	$ 6,763,431	$ 12,671,093	$ 15,768,163	$ 17,600,400	$ 19,400,236	$ 21,505,594
Remaining Value as % of Acquisition Cost								
Scientific Research Equipment	53.9%	50.1%	48.1%	50.1%	50.2%	50.1%	49.9%	50.1%
Scientific Computing Equipment	61.7%	34.1%	24.4%	50.4%	50.0%	50.2%	49.9%	49.8%
Administrative Information Equipment	23.6%	8.9%	-8.1%	49.9%	49.9%	49.9%	50.0%	50.4%
Other Equipment	70.1%	66.2%	58.8%	51.5%	50.5%	50.0%	49.9%	49.3%
Average	49.8%	42.6%	36.9%	50.2%	50.1%	50.1%	49.9%	50.1%
Replacement Equipment Value (REV)								
Scientific Research Equipment	$10,724,309	$12,192,438	$14,212,971	$15,639,361	$17,308,541	$19,267,798	$21,573,831	$24,294,646
Scientific Computing Equipment	$603,753	$711,753	$1,107,753	$3,607,753	$6,107,753	$6,107,753	$6,107,753	$6,107,753
Administrative Information Equipment	$2,708,421	$3,129,621	$3,432,021	$6,332,021	$8,232,021	$9,832,021	$11,132,021	$12,432,021
Other Equipment	$1,432,024	$1,495,024	$1,495,024	$1,695,024	$1,895,024	$2,095,024	$2,295,024	$2,495,024
Total Equipment	$15,468,507	$17,528,836	$20,247,769	$27,274,158	$33,543,339	$37,302,595	$41,108,629	$45,329,444
Deferred Backlog								
Scientific Research Equipment	$3,147,007	$3,230,978	$3,314,949	$2,651,959	$1,988,969	$1,325,979	$662,990	$0
Scientific Computing Equipment	$0	$301,877	$603,753	$402,502	$201,251	$0	$0	$0
Administrative Information Equipment	$1,659,361	$2,071,723	$2,484,084	$1,656,056	$828,028	$0	$0	$0
Other Equipment	$154,603	$203,903	$253,202	$253,202	$202,562	$151,921	$101,281	$50,640
Total Equipment	$4,960,972	$5,808,480	$6,655,988	$4,963,719	$3,220,810	$1,477,901	$764,271	$50,640
Deferred Backlog as % of REV								
Scientific Research Equipment	29.3%	26.5%	23.3%	17.0%	11.5%	6.9%	3.1%	0.0%
Scientific Computing Equipment	0.0%	42.4%	54.5%	11.2%	3.3%	0.0%	0.0%	0.0%
Administrative Information Equipment	61.3%	66.2%	72.4%	26.2%	10.1%	0.0%	0.0%	0.0%
Other Equipment	10.8%	13.6%	16.9%	14.9%	10.7%	7.3%	4.4%	2.0%
Average	32.1%	33.1%	32.9%	18.2%	9.6%	4.0%	1.9%	0.1%

** This data reflects equipment that is intended to be replaced with institutional capital equipment funds.*

Table 4.2.1.5 Funding Required to Achieve Required Characteristics of Institutional Equipment Portfolio

	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
Funding Required to Work Down Deferred Replacement								
Scientific Research Equipment	$0.000	$0.140	$0.707	$0.663	$0.663	$0.663	$0.663	$0.663
Scientific Computing Equipment	$0.000	$0.000	$0.000	$0.201	$0.201	$0.201	$0.000	$0.000
Administrative Information Equipment	$0.000	$0.000	$0.000	$0.828	$0.828	$0.828	$0.000	$0.000
Other Equipment	$0.000	$0.000	$0.000	$0.000	$0.051	$0.051	$0.051	$0.051
Total Equipment	$0.000	$0.140	$0.707	$1.692	$1.743	$1.743	$0.714	$0.714
Funding Required for OnTime Replacements								
Scientific Research Equipment	$0.285	$0.000	$0.000	$1.140	$0.940	$1.000	$1.050	$1.250
Scientific Computing Equipment	$0.000	$0.000	$0.000	$0.250	$0.770	$2.050	$2.020	$2.030
Administrative Information Equipment	$0.090	$0.000	$0.000	$2.120	$1.110	$1.650	$2.150	$2.500
Other Equipment	$0.085	$0.000	$0.000	$0.000	$0.050	$0.070	$0.090	$0.090
Total Equipment	$0.460	$0.000	$0.000	$3.510	$2.870	$4.770	$5.310	$5.870
Funding Required to Add New Capabilities for Current Missions								
Scientific Research Equipment	$1.374	$1.146	$1.655	$1.000	$1.200	$1.440	$1.728	$2.074
Scientific Computing Equipment	$0.000	$0.108	$0.396	$2.500	$2.500	$0.000	$0.000	$0.000
Administrative Information Equipment	$0.000	$0.421	$0.302	$2.900	$1.900	$1.600	$1.300	$1.300
Other Equipment	$0.118	$0.162	$0.000	$0.000	$0.100	$0.100	$0.100	$0.100
Total Equipment	$1.492	$1.838	$2.353	$6.400	$5.700	$3.140	$3.128	$3.474
Funding Required Total								
Scientific Research Equipment	$1.659	$1.287	$2.362	$2.803	$2.803	$3.103	$3.441	$3.987
Scientific Computing Equipment	$0.000	$0.108	$0.396	$2.951	$3.471	$2.251	$2.020	$2.030
Administrative Information Equipment	$0.090	$0.421	$0.302	$5.848	$3.838	$4.078	$3.450	$3.800
Other Equipment	$0.203	$0.162	$0.000	$0.000	$0.201	$0.221	$0.241	$0.241
Service Contracts								
Building Equipment (not in equipment pool)	$0.000	$0.000	$0.559	$0.000	$0.000	$0.000	$0.000	$0.000
Total Equipment	$1.952	$1.978	$3.620	$11.602	$10.313	$9.653	$9.152	$10.057
Replacement Funding (Deferred and OnTime) as % of Replacement Equipment Value								
Scientific Research Equipment	2.7%	1.2%	5.0%	11.5%	9.3%	8.6%	7.9%	
Scientific Computing Equipment	0.0%	0.0%	0.0%	12.5%	15.9%	36.9%	33.1%	
Administrative Information Equipment	3.3%	0.0%	0.0%	46.6%	23.5%	25.2%	19.3%	
Other Equipment	5.9%	0.0%	0.0%	0.0%	5.3%	5.8%	6.1%	
Total Equipment	3.0%	0.8%	3.5%	19.1%	13.8%	17.5%	14.7%	

** This data reflects equipment that is intended to be replaced with institutional capital equipment funds.*

Institutional capital equipment requirements are discussed in four categories (scientific research, scientific computing, administrative information, and other) in the following subsections.

Institutional Scientific Research Equipment. Current equipment at NREL includes:

- Scanning electron, transmission electron, atomic force, and other microscopes for surface studies of all solid-state materials including thin-films, nanostructures, and organic solids
- X-ray diffraction, Auger, photoelectron, and other spectrometers for solid-state surface studies
- Ion-beam milling instruments for solid-state sample preparation
- Deposition and solid-state growth equipment for thin-film and nanostructure preparation
- Nuclear magnetic resonance spectrometers for organic materials
- Chromatographs, mass spectrometers, and combination instruments for organic material separation and characterization
- Metrology and calibration equipment
- Calorimeters, infrared cameras, and other thermal measurement instrumentation
- Lasers, centrifuges, sterilizers, autoclaves, and other general instrumentation and equipment
- Accessories to upgrade existing instrumentation such as vacuum pumps and chambers, autosamplers, and microprobes.

NREL is evolving from more isolated programmatic R&D to more integrated, interdisciplinary, and multidisciplinary approaches to science and technology development. NREL expects to continue emphasizing integrated R&D wherever possible.

- Integrated approaches to science encourage greater creativity, more effective problem-solving, increased likelihood of breakthroughs, and more rapid research progress.
- Shared instrumentation avoids duplication, lowers costs, and improves flexibility.

While it is sometimes effective for programs to pool capital funding and jointly purchase a particular instrument needed by both, it has proven most effective to purchase shared instrumentation through the use of institutional funds and manage the equipment to benefit the entire Laboratory. This management solution establishes a laboratory or instrument owner who oversees issues of use, maintenance, training, and fair distribution of operating costs for the benefit of all potential users at NREL.

Institutional Scientific Computing Equipment

Current activities at NREL include prediction of material properties and material design at the nanoscale, molecular dynamics simulations and visualization of proteins and DNA, optimization of component designs for advanced hybrid vehicles, modeling of energy use in buildings, and modeling of wind turbine aerodynamics. Geographic information systems are used in analysis of energy resource availability; systems-driven analyses of energy options focusing on regional characteristics, and related applications.

NREL began a major investment in its institutional computational science capability in 2002, and NREL's initial high-performance computing resources in April 2002 consisted of a 48-processor IBM system with an absolute peak performance of 96 gigaflops. The system quickly became a popular resource, and demand was so high at times that users had to wait up to 36 hours from the time that they submitted their compute job into the queue until the job first started running. These long wait times mitigate the scientific progress of existing users and deter new users from getting started utilizing high performance computing in their research.

In August 2004, NREL invested GPE funds to substantially augment the Lab's high performance computing capabilities with two systems which combined have a peak floating point capability of 787 Gigaflops (0.8 Tflops). Subsequently, the IBM system was decommissioned in April 2005. It was two full generations behind the current state-of-the-art systems available and the cost to operate and maintain it exceeded its value as a computational resource. While the new acquisition increased NREL's compute capabilities eight-fold, it was quickly utilized at near capacity. Additional processors were purchased in FY2005 and FY2006 to bring the current capacity in December 2006 to 1.2 Tflops. The system use is near capacity by NREL scientists and engineers. These resources will need to be maintained in the future, with an average service life of three years. At the end of FY2006 NREL had 11 full-time staff and three graduate students devoted exclusively to provide computational science expertise wherever needed in the Laboratory.

Institutional Administrative Information Equipment

This equipment provides the backbone for scientific interchange, knowledge management, and all administrative computing needs for the Laboratory. Effective execution of NREL's mission requires information technology that supports all administrative functions including communications, and provides the architecture and networks necessary for analysis and communication of scientific information. NREL's institutional information technology supports opportunities that improve NREL's science and research; balances scientific flexibility with a stable and current information technology environment; empowers researchers and administrative staff with tools and training; and maintains consistent IT standards for the Laboratory.

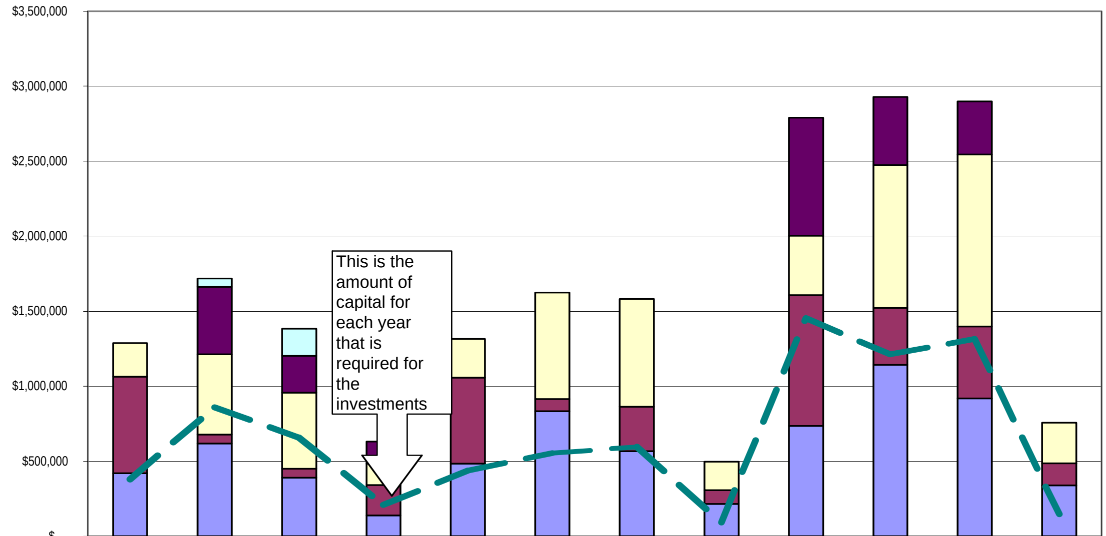
NREL's emphasis today is on improving operations, including safeguarding information and IT assets, and delivering cost-effective services. Over time, the emphasis of investments is expected to shift towards the longer-range goals of sharing research and enabling new knowledge. With the establishment of a research support facility on the permanent site, the data center, currently housed in leased space in Building 17 is expected to move to the permanent site in the FY2008 – FY2010 timeframe.

In FY2000, the Laboratory committed capital funds for a wide-ranging series of IT improvements. This upgrade addressed several prior years of significantly diminished or deferred investment in the Laboratory's IT infrastructure. Since then, the Laboratory has worked hard to maintain and improve the Lab's IT with regular investments. However, the institutional equipment funding has not been sufficient for all needs, and institutional IT currency and effectiveness is a continuing challenge.

NREL faces a difficult challenge to maintain the existing institutional information systems somewhere near the state-of-the-art in performance and technical capability. In practice, IT equipment is often obsolete for technology reasons long before the equipment stops working. The average age of NREL's institutional information equipment is 5.2 yrs compared to its average useful life of 4.0 years. This is due to the rapid obsolescence of computer equipment, and the insufficient funding available to keep computer equipment up-to-date. The value of equipment in this category that is already beyond its strategic useful life (deferred replacement backlog) as of 9/30/06 is $1.7 million, more than 60% of the value of all equipment in this category. Reversing this trend continues to be a challenge that, if unaddressed, will necessitate another 'forklift' upgrade – a significant infusion of capital – at some point in the near future.

The investments shown below are intended to reverse this trend as quickly as possible, to achieve and maintain a ratio of 50% depreciated to 50% remaining value on average. Major investments in storage are required every four years (in FY2007, FY2011 and FY2015), to replace aging hardware and to accommodate projected growth and demand. Consistent annual investment for maintenance of networks and servers is also required. The capital dollars required for institutional administrative information equipment requirements as shown in Table 4.2.1.5 differ in detail from the capital dollars required as shown in Figure 4.2.1.6. The projections were generated using different methodologies. However, the general levels of funding required between FY2007 and FY2009 for both these methodologies is quite similar.

Figure 4.2.1.6 Maintaining Investments by Type (combination of operating and capital)



	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
Cyber		$57,000	$181,000									
Telecom		$450,000	$245,000	$150,000	$-	$-	$-	$-	$787,500	$453,250	$352,500	$-
Network	$225,000	$535,000	$505,000	$140,000	$258,750	$708,250	$718,750	$189,500	$393,750	$955,750	$1,146,250	$270,500
Storage	$644,000	$60,000	$60,000	$204,000	$575,000	$81,000	$295,800	$93,000	$875,000	$377,400	$479,400	$147,000
Servers	$419,200	$617,400	$391,200	$138,000	$482,080	$833,490	$567,240	$213,900	$733,600	$1,142,190	$919,320	$338,100
Maintaining Total (Capital)	$380,000	$860,000	$655,000	$210,000	$437,000	$553,500	$594,500	$93,000	$1,452,500	$1,211,750	$1,316,000	$147,000

4.2.2 Program Capital Equipment

Of the $89 million in total capital equipment at NREL today, EERE has purchased capital equipment for specific programs that today requires $70 million to replace; Office of Science has purchased equipment for NREL worth $6 million today (Table 4.2.2.1).

Table 4.2.2.1

NREL Program Capital Equipment Condition Assessment (09/30/06)*

	Units	EERE Program Equipment	Office of Science Program Equipment	All Program Equipment
Acquisition Cost (Full Use)	million	$52.758	$4.677	$57.435
Remaining Value Today (Full Use)	million	$13.296	$1.913	$15.209
Remaining Value (%)	%	25.2%	40.9%	26.5%
Estimated Value Today (Full Use)	million	$69.709	$6.123	$75.833
Deferred Replacement Backlog	million	$21.361	$0.604	$21.965
Deferred Backlog (%)	%	30.6%	9.9%	29.0%
Average Useful Life	yrs	10.0	9.8	10.0
Average Age	yrs	10.9	10.7	10.9

** This data includes only items originally purchased with program funds.*

NREL's portfolio of program capital equipment at the end of FY2006 had a remaining value of 26.5% of original acquisition cost for items intended to be replaced by program capital funding. However, the flat levels of funding expected in FY2007 and FY2008 result in a continuing drop in remaining value through the end of FY2008. To reach the target level of 50% remaining value requires an immediate and substantial increase in FY2009. After that time, maintaining a level of 50% remaining value will require from $9 million to $12 million per year. Figures 4.2.3.3 and 4.2.3.4 indicate the projected funding requirements and the resulting value of the equipment portfolio that achieves the 50% target. Table 4.2.3.5 describes the important characteristics for the program equipment portfolio required to meet the NREL mission and gives details of the funding required to achieve these characteristics.

4.2.3 Equipment Maintenance Contracts

Scientific research equipment today is very sophisticated and sensitive, and must be regularly monitored and adjusted to stay within the very tight specifications required for examining individual atoms, studying single protein molecules, and other experiments that stretch the boundaries of science. In contrast to previous generations of instruments, where individual scientists could more easily make adjustments and replace parts, the sophisticated nature of today's instruments precludes do-it-yourself solutions. One of the most important ongoing tasks to maintain the serviceability, availability, and tight specifications needed for today's research is maintenance contracts with the instrument manufacturer. Maintenance contracts provide the following benefits in the effort to retain the full value of scientific research and computing equipment:

- Factory-certified engineers are required to repair instruments and ensure that they remain within specifications for accurate research results.
- Maintenance contracts include preventative maintenance service calls to calibrate instruments and computing equipment and reduce the probability of unplanned downtime.
- Maintenance contracts give NREL priority status if unplanned maintenance is require, ensuring more timely repairs and less downtime.

As a vital element of maintaining equipment assets, maintenance contracts on institutional capital equipment that serves multiple programs or the entire Laboratory are proposed to be covered beginning in FY2009 by general purpose equipment operating funds. Actual costs for maintenance contracts in FY2006 were about $1,000,000. Because of rising costs of both labor and parts, and the increasing value of equipment, maintenance contracts on this equipment is estimated to rise to over $1.8 million by FY2009. Table 4.2.3.1 and Figure 4.2.3.2 indicate the funding required for maintenance contracts on institutional capital equipment expected through FY2013.

Table 4.2.3.1

Maintenance Contract Costs for Institutional Capital Equipment

	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
Renewable Fuels	$0.246	$0.346	$0.462	$0.484	$0.550	$0.629	$0.722	$0.833
Renewable Electricity	$0.427	$0.479	$0.560	$0.673	$0.765	$0.874	$1.004	$1.159
Scientific Computing	$0.076	$0.071	$0.111	$0.361	$0.611	$0.611	$0.611	$0.611
Administrative Information	$0.250	$0.267	$0.286	$0.307	$0.331	$0.356	$0.385	$0.417
Total	$0.999	$1.163	$1.419	$1.825	$2.257	$2.470	$2.722	$3.019

Figure 4.2.3.2

Maintenance Contract Costs for Institutional Capital Equipment

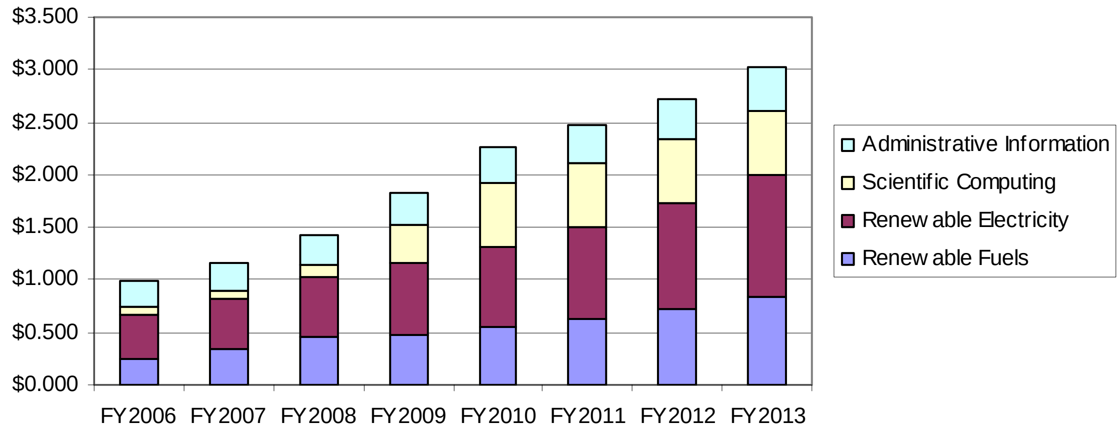


Figure 4.2.3.3 EERE Program Capital Equipment Funding Required to Meet Mission Needs and Maintain Remaining Value at 50% of Acquisition Cost

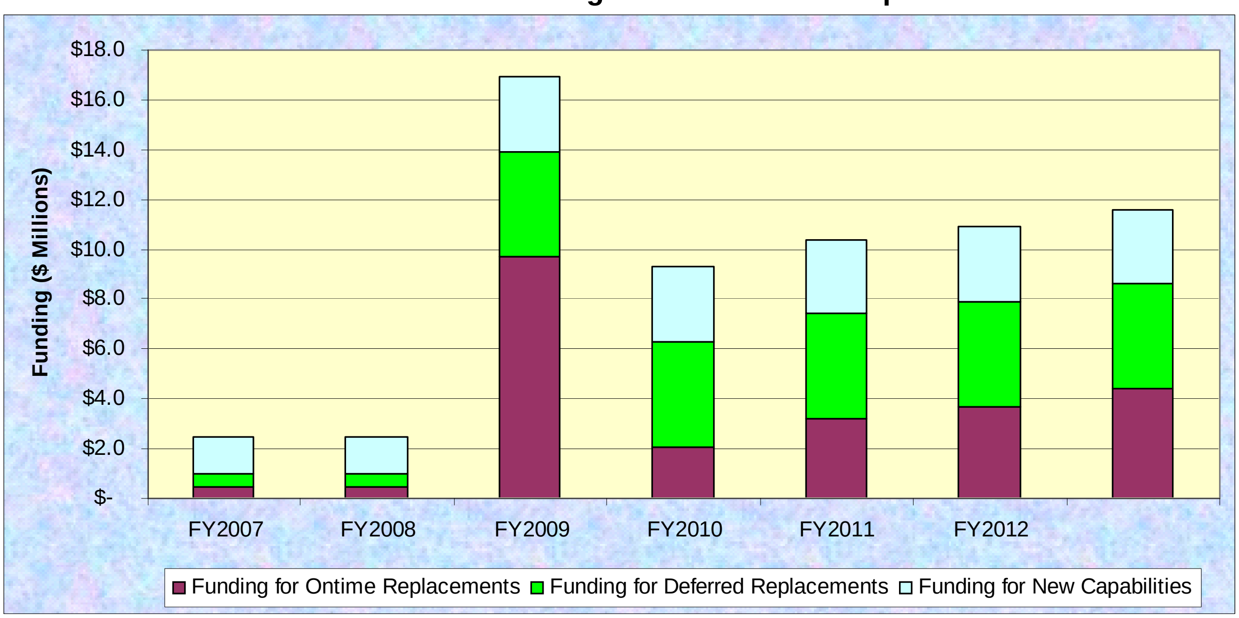


Figure 4.2.3.4 Achievement of 50% Remaining Value for EERE Program Capital Equipment with the Funding Portfolio Above

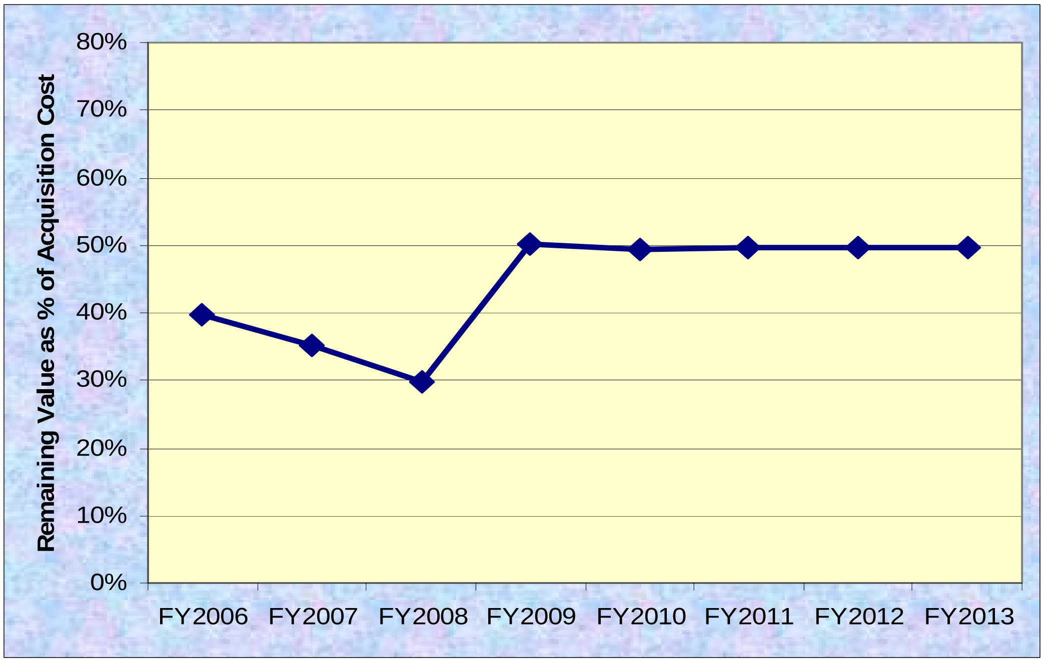


Table 4.2.3.5 Current and Required Characteristics of EERE Program Capital Equipment Portfolio and Funding Required to Achieve the 50% Remaining Value Target *(This data reflects equipment intended to be replaced with program capital equipment funds.)*

	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
Original Acquisition Cost	$ 30,018,911	$ 31,835,845	$ 33,652,779	$ 40,721,070	$ 45,847,556	$ 51,255,093	$ 56,790,380	$ 62,504,517
Accumulated Depreciation	$ 18,129,234	$ 20,635,632	$ 23,615,921	$ 20,314,617	$ 23,185,103	$ 25,778,392	$ 28,553,983	$ 31,380,893
Remaining Value	$ 11,889,677	$ 11,200,213	$ 10,036,858	$ 20,406,453	$ 22,662,453	$ 25,476,700	$ 28,236,397	$ 31,123,624
Remaining Value as % of Acquisition Cost	39.6%	35.2%	29.8%	50.1%	49.4%	49.7%	49.7%	49.8%
Replacement Equipment Value (REV)	$38,635,047	$41,294,098	$44,032,921	$48,353,909	$52,804,526	$57,388,662	$62,110,322	$66,973,632
Deferred Backlog	$19,537,600	$20,274,005	$21,010,409	$16,808,328	$12,606,246	$8,404,164	$4,202,082	$0
Deferred Backlog as % of REV	50.6%	49.1%	47.7%	34.8%	23.9%	14.6%	6.8%	0.0%
		FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
Funding Required to Work Down Deferred Replacement		$0.500	$0.500	$4.202	$4.202	$4.202	$4.202	$4.202
Funding Required for OnTime Replacements		$0.500	$0.500	$9.700	$2.100	$3.200	$3.700	$4.400
Funding Required to Add New Capabilities for Current Missions		$1.500	$1.500	$3.000	$3.000	$3.000	$3.000	$3.000
Funding Required Total		$2.500	$2.500	$16.902	$9.302	$10.402	$10.902	$11.602
Replacement Funding (Deferred and OnTime) as % of Replacement Equipment Value		2.4%	2.3%	28.8%	11.9%	12.9%	12.7%	12.8%

** This data reflects equipment that is intended to be replaced with program capital equipment funds.*

Capital equipment for specific programs is further discussed in Section 5 under the individual programs within EERE.

5.0 Program Summaries

5.1 NREL Capital Investment Strategy – Solar Technologies

Strategic Goals
DOE:
Strengthen America's energy security by developing technologies that foster a diverse supply of reliable, affordable, and environmentally sound energy by providing for reliable delivery of energy, guarding against energy emergencies, exploring advanced technologies that make a fundamental improvement in our mix of energy options, and improving energy efficiency.

EERE:
- Increase the viability and deployment of renewable energy technologies
- Increase the reliability and efficiency of electricity generation, delivery, and use

Program:
- Accelerate the development of advanced photovoltaic, solar-thermal electric, solar-heating, and solar lighting technology devices/components leading to integrated systems that are economically competitive, reliable, and adopted by industry.
- Utilize and operate laboratory and engineering facilities in partnership with universities and industry in order to provide viable technology paths that bridge the gaps between the laboratory technologies (research) and the market places.
- Provide world-class R&D facilities and capabilities that will attract highly expert staff and industry/university partners; and, that will maintain and grow NREL's leadership roles in the DOE Solar Energy Technologies Program.

Current Activities at NREL

Solar FY06 Financials and FTEs		
FY06 Budg Auth - Operating	$52.9	million
FY06 Budg Auth - Capital Equipment	$2.0	million
FY06 Inhouse Costs	$36.2	million
FY06 Average FTEs	119	FTEs

Planned R&D Activities

- Research on photovoltaic (PV) materials and devices (cells and modules).
- Research on solar thermal materials for converting solar radiation to heat.
- Research on thin-film, highly solar-reflective, materials for producing inexpensive solar mirrors.
- Research on materials suitable for encapsulating photovoltaic and/or solar thermal conversion devices.
- Technology R&D, in partnership with universities and industry partners, to develop advanced solar energy system components: such as; PV modules, solar thermal reflective mirrors and collectors, and solar hot water heating collectors.
- Manufacturing R&D to develop improved and integrated manufacturing processes and equipment.
- Outdoor and accelerated engineering performance and reliability testing on PV and solar thermal systems and components.

Facility Issues and Opportunities

- The Solar Energy Research Facility is the primary research facility for photovoltaic materials research, including deposition systems and measurements and characterization of materials and devices. It provides lab space and office/support space for researchers.
- The Science & Technology Facility is the primary research facility for process and manufacturing research for solar modules, and other thin-film and nano-scale materials related to fuel cells, hydrogen storage applications, electrochromic coatings, and optoelectronic applications.
- The Joyce St Warehouse is used for storage of equipment and specialized assembly of components and small systems.
- The Field Test Laboratory Building includes solar thermal materials research and durability testing (e.g. environmental chambers).
- The Outdoor Test Facility is used for indoor accelerated and standardized testing of PV modules and outdoor performance and reliability testing of PV modules and small systems.
- Bldg 16 is used for more short-term, specialized, and exploratory materials research.
- Mesa Top facilities are used for outdoor testing and characterization of solar concentrator collectors and systems, and solar radiation measurements.

Larger Module R&D

The Outdoor Test Facility currently houses all of NREL's module measurement test beds, environmental test chambers, data acquisition labs, module performance and reliability measurement equipment, and electronics labs in support of the module measurements. These are highly interactive activities that share many common resources as well as modules received by industry. The modules are constructed of tempered glass and can be quite large in size (8-20 square feet). The current trend in PV is to move to larger modules for building integrated PV applications. In order to maintain the measurement capabilities required by DOE and industry, larger test beds are necessary from program capital equipment, and a larger facility is needed to accommodate them. NREL is in process (December 2006) on a general plant project to expand the Outdoor Test Facility.

Facility Recommendations

Energy Systems Integration Facility

The Solar Program will benefit from the interconnection improvements that this new capability will support, both for grid and distributed applications. The Solar Program will also benefit from expanded modeling and simulation capabilities to support deployment, based on R&D intended for this facility.

Biological and Chemical Research Facility

The solar Program will benefit from additional laboratory space to pursue the development of materials and fundamental che3mistry and physics underlying future-generation (e.g. organic PV cells) solar technologies.

Equipment Issues and Opportunities

Solar Capital Equipment Status (09/30/06)		
Estimated Cost Today (Full Use)	$28.8	million
Deferred Replacement Backlog	$17.2	million
Deferred Backlog (%)	59.6%	%
Average Useful Life	10.0	yrs
Average Age	13.3	yrs

As can be seen from the table above, the average age of Solar capital equipment is far older at thirteen years than its average useful life of 10 years. More than $17 million worth of Solar equipment today is older than its useful life. This is the most difficult challenge of any program at NREL.

The success of the Solar Program relies on (i) state-of-the-art measurement and characterization laboratories that directly assist these industry, university, and laboratory partners in the critical evaluation of their products; and (ii) materials and device research facilities that provide both fundamental and applied research support for the Solar Program. The Program is in danger of losing its key leadership and a critical technical resource that has been more than 25 years in the making.

The capital equipment investments in the PV Program have declined to insignificant levels since 1994, and these levels have only allowed for the replacement of a few critical components. Maintenance and service costs have also escalated on existing major equipment due to age. In fact, several major systems are in jeopardy of becoming decommissioned because critical components are unavailable.

NREL's laboratories are the DOE leads for standards, measurements, and tests with the world photovoltaics community. But it is difficult to maintain technological and scientific leadership as investments in required capital equipment steadily erode. It has not been possible to invest in many newly available techniques and processes that have been developed since the last major capital equipment infusion in 1992. Much of the equipment is one or more generations removed from the state-of-the-art.

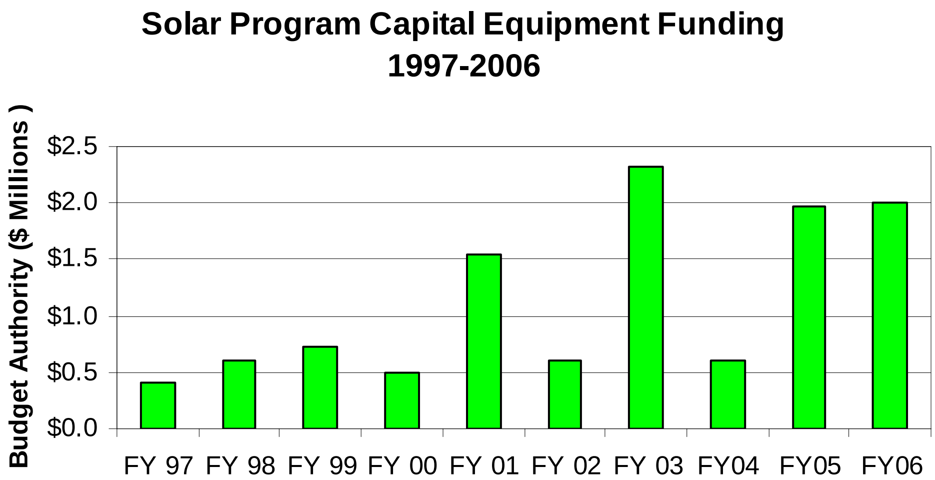
In the current world context, these centralized activities are key to maintaining the strategic and competitive edge for the U.S. PV industry over the growing foreign competition, including laboratories in Europe and Asia that have established facilities analogous to the DOE/NREL operations to assist their own industries and economies. To ensure the U.S. advantage *in* photovoltaics technology, it is critical to maintain support facilities, providing state-of-the-art equipment that can meet the growing needs of the U.S. Program toward meeting the performance and reliability goals of the U.S. PV Industry 20-Year Roadmap and the DOE EERE Multi-Year Technical Plan.

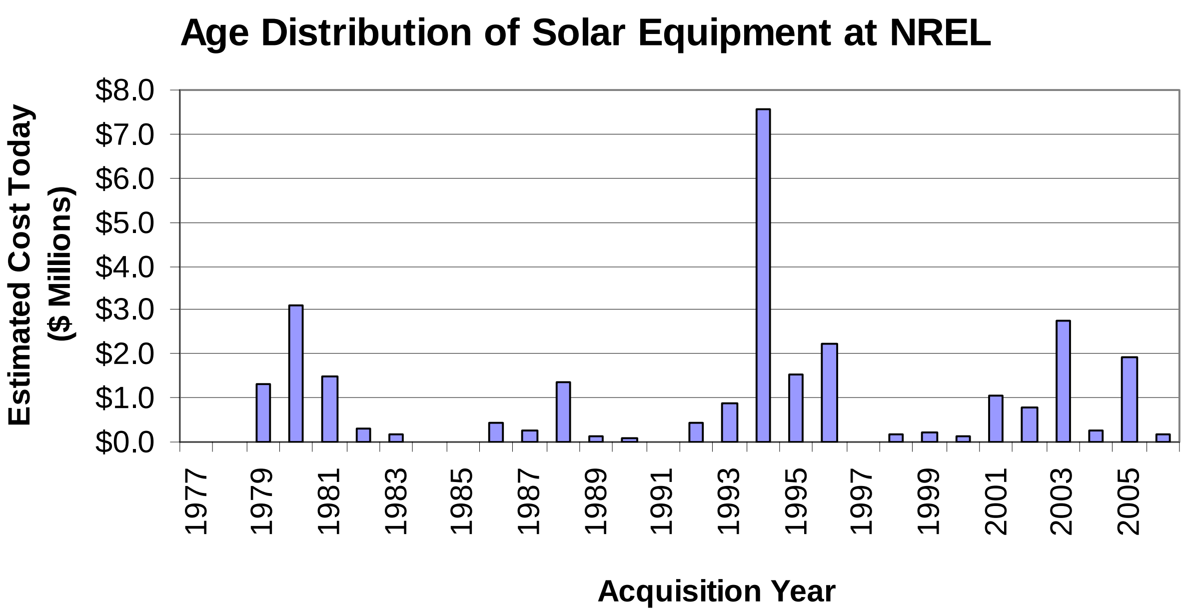
The strategy for the period of 2007-2013 is to:

1. Replace and upgrade seriously deficient and aging equipment that is several generations old and/or has become "cost ineffective" based on maintenance considerations
2. Provide new equipment that provides capabilities introduced in the past 10 years that are essential to the competitiveness of the U.S. PV Program
3. Provide the capital equipment necessary to fully outfit the Science and Technology Facility (S&TF) so that we can meet our goal of reducing the time it takes to move a technology from the lab to the marketplace.

Each of these approaches is critical to meeting the EERE key strategic goals of reducing the cost of PV and CSP electricity to competitive levels, by 2020. This plan follows the last major capital equipment investment by some 10 years, about 4-6 years beyond the expected lifetime of the majority of techniques. Continued neglect will jeopardize the U.S. PV leadership and its existing investment in its resources.

A significant investment in NREL's Computational Sciences expertise and high performance computing capabilities would benefit the Solar Energy Technologies Program. There is a general need for increased computational modeling, simulation and data handling of materials, devices and processes used in photovoltaics and solid state lighting. Specific examples include the quantum mechanical simulations of solid state and organic materials, fluid dynamics simulation of metal-organic vapor phase epitaxy reactors, and mining of experimental data for hidden correlations to improve stability of Cadmium Telluride high performance solar cells.





5.2 NREL Capital Investment Strategy – Biomass

Introduction

NREL's primary mission in the biomass area is to support the Office of Biomass Program (OBP) in achieving its objective of developing and deploying biofuels technology. Liquid transportation fuels produced from biomass have significant near- and long-term potential for major impact on the nations transportation fuel supply and hence imported oil displacement. A recent report shows that over 1.3 billion tons of biomass could be produced near-term annually in the U.S. on a sustainable basis mostly from agriculture and forestry sources using predominantly existing practices and approaches while meeting the nations' current feed, food and fiber needs. Building upon this study which shows that an adequate feedstock resource exists, a goal of 30 x 30 (supplying 30% of 2004 motor gasoline demand with ethanol by 2030) was set. Achieving the 30 x 30 goal will require completing two critical R&D goals at NREL; demonstrating at the NREL pilot plant scale both biochemical and thermochemical production of cellulosic ethanol at a cost of $1.07/gallon plus a long-term advanced state of technology target.

To achieve its objectives, DOE's Office of the Biomass Program (OBP) is sponsoring R&D at the national laboratories led by NREL to accomplish the technology cost targets and with industry to begin the deployment process. Together these two activities will enable OBP to accomplish the 30 x 30 objective.

Biomass FY2007 Financials and FTEs	
FY2007 Budg Auth - Operating	$30MM
FY2007 Budg Auth. – Capital Equip	$4MM
FY2007 Inhouse Costs	$26MM
FY2007 Average FTEs	68

Strategic Goals

NREL's key role in supporting OBP is to conduct the core research to develop and demonstrate core biochemical and thermochemical conversion processes of biomass to biofuels to the point that the $1.07 production cost technical targets can be demonstrated at the NREL PDU scale by 2012. NREL's work on bioconversion and thermochemical conversion technologies is aimed at resolving the underlying science and technology issues that stand as barriers towards achieving this cost target by 2012. Beyond 2012 NREL will focus on advanced state of technology targets which will further improve yields and economics to enable the long-term 30 x 30 goal.

Bioconversion (BC). Using a combination of fundamental, computational and applied experimental techniques, NREL is conducting bioconversion research to overcome the technical and economic barriers towards large-scale deployment of this technology. Research to overcome these barriers will be focused in the following major areas:

- **Pretreatment and Enzymatic Hydrolysis -** A major cost and technical barrier to the bioconversion of biomass to fuels is efficient and cost effective conversion of biomass to its component hexose and pentose sugars. A number of promising different pretreatment technologies have emerged and great strides have been made in reducing costs of cellulose enzymes. However, increased monomeric sugar yields with minimal degradation at a specified cost target are still a barrier to commercial deployment of biomass bioconversion technology.

- **Integration of all of the Bioconversion Processes** – Although great strides have been made in developing and demonstrating the unit processes in bioconversion of biomass to fuels. The effective integration of these unit processes into an efficient holistic process is necessary to demonstrate overall process performance and will identify cost barriers associated with biological conversion of biomass to biofuels.
- **Overcoming the Fundamental Recalcitrance of Biomass –** Sugars in biomass are commonly referred to as structural sugars which means they make up the polysaccharides, the plant cell wall of the biomass. Hence, by their inherent nature they are resistant or "recalcitrant" to breakdown to their simple monomeric C5 and C6 sugars. Detailed understanding of the physical and chemical characterization of the biomass is critical to developing processes that can break down biomass to its monomeric sugars quickly, inexpensively and with minimal degradation of the sugars.
- **Fundamental Barriers to Efficient Hexose/Pentose Fermenting Organisms -** An efficient organism that co-ferments all biomass sugars remains as a major barrier to the economical production of ethanol from biomass. Although considerable progress has been made in this area, cell wall transport and efficient metabolic pathway development remain as fundamental barriers to the development of an efficient organism.

Thermoconversion (TC). Using a combination of fundamental, computational and applied experimental techniques, NREL is conducting thermal conversion research to overcome the technical and economic barriers towards large-scale deployment of this technology. Research to overcome these barriers will be focused in the following major areas:

- **Integration of TC/BC into the integrated biorefinery concept** - Maximizing value and fuel/energy production per ton of biomass is absolutely necessary for the economic viability of the Integrated Biorefinery. The integrated biorefinery concept is based on bioconversion of the carbohydrate portion of the biomass and thermochemical conversion of the lignin and off-spec portion. Methods for in-plant process stream transfer and the efficient integration of the bioconversion and thermoconversion aspects of the integrated biorefinery need to be developed.
- **Catalyst fundamentals for Tar Reforming in Syngas –** An undesirable side effect of biomass gasification is the unwanted formation of higher molecular weight compounds (tars). These tars lead to a multitude of problems in downstream synthesis processes for converting the syngas to biofuels. Research at NREL has shown that catalytic reforming of these tars to syngas is a cost effective method for removing the tars while recovering the energy value of these tars. Considerable progress has been made in developing an effective reforming catalyst however, developing and demonstrating a catalyst that is effective in reforming the spectrum of tars that can be made fluidizable remains as a barrier to be addressed.
- **Syngas Conversion Issues for Biofuels Production –** A very attractive feature of syngas synthesis to liquid fuels is the multitude of fuels that can be produced (DME, Mixed Alcohols and possibly others) with relatively straight forward changes in catalysts. This would afford the integrated biorefinery flexibility by having the ability to produce a multitude of products in response to changing market conditions. However current generation synthesis catalysts suffer form low selectivity, low single pass efficiency and deactivation problems. Development and demonstration of synthesis catalysts that can overcome these limitations would greatly improve the economic viability of the integrated biorefinery. In the near-term the focus will be on mixed alcohol synthesis catalysts.
- **Pyrolysis of Biomass for Processing in Oil Refinery** – If biomass pyrolysis oil or biocrude could be developed to a form that could be fed directly to an existing oil refinery the

existing oil refining and distribution infrastructure could be leveraged to rapidly bring biofuels into the market place and displace imported oil. Biomass pyrolysis is the thermal depolymerization of the original macro polymers: cellulose, hemicellulose, and lignin. Bond cleavage during biomass pyrolysis yields molecular fragments that when condensed, result in a highly oxygenated bio-oil based on the high oxygen content of the original biomass feedstock. The chemical and physical properties of crude bio-oil limit the application of this material as a transportation fuel or a useful intermediate. The high oxygen content and low pH of bio-oils limit their long-term storability because polymerization reactions catalyzed by suspended char particles, increase bio-oil viscosity over time. The poor chemical selectivity of biomass pyrolysis, coupled with the low pH and poor long-term stability of crude bio-oils suggest that chemical or catalytic modification is a logical strategy to improve properties of bio-oil for use an intermediate to be fed directly to an existing oil refinery for conversion to biofuels.

Although this area shows significant near-term and long-term potential, current funding limitations and priorities do not allow for work in this area. Work will only be started in this promising area if OBP deems it warranted.

Facility Issues and Opportunities

Current Facilities

Biomass research is accomplished in two primary research facilities at NREL. The Field Test Laboratory Building, currently devoted 65% to Biomass research, provides chemistry and biology laboratories and offices for researchers and program management staff. Some of the key Biomass Program facilities housed in the FTLB include a Nuclear Magnetic Resonance Facility, a Biomass Surface Characterization Facility, and a Genomics Laboratory. The FTLB also houses the 6,000-sf Thermochemical Process Development Unit (TCPDU). The Alternative Fuels User Facility (AFUF) is used exclusively by the Biomass program, providing chemistry and biology laboratories, the 6,800-sf Biochemical Process Development Unit (BCPDU), and offices for researchers and analysts.

New Facilities

The proposed **Integrated Biorefinery Research Facility (IBRF)** project would expand NREL's existing biochemical facility to result in additional and reconfigured space, including high-bay space for process research, laboratories for analysis, storage space for biomass feedstocks, and a small amount of office support space. Expanded pilot plant facilities are required to achieve OBP's 2012 ethanol cost target as well as the long term 30x30 goal. Specifically, new process equipment will be added to support OBP's near- and long-term objectives and provide industry with pilot scale capabilities for testing specific unit operations or complete integrated processes. Assuming FY2008 funding, the total project cost (conceptual design, design/build, essential capital equipment, and equipment relocation) would be $19.5 million. With a design/build approach to project design and construction, and expedient approvals through the DOE construction management process, this expansion should be essentially complete by the fourth quarter FY2009.

As an alternative to the IBRF, the existing office and laboratory space in the north wing of the AFUF could be converted into high bay space. This concept would extend the current high bay floor area by an additional 75 ft toward the east end of the existing building adding 50% more high bay floor space. This new area would support additional pilot scale equipment that would be necessary to meet OBP's objectives. This conversion could potentially be completed by the fourth quarter FY2008 allowing us to accelerate plans for pilot scale testing.

An upgraded Thermochemical Users Facility is proposed that will improve versatility and permit experimental testing of thermochemical conversion process alternatives on an integrated basis. The major features of these upgrades will include a) the addition of a small scale, 1-2 kg/hr gasification/pyrolysis pilot plant and associated analytical equipment, b) structural modifications to the floor of the high-bay to permit construction/use of refractory-lined reactors and vessels, c) design, construction, and installation of a gasification/pyrolysis reactor that uses process char as the primary heating source and back-up electrical heating to permit pseudo-adiabatic operation, d) reconfiguration of the TCPDU to optimize both gasification and pyrolysis operations, including addition of a permanent hot-gas filter for pyrolysis experiments, e) addition of a multi-stage quench system using a high-temperature organic quench, followed by a water quench, f) modification of the tar reformer for continuous catalyst regeneration, g) addition of a skid-mounted gas cleanup module for removal of contaminants, e.g. H2S and COS, and adjustment of syngas composition, e.g. shift reactors, and h) addition of an internal (building use code considerations) or external high pressure bay (trailer mounted or located in external flammable materials storage area) to permit high-pressure fuels synthesis experiments using the full output of the TCPDU.

This upgrade will allow OBP to accelerate the timeline for thermochemical technology development and commercialization in support of the goals of 30 x 30 by having a versatile experimental facility where integrated thermochemical conversion-fuels production can be tested using real feeds and using all unit operations necessary for production of transportation fuels at a scale that can generate the engineering data needed for demonstration and pioneer plants.

The proposed **Energy Systems Integration Facility** would provide the required research space dedicated to the design and testing of renewable electricity and hydrogen systems, and fully integrated energy systems. This facility supports long term efforts to produce hydrogen from biomass.

The **Biological and Chemical Research Facility** is proposed for funding totaling $135 million, beginning in FY2009. This state-of-the-art laboratory building will provide space that will benefit Biomass, Hydrogen, and Office of Science; initially it will also benefit the Solar program. This new facility will provide biology and chemistry laboratories for all areas of basic research supporting Biomass and Hydrogen, including structural biology, genomics, enzymes and biological catalysts, biological materials, separations and membranes, bio-nanoscale materials, and biomimetic energy conversion processes, supporting the future development of all types of bio-based and hydrogen fuels. These activities will be moved out of the Field Test Laboratory Building, freeing up space for the expansion of related applied research in mid-scale bioprocess and hydrogen development. Expanding our capability to understand and modify enzymatic and microbial systems is required to accelerate effort to develop cost effective biocatalyst required for efficient conversion of biomass to fuels and chemicals.

The Biological and Chemical Research Facility will also provide dedicated space for NREL's scientific computing capabilities and will further enhance our abilities to develop effective biocatalyst for biomass conversion. Computer modeling and simulation is firmly established as an equal and indispensable partner, along with theory and experiment, in the advance of scientific knowledge and engineering practice. In fact, numerical simulation is the only viable way to advance knowledge and understanding in many areas of scientific and engineering pursuit. For example, the design of practical and efficient catalysts for biomass conversion requires the ability to predict, at the molecular level, the detailed behavior of the large, complex molecules and materials involved in catalytic processes. Since even the most sophisticated experimental techniques are unable to provide the details of the structures, processes, and chemical reactions occurring at the surface of a catalyst, the required understanding is only possible by taking advantage of high performance computational hardware and software.

The **Renewable Fuels & Vehicle Systems Facility** will provide testing of alternative and renewable fuels for today's transportation vehicles. This activity will allow testing of ethanol and other fuels derived from biomass feedstocks.

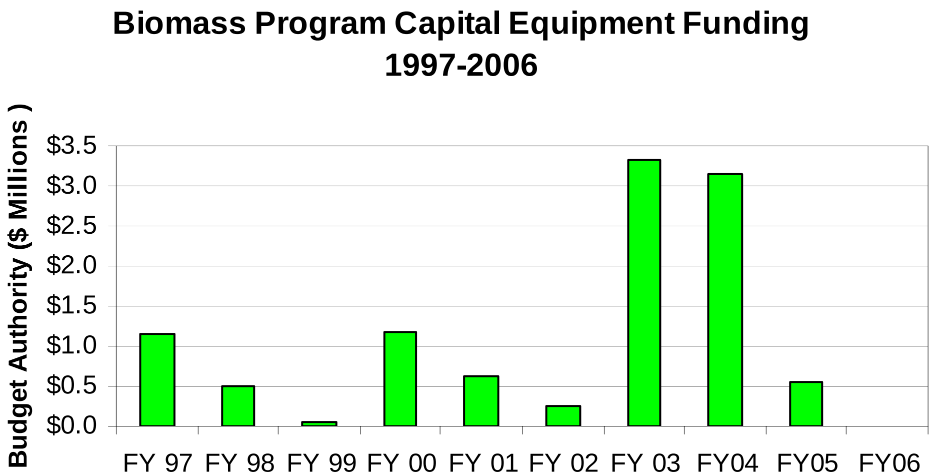
Equipment Issues and Opportunities

Biomass Capital Equipment Status (09/30/06)		
Estimated Cost Today (Full Use)	$23.2	million
Deferred Replacement Backlog	$2.7	million
Deferred Backlog (%)	11.8%	%
Average Useful Life	10.0	yrs
Average Age	9.2	yrs

Investment in new capital equipment is required to build new capabilities in the areas of biochemical and thermochemical conversion, our two areas of core competency for OBP. We believe that focus on these two areas provides the best opportunity to remove the key technical barriers identified by DOE and its industry partners. The Biomass Program's goal to demonstrate $1.07 ethanol cost at the pilot scale by 2012 will require new process equipment with the capability of testing the newest and most advance process concepts having potential to reduce production cost. Much of this new equipment will be installed in the expanded BC and TC pilot plants.

Also, many of analytical instruments required for accurate measurements must be regular replaced or upgraded to maintain high quality standards. We intend to purchase new analytical instruments to replace aging equipment, such as, High Performance Liquid Chromatographic systems, with either new instruments or more advanced and improved instruments that provide high quality measurements and/or more rapid measurement for both BC and TC platforms. Accurate measurements are key to providing high quality data and results to industry, which is required to validate process performance parameters such as conversion yields.

Finally, advanced computer systems, imaging tools, and genomic and proteomic tools and instruments are required to advance biocatalyst development efforts. Ultimately, these instruments provide the tools necessary to develop cost effective enzymatic and microbial catalytic systems necessary to achieve our ethanol cost target.


Biomass Program Capital Equipment Funding
1997-2006
Budget Authority ($ Millions)
$3.5
$3.0
$2.5
$2.0
$1.5
$1.0
$0.5
$0.0
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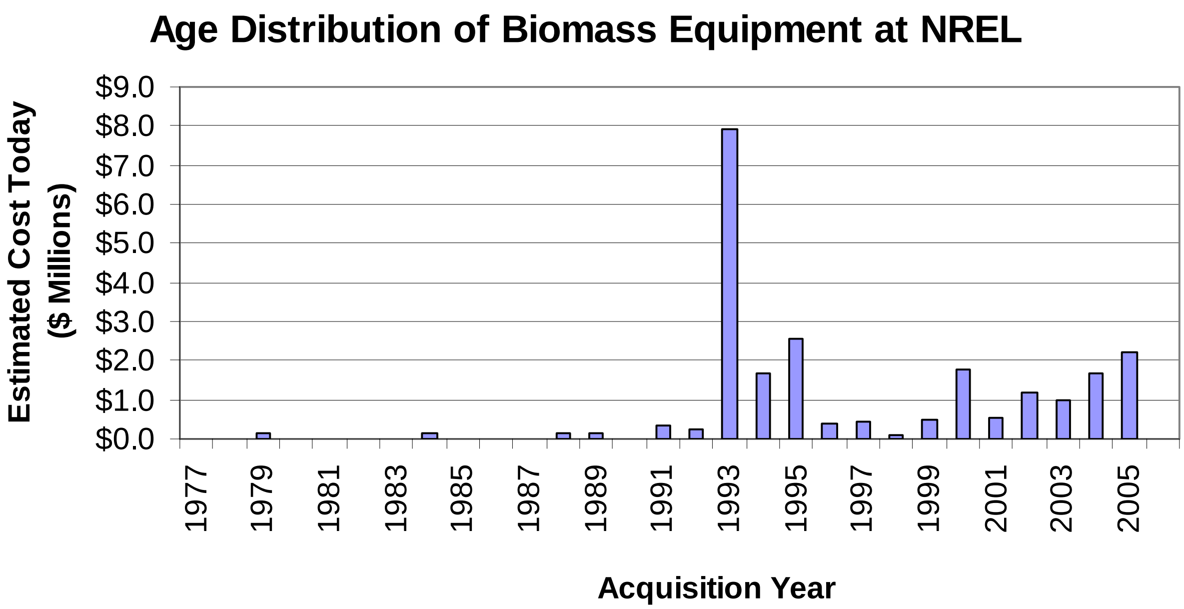
Age Distribution of Biomass Equipment at NREL
Estimated Cost Today ($ Millions)
$9.0
$8.0
$7.0
$6.0
$5.0
$4.0
$3.0
$2.0
$1.0
$0.0
1977
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Acquisition Year

5.3 NREL Capital Investment Strategy – Wind Program

Strategic Goals

- By 2007, reduce the cost of electricity from distributed wind systems to 10-15 cents/kWh in 2007 in Class 3 wind resources (from a baseline of 17-22 cents/kWh in 2002).
- By 2012, reduce the cost of electricity from large wind systems in Class 4 winds to 3 cents/kWh for onshore systems (from a baseline of 5.5 cents/kWh in 2002).
- By 2010, facilitate the installation of at least 100 MW of wind energy in 30 states (from a baseline of 8 states in 2002).
- By 2012, complete program activities addressing electric power market rules, interconnection impacts, operating strategies, and system planning needed for wind energy to compete without disadvantage to serve the Nation's energy needs.

Current Activities at NREL

Wind FY06 Financials and FTEs		
FY06 Budg Auth - Operating	$19.6	million
FY06 Budg Auth - Capital Equipment	$0.3	million
FY06 Inhouse Costs	$14.1	million
FY06 Average FTEs	43	FTEs

Wind energy will become a major source of energy for the Nation, which has only begun to tap its vast wind resources. Although wind energy accounts for less than 1% of the electricity generated in the United States today, the American Wind Energy Association (AWEA) believes that producing 20 percent of the nation's electricity from wind by 2030, increasing wind capacity from 10.5 Gigawatts (GW) in operation today to about 350 GW, is feasible and affordable. As the DOE Wind Program looks to the future of wind technology, it appears that large-scale technology will take multiple development paths (e.g.: land-based, emerging applications, etc.). Each of these paths will present a set of technology challenges and unique non-technology barriers. All will emanate from current technology, which is oriented toward producing bulk power from land-based wind farms. Outside of the use of large, bulk power generation facilities, distributed wind technologies have been a focus of the program since its inception and show great potential for engaging local populations in addressing America's energy future.

Within all of the different paths for both bulk and distributed power, the program continues to address issues of technology acceptance, primarily through Wind Grid Integration and Technology Acceptance and Coordination activities. Each of the different technology pathways will require the program to address specific acceptance barriers as is currently the case with the land-based bulk and distributed wind technology. The outreach and applications based research activities will allow the program to continue to coordinate the technical and acceptance activities as each of the new pathways are further developed.

Planned R&D Activities

The Wind Program's mission is to "support the President's National Energy Policy and Departmental priorities for increasing the viability and deployment of renewable energy; lead the Nation's efforts to improve wind energy technology through public/private partnerships that enhance domestic economic benefit from wind power development; and coordinate with stakeholders on activities that address barriers to use of wind energy."

The Wind Energy Program research portfolio includes both near-term and long-term focused research to balance the need to work with industry to solve pressing short-term technical issues and the need to maintain U.S. industry momentum as a technological innovator.

DOE's efforts to achieve the mission was focused by The Energy Policy Act of 2005, which directs that "The Secretary shall conduct a program of research, development, demonstration, and commercial application for wind energy, including: low speed wind energy; testing and verification (including construction and operation of a research and testing facility capable of testing wind turbines); and distributed wind energy generation." This was again enhanced in the President's 2006 Advanced Energy Initiative which stated "Areas with good wind resource have the potential to supply up to 20% of the electricity consumption of the United States."

Facility Issues and Opportunities

- All research for the Wind Program at NREL is conducted at the National Wind Technology Center (located about 20 miles north of the main NREL South Table Mountain Site). The 305-acre NWTC is comprised of over 30 facilities (e.g. test laboratories, field test sites, and buildings including the 50m blade test stand at the Industrial User Facility and 2.5 MW Dynamometer Test Facility), and over 150 associated components (e.g. industry prototype turbines, research turbines, meteorological towers, test buildings, supporting equipment).
- The main NWTC building (building 251) houses offices for program administration and staff, and computer labs for wind turbine systems electrical and mechanical dynamics modeling, computer code development and wind turbine control system development. Building 251 also contains a small dynamometer facility (drive trains up to100 kW), a small blade test bay (blades up to 19m), and a machine shop.
- The Industrial User Facility (also known as the Blade Test Facility) has been primarily used by DOE Wind Program subcontractors and wind industry partners for full-scale testing of wind turbine blades up to 50 meters in length. The IUF is the only such wind turbine blade structural testing facility in the US. DOE was not able to accommodate a FY04 Wind Program request for a larger blade test facility (up to 70m) at the NWTC. NREL therefore stretched blade test capability in FY05 with a temporary outdoor blade test stand to allow limited testing of blades up to 50m in length and provide the Wind Program with a stop-gap means of meeting critical near-term goals and milestones. The Wind Program is now pursuing a plan to form a collaborative partnership with industry and state entities to fund a larger blade test facility. This facility will likely be built in a location that facilitates ocean shipping of anticipated larger-scale turbines and components needed to meet Program goals.
- The NWTC 2.5 MW Dynamometer Facility was completed in FY99 and is a dedicated test bed for wind turbine drive trains, drive train components, and power systems. Dynamometer testing services are provided at the request of industry partners, and are an integral part of Wind Program phased technology development activities. Tests are conducted to validate new prototype designs, qualify commercial components before they are deployed, or investigate field problems under controlled conditions. The latest MW-scale wind turbine designs have outgrown the capability of the Dynamometer Test Facility. The existing dynamometer cannot adequately endurance test drive trains larger than 1.5 MW because higher-than-rated levels of torque are needed for endurance testing and accelerating fatigue failures. The NWTC is exploring various possible means of extending the capabilities of the current facility to meet the immediate needs of Program goals and industry partners. The Wind Program is also planning a longer-term effort to pursue funding to build a larger dynamometer test facility at the NWTC, or fund it via a collaborative partnership with industry and state entities.

Facility Recommendations

Upgrades to IUF to Support 50-Meter Testing

In FY05, a large concrete structure was built outside the perimeter of the existing 32-meter blade test facility at the NWTC as a test stand for 50-meter blades. The stand has two faces – one for fatigue testing, and one for static testing. Blades attached to the fatigue face extend into the interior of the existing IUF and utilize NREL's existing patented Blade Resonant Excitation test apparatus. Further IUF upgrades and additional equipment are needed to expand capabilities to provide critical ultimate strength and edgewise fatigue testing for blades up to 50m. Planned upgrades include extending the IUF structure to shelter the 50m stand, extending the IUF gantry crane to service the 50m stand, expanding the interior area of the IUF to enable edgewise fatigue testing, and adding buildings to house equipment and provide moveable shelter needed for outdoor static testing.

Stretch NWTC Dynamometer Test Facility

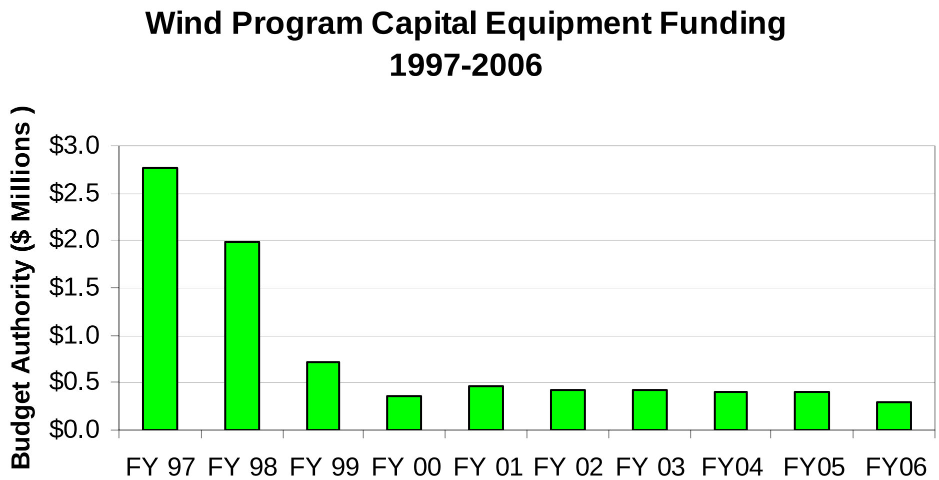
NREL is exploring options for stretching the existing NWTC dynamometer test capabilities to 4 MW or more. The most promising strategy is to add another generator in-line with the existing dynamometer to augment torque. The Program is evaluating motor drive configurations that may be suitable to consider for torque augmentation. Associated required activities include electrical switchgear upgrades, expanded control capabilities, and a larger test stand foundation. Industry partners are also requesting NREL provide the ability to simultaneously apply radial and axial loads to the low-speed shaft of test articles (to simulate gravity and turbulence-induced loads imparted into the drive train from the rotor). Wind Program staff are planning to design and incorporate hydraulically-driven load frames to the existing facility.

Equipment Issues

Wind Capital Equipment Status (09/30/06)		
Estimated Cost Today (Full Use)	$13.6	million
Deferred Replacement Backlog	$0.6	million
Deferred Backlog (%)	4.1%	%
Average Useful Life	10.8	yrs
Average Age	9.6	yrs

As mentioned above, in addition to the IUF and Dynamometer facilities, there are many other Program capital items, equipment items, and test articles at the NWTC. This includes two 600 kW wind turbines custom-configured for controls research; industry prototype turbines undergoing field testing, and large components undergoing structural and dynamometer testing. Equipment needed to support NWTC test activities include aerial work platforms, boom trucks, forklifts, and other apparatus for moving and positioning large wind components. There are also items needed for accredited measurement and testing such as instrumentation, data acquisition systems, sensors, transducers and associated computer equipment.

The equipment needs to be maintained, repaired, upgraded and sometimes replaced by larger capacity equipment as the wind industry grows, producing the evolution of new R&D challenges and its associated technical issues (much larger drive trains and blades, low wind speed development, hydrogen production, etc.) These are documented in multi-year program plans.


Wind Program Capital Equipment Funding
1997-2006
Budget Authority ($ Millions)
$3.0
$2.5
$2.0
$1.5
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FY 97
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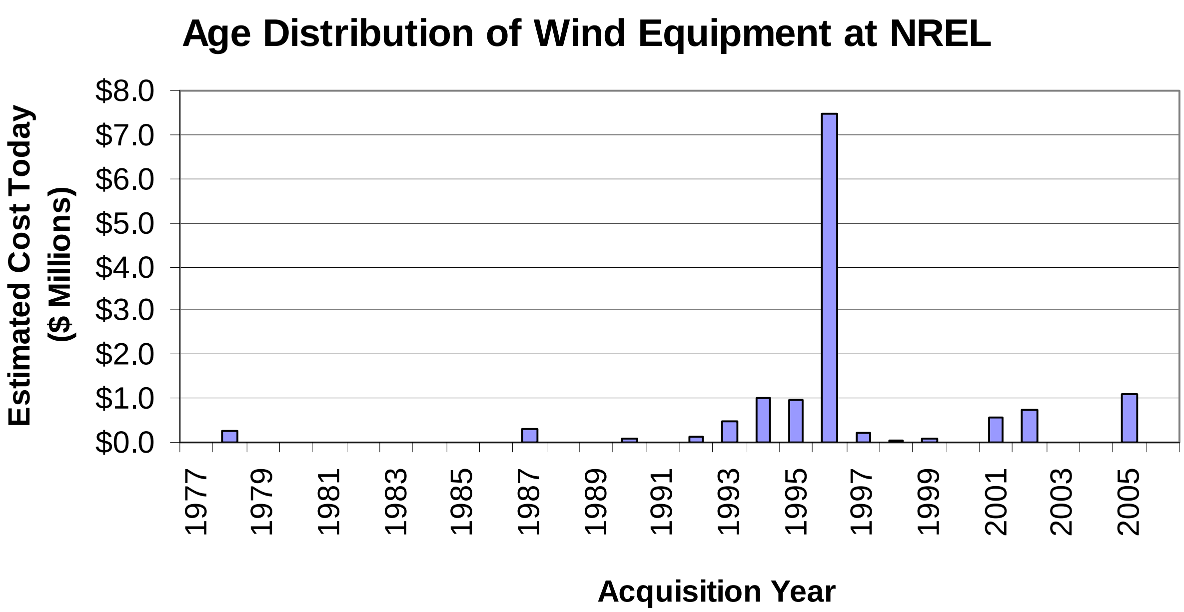
Age Distribution of Wind Equipment at NREL
Estimated Cost Today ($ Millions)
$8.0
$7.0
$6.0
$5.0
$4.0
$3.0
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$1.0
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5.4 NREL Capital Investment Strategy – Hydrogen

Strategic Goals

EERE Goals:

- Dramatically reduce dependence on foreign oil
- Promote the use of diverse, domestic, and sustainable energy resources
- Reduce carbon emissions from energy production and consumption
- Increase the reliability and efficiency of electricity generation

The mission of DOE's and NREL's Hydrogen, Fuel Cells & Infrastructure Technologies Programs is to research, develop and validate fuel cells and hydrogen production, delivery, and storage technologies for transportation and stationary applications.

Current Activities at NREL

Hydrogen FY06 Financials and FTEs		
FY06 Budg Auth - Operating	$10.9	million
FY06 Budg Auth - Capital Equipment	$0.0	million
FY06 Inhouse Costs	$7.8	million
FY06 Average FTEs	29	FTEs

- Partnerships with industry, universities, and other national laboratories
- Hydrogen production from renewable energy: electrolysis, photoelectrochemical and photobiological systems, fermentation, solar-driven high temperature chemical reaction cycles and thermochemical conversion of biomass.
- Hydrogen delivery analysis
- Hydrogen storage on nano-structured, carbon-containing materials
- Fuel cell research in components
- Technology evaluation and validation for DOE's controlled hydrogen fleet and infrastructure demonstration and for fuel cell buses
- Codes and Standards development and underlying R&D
- Analysis of resources, hydrogen systems, and scenarios for implementing hydrogen
- Information development about fuel cell and hydrogen systems

Planned R&D Activities

- *Production* – Research and develop low-cost, highly efficient hydrogen production technologies from diverse, domestic, renewable sources of energy.
- *Delivery* – Develop hydrogen fuel delivery technologies that enable the introduction and long-term viability of hydrogen as an energy carrier for transportation and stationary power.
- *Storage* – Develop and demonstrate viable hydrogen storage technologies for transportation and stationary applications.
- *Fuel Cells* – Develop and demonstrate fuel cell power system technologies for transportation and stationary applications.
- *Technology Validation* – Validate integrated hydrogen and fuel cell technologies for transportation, infrastructure, and electric generation in a systems context under real-world operating conditions.
- *Hydrogen Safety* – Develop and implement the practices and procedures that will ensure safety in the operation, handling, and use of hydrogen and hydrogen systems.
- *Cross-Cutting Analysis* – Provide analysis of energy and cost elements of hydrogen electric systems.

- *Manufacturing R&D and*– Conduct R&D on manufacturing processes and underlying crosscutting issues to support industry's establishment of a domestic manufacturing base for components and systems in fuel cells, onboard hydrogen storage, and distributed production of hydrogen.

Facility Issues and Opportunities

- Hydrogen research is conducted in several different facilities at NREL. Building 16 is a leased office building that has been partially converted to laboratories. It houses research for photoelectrochemical hydrogen production and fuel cell components.
- Hydrogen storage research is done in both the SERF and the FTLB.
- Hydrogen systems engineering and testing, such as testing of fuel cells and electrolyzers is conducted at the National Wind Technology Center 20 miles north of the other hydrogen activities.
- *Fragmented locations* – NREL does not have dedicated facilities for hydrogen research. As a result, today's pressing needs are being accommodated with creativity, but having the various R&D activities scattered over five different buildings and a distance of 20 miles creates management and productivity inefficiencies and discourages research integration and synergy.
- *Photoelectrochemical Hydrogen Production Research* – Future directions in this research will be limited by its current facilities in Building 16. The four currently unassigned laboratory spaces in Building 16 have significant restrictions on ventilation, levels of hydrogen and toxic materials, and physical access because of their location in a leased office building. The research labs in the FTLB and SERF are fully and continuously in use, compared to the desired practical utilization rate for research labs of 90%. This 100% utilization rate results in no practical flexibility to quickly respond to changing research priorities or directions, or accommodate the additional research activities of students, visiting professionals, or industry partners.
- *Hydrogen Storage Research* – Future directions in this research will be limited by the lack of available laboratories in the SERF and FTLB, as noted above.
- *Photobiological Production Research* – At the laboratory scale, this research will also limited by the lack of available laboratories in the SERF and FTLB, as noted above.
- *Other Laboratory-Scale Research* – Research in hydrogen permeation and separations, fuel cell materials and components, and sensors will be similarly restricted due to the absence of available laboratories.
- *Photobiological Research Scale-Up* – Projections for the scale-up of photobiological hydrogen production will require such facilities as a clean room, temperature-controlled environmental chambers, and several bioreactors. These facilities are not currently available.
- *Hydrogen Production from Concentrated Solar* – This research requires the NREL High Flux Solar Furnace (HFSF), located on NREL's mesa top. The current facility does not include a simple laboratory, so that samples need to be driven to another location for testing. The current facility will not accommodate a laboratory or additional research.
- *Engineering and Testing* – This includes system-level R&D in both mobile and stationary fuel cells, electrolyzers, and photoelectrochemical systems to generate hydrogen. Engineering and testing at a small scale for electrolysis and wind and PV systems is conducted in two locations.
- *Manufacturing R&D* – NREL does not have adequate facilities in which to conduct manufacturing R&D for hydrogen and fuel cell systems. The new Science and Technology Facility will support limited manufacturing R&D on thin films for hydrogen applications. New

equipment for manufacturing R&D could be housed in the proposed Energy Systems Integration Facility.

Facility Options

In considering facility needs, the following options should be included:

Laboratory-Scale Research of all Types -- Photoelectrochemical production, hydrogen storage, fuel cell components, and separations

- Limit R&D at NREL to that which can be accomplished with the current facilities.
- Temporarily lease more commercial space, duplicate services and equipment as necessary, and continue to accept the decrease in productivity inherent in split locations.
- Improve the utilization of the FTLB by moving offices out of interior spaces and building out unused or underutilized space in the interior of the FTLB by adding walls and casework, and upgrading and expanding building ventilation and drains.
- Combine Hydrogen needs with other programs' needs for laboratories at NREL in a new Biological and Chemical Sciences Facility and Solid-State Research Facility.

Photobiological Research Scale-Up

- Limit R&D at NREL to that which can be accomplished with the current facilities.
- Temporarily lease more commercial space, duplicate services and equipment as necessary, and continue to accept the decrease in productivity inherent in split locations.
- Conduct near-term research in the 1,300-gsf existing glass-enclosed research area currently available in the FTLB. In addition, remodel 3,000 gsf of space in the FTLB to provide a temperature-controlled room for growth chambers for growing research organisms; a clean room for computer-controlled high-throughput screening of algal colonies; and wet laboratory space for anaerobic protein purification. A temporary trailer is likely to be needed for office space.
- Construct an addition to the FTLB to provide space designed to accomplish this work now and in the future. Required space includes 4,000 gsf of glass-enclosed research space for bioreactors and 3,000-4,000 gsf of lab space for temperature-controlled rooms and growth chambers for growing research organisms; clean rooms for computer-controlled high-throughput screening of algal colonies; wet laboratory space for anaerobic protein purification; offices; and support space. Three options have been studied – the minimum addition (12,600 gsf) projected to be needed at this time; a larger addition (19,000 gsf) that would provide more flexibility for the future with additional offices and labs that could benefit other programs as well; and a full, two-story addition (30,000 gsf) that would provide significant new space for several programs.

Hydrogen Production from Concentrated Solar

Because of the uniqueness of NREL's High Flux Solar Furnace (HSFS), the only viable option is to expand the support space adjacent to the furnace itself. Three options have been studied to construct new integrated Mesa Top Facilities at NREL that would address the various needs of the Hydrogen Program, the Solar Program, the Office of Science, and the various other work-for-others partners who use the HFSF. All three options propose some degree of construction and build-out of two new facilities on the mesa top, the Mesa Solar Research Laboratory and Mesa Solar Optics Laboratory. The Hydrogen program would benefit from the Mesa Solar Research Laboratory in each option, and may contribute a reasonable portion of the cost.

- Option 1 – Full build-out of a total of 10,500 gsf (7,500 gsf for the Mesa Solar Research Laboratory and 3,000 gsf for the Mesa Solar Optics Laboratory), for a total cost of $6.0 million, including estimated capital equipment essential to this facility. Hydrogen would pay only a portion of this cost.

- Option 2 – Full shell and partial build-out of the proposed 10,500 gsf for a total cost of $3.5 million, including estimated capital equipment essential to this facility. Hydrogen would only pay a portion of this cost.
- Option 3 – Full build-out of a portion of the proposed building (2,800 gsf for the Mesa Solar Research Laboratory and 3,000 gsf for the Mesa Solar Optics Laboratory) at this time, with additional construction at some time in the future. Hydrogen would only pay a portion of this cost.

Engineering and Testing

- Limit R&D at NREL to that which can be accomplished with the current facilities
- Temporarily lease more commercial space, duplicate services and equipment as necessary, and continue to accept the decrease in productivity inherent in split locations.
- Construct a new facility of about 11,000 gsf that will meet the needs today for engineering and testing of Hydrogen, Distributed Energy, and Transmission and Distribution systems using renewable energy.
- Combine today's Hydrogen needs with other current engineering and testing needs related to Distributed Energy, and Transmission and Distribution programs and construct the new Energy Systems Integration Facility. This would accommodate the same functions as the 11,000-gsf facility proposed and add flexibility and efficiency by sharing equipment and resources with other programs.

Manufacturing R&D – The new Science & Technology Facility has some immediate capabilities to assist in manufacturing and process research for thin-film components of fuel cells, and photoelectrochemical systems. Mid and longer term manufacturing R&D capabilities would be located in the proposed Energy Systems Integration Facility. New state-of-the-art equipment for manufacturing R&D would include a flexible facility that could be adaptable to different and emerging technologies. This would be an industrial user's facility that would be based on industry defined needs with a focus on collaborative R&D.

A full analysis of these options is not included here due to space limitations.

Facility Recommendations

Energy Systems Integration Facility

This new facility would accommodate critical engineering, testing, optimization, and verification research needed for integrated engineering systems development for EERE programs. The Energy Systems Integration Facility is proposed as the "first of its kind" integrated test and validation facility for new technologies being developed by the EERE programs and industry research partners nationwide, including engineering performance and testing of renewable hydrogen systems. Developing engineering-scale integrated energy system capability is critical to optimizing technology penetration into the energy market. The availability of an engineering scale integrated energy systems test facility for renewable energy technologies power production and stationary and transportation use will immediately benefit the U.S. renewable energy solar, wind, buildings, and hydrogen industries. As envisioned at NREL, the Energy Systems Integration Facility will leverage technology developments from EERE's Solar Energy and Wind Technologies programs for renewable hydrogen generation. With multidisciplinary engineering experts (mechanical, electrical, thermal) working together in one location, the facility will encourage the development of enabling technologies such as advanced power electronics, electrical interfaces and connections, grid-connected hybrid propulsion systems, and environmental testing. Estimated cost is $77 million in the FY2009-FY2011 budgets.

Biological and Chemical Research Facility
The Biological and Chemical Research Facility would provide biology and chemistry laboratories for all areas of basic research supporting hydrogen, including structural biology, enzymes and biological catalysts, biological materials, separations and membranes, bio nano-scale materials, and biomimetic energy conversion processes. These activities will be moved out of the Field Test Laboratory Building, freeing up space for the expansion of related applied research in mid-scale hydrogen development. The Biological and Chemical Research Facility will also provide dedicated space for NREL scientific computing capabilities, which are critical to research and development on hydrogen. The proposed funding totaling $135 million begins in FY2009.

Solid-State Research Facility
The Solid-State Research Facility is a companion facility to the Biological and Chemical Research Facility. This facility would provide updated and additional laboratories for foundational research supporting photoelectrochemical production of hydrogen as well as other hydrogen production technologies. The foundational science and necessary to sustain this research includes theoretical physics, atomic-scale characterization and measurement, smart materials, chemical kinetics, and optic and thermal properties of materials. This facility is proposed for funding totaling $109 million starting in FY2011.

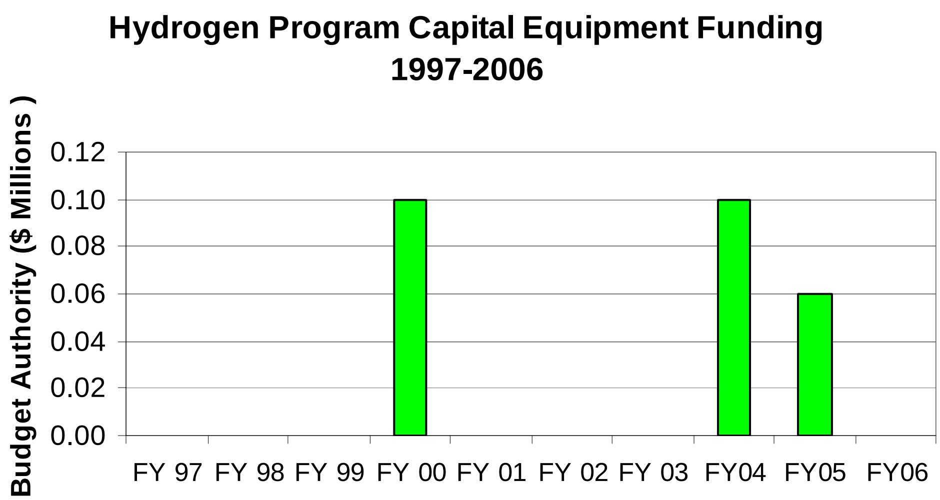
Renewable Fuels and Vehicle Systems Facility
The Renewable Fuels and Vehicle Systems Facility would provide the capability for testing hydrogen fueled vehicles and fuel systems. Estimated funding for this facility is $67.2 million over the period FY2011-FY2013.

Equipment Issues and Opportunities

Hydrogen Capital Equipment Status (09/30/06)		
Estimated Cost Today (Full Use)	$0.5	million
Deferred Replacement Backlog	$0.3	million
Deferred Backlog (%)	51.4%	%
Average Useful Life	10.0	yrs
Average Age	13.5	yrs

This equipment needs to be upgraded and sometimes replaced by newer equipment, and new equipment added, as research priorities change. These needs are documented in multi-year program plans.

A significant investment in NREL's Computational Sciences expertise and high performance computing capabilities would benefit the Hydrogen, Fuel Cells & Infrastructure Technologies Program. There is a general increased need for computational modeling, simulation and data handling of materials, devices and processes used in hydrogen production and storage, and in fuel cells. Specific examples include the quantum mechanical simulations of solid state materials for photoelectrochemical hydrogen production, detailed biomolecular simulations for enzyme engineering for biological hydrogen production, and mining of data for optimizing high throughput experimental design of materials.


Hydrogen Program Capital Equipment Funding
1997-2006
Budget Authority ($ Millions)
0.12
0.10
0.08
0.06
0.04
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FY 97
FY 98
FY 99
FY 00
FY 01
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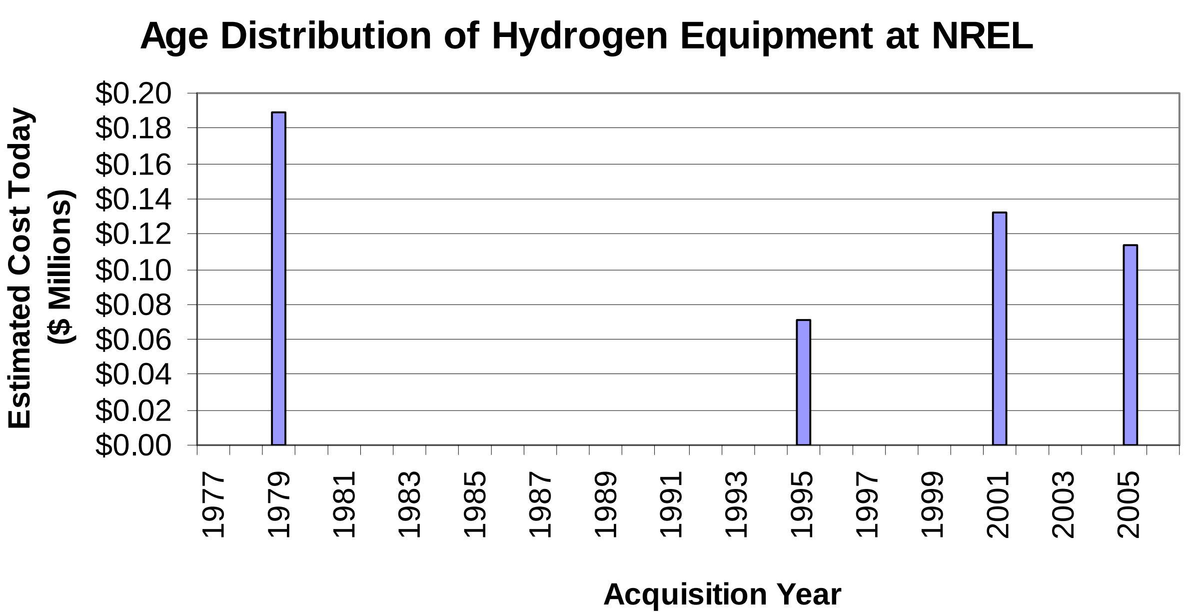
Age Distribution of Hydrogen Equipment at NREL
Estimated Cost Today
($ Millions)
$0.20
$0.18
$0.16
$0.14
$0.12
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Acquisition Year

5.5 NREL Capital Investment Strategy for Distributed Energy and Electric Reliability (DEER) Program

The NREL DEER Program activities are carried out in support of the Department of Energy (DOE) Office of Electricity Delivery and Energy Reliability (OEDER), and the Office of Energy Efficiency and Renewable Energy (EERE) Nevada project.

- OEDER NREL R&D Activities include: Distributed Power Systems Integration (Electric Distribution); Transmission; High Temperature Superconductivity; OE/DE Website; and DE Electrical System Integration/Power Electronics; Thermally Activated Technologies, DE Sensors and Controls, and Energy Storage. Also includes CEC collaboration.
- EERE DE NREL R&D Activities include: DOE NREL Nevada Virtual Laboratory in the Southwest project.

Strategic Goals

- Increase the reliability and efficiency of electricity generation, delivery, and use
- Increase the viability and deployment of renewable energy technologies
- Develop non-vacuum High Temperature Superconductors (HTS) for wires and tapes and support for electric power systems.
- Reduce stress on the grid by limiting peak demand through the advancement of thermally activated cooling and demand-controlled ventilation and ventilation credit strategies

Current Activities at NREL

Distributed Energy and Office of Electricity FY06 Financials and FTEs		
FY06 Budg Auth - Operating	$6.8	million
Distributed Energy	*$5.4*	million
Office of Electricity	*$1.4*	million
FY06 Budg Auth - Capital Equipment	$0.0	million
FY06 Inhouse Costs	$2.9	million
Distributed Energy	*$1.7*	million
Office of Electricity	*$1.1*	million
FY06 Average FTEs	10	FTEs
Distributed Energy	*6*	FTEs
Office of Electricity	*4*	FTEs

- Distributed Power Systems Integration - Electrical Distribution (OEDER)
  - Interconnection Standards and Technology Development and Validation
  - Interconnection Systems Characterization and Operational Field Testing
  - Stakeholder and Institutional Adoption
- High Temperature Superconductivity (OEDER)
  - Development of buffer layers for YBCO superconductor by non-vacuum electrodeposition technique
  - Preparation and characterization of YBCO superconductor by non-vacuum techniques.
  - Work with industries, national laboratories and universities
- Thermally Activated Technologies (OEDER)
  - Research and develop thermal conversion systems that convert waste heat from onsite prime movers to heating/cooling work, thereby more than doubling source energy utilization efficiency in buildings from approximately 30% to over 70%

– Assist in the design, analysis and evaluation of packaged, combined cooling, heating and power systems for buildings

Planned R&D Activities

Distributed Power Systems Integration - Electrical Distribution

- Development of national and international standards for interconnection and integration of distributed resources and electric power systems and to develop advanced technologies that integrate distributed resources with distribution systems.
- Characterization and testing of advanced technologies for interconnection, integration, and control of distributed resources. This is done by conducting system characterization on prototype DR interconnection systems, test procedure validation, and examining the effects of DR on distribution systems.
- Working to ensure the understanding, adoption or reference, and maximum impact of the interconnection and communication standards work of the program by relevant operating, regulatory and related institutions, such as authorities having jurisdiction over the electric power system. This is done by identifying, analyzing, and developing solutions to reduce institutional and infrastructural barriers to the development and commercialization of distributed power systems and the deployment of next generation communications, controls and other technical innovations.
- Develop multiyear power electronics program plan and testing activities for interconnection technologies, micro-grid designs, and standard testing protocols with the California Energy Commission in collaboration or concert with the EERE DE DOE program.

High Temperature Superconductivity

- Prepare electrodeposited biaxially textured buffer layer (innovative and simplified) for YBCO HTS.
- Demonstrate Jc > 106 A/cm2 at 77 K for YBCO using the NREL developed buffer layer.
- Investigate non-vacuum techniques (specially electrodeposition technique) for producing YBCO superconductor.
- Work on YBCO-coated conductor in collaboration with IGC SuperPower Corporation. Establish new CRADA agreement with IGC SuperPower.
- Technical communications for the DOE Headquarters' staff.
- NREL and University of Colorado working together on electrodeposition and spray deposition process. NREL established new collaborative effort with SuperPower Corporation. NREL is also working with other national laboratories; especially ORNL and LANL, on YBCO coated conductors.

Thermally Activated Technologies

- Research and develop advanced desiccant materials that enhance energy efficiency, durability, and performance in emerging applications.
- Develop accurate and fast air quality sensors and low-concentration test protocols to support evaluation of the indoor environmental quality benefits of desiccant systems and other air-cleaners.
- Assist industry in market entry of novel packaged systems for improved humidity control and indoor air quality

Facility Issues and Opportunities

- Researcher offices for Distributed Energy and Electric Reliability are in Buildings 16 and 17. Research work at this time is limited to the very small Hybrid Power Test Bed at the NWTC site, and small portions of laboratories in the Solar Energy Research Facility for HTS research and the Thermal Test facility for TAT work.

Because NREL's unique capabilities in distributed energy and electric reliability research has evolved in the past several years, there has not been significant capital investment in dedicated facilities for this work. As a result, today's needs are being accommodated with "seed" spaces resulting from creative reconfigurations of available space using general plant projects funds.

Facility Recommendations

Energy Systems Integration Facility (ESIF)

This new facility would accommodate critical engineering, testing, optimization, and verification research needed for integrated engineering systems development for EERE programs. The ESIF is proposed as the "first of its kind" integrated test and validation facility for new technologies being developed by the EERE programs and industry research partners nationwide, including engineering performance and testing of renewable hydrogen systems. Developing engineering-scale integrated energy system capability is critical to optimizing technology penetration into the energy market. The availability of an engineering-scale integrated energy systems test facility for renewable energy technologies power production and stationary and transportation use will immediately benefit the U.S. renewable energy solar, wind, buildings, and hydrogen industries. As envisioned at NREL, the ESIF will leverage technology developments from EERE's Solar Energy and Wind Technologies programs for renewable hydrogen generation. With multidisciplinary engineering experts (mechanical, electrical, thermal) working together in one location, the facility will encourage the development of enabling technologies such as advanced power electronics and electrical interfaces and connections.

5.6 NREL Capital Investment Strategy – Buildings

Strategic Goals

- Improve the energy efficiency of residential and commercial buildings and the energy-using equipment in these buildings
- Integrate renewable energy technologies into building systems to enable net-zero energy buildings at low incremental cost by 2025.

Mission

Develop and validate technologies, techniques, and tools to make residential and commercial buildings more energy efficient, productive, and affordable.

Building America R&D. The technical goal is to reduce the energy consumption in residential buildings and integrate renewable on-site energy in a whole building systems approach optimized for specific climate zones across the country. Building America works in partnership with leading production builders and energy consulting teams for field testing and validation of advanced energy efficiency and renewable energy technologies and construction practices.

High Performance Commercial Buildings R&D. The technical goal is to reduce the energy consumption in commercial buildings and integrate renewable on-site energy in a whole building systems approach optimized for specific commercial building types across the country. Advanced energy analysis tools are developed and validated through well-documented case studies of high performance commercial buildings from conceptual design and construction through operation for at least two years.

Emerging Technologies R&D. Advanced energy efficiency technologies including building equipment, windows and thermal envelope systems are developed and tested in laboratory and building environments. Advanced energy analysis and whole building simulation tools are developed and validated to improve the industries ability to design energy efficient buildings.

Current Activities at NREL

Buildings FY05 Financials and FTEs		
FY05 Budg Auth - Operating	$14.6	million
FY05 Budg Auth - Capital Equipment	$0.0	million
FY05 Inhouse Costs	$5.1	million
FY05 Average FTEs	16	FTEs

- Building America
- High Performance Commercial Buildings
- Emerging Technologies

Planned R&D Activities

Building America R&D. NREL provides the field technical management and R&D support for the Building America program. The FY2005-FY2006 goals are validation by production builders of cost competitive whole building energy savings of 30% in the five major U.S. climate zones. The energy savings goals increase to 40% whole building energy savings (including building integrated on-site renewable energy) by 2010 and net zero energy buildings by 2020. NREL develops the program benchmark, analysis tools, energy monitoring protocols, and laboratory test data supporting the field tests.

High Performance Commercial Building R&D. NREL works with building developers, architects and owner/operators to design, construct, and operate a range of commercial building types that achieve high levels of energy savings and incorporate on-site renewable energy sources. Previously completed case studies serve as the basis for efforts underway in FY2005-FY2006 to design technology options for different building types for various climate zones. In addition, NREL is developing and using an optimization methodology to compare multiple options within building systems and to identify key technology improvements needed to meet the EERE goal of zero net energy commercial buildings by 2025.

Emerging Technologies. NREL's primary role is testing the durability and failure mechanisms of advanced windows. In addition, the Laboratory develops advanced material systems to improve the performance and life-cycle cost of dynamic windows. As part of the Analysis Tools work under Emerging Technologies, NREL supports the ongoing development and enhancement of Energy Plus, and provides software validation support on existing software tools.

Facility Issues and Opportunities

- Researcher offices for Building Technologies are housed in Building 17 of the Denver West Office Park.
- R&D for the Building America and High Performance Commercial Buildings activities is conducted primarily in the Thermal Test Facility. The Thermal Test Facility is shared with the battery thermal management research for FreedomCAR and Vehicle Technologies, and there is insufficient space for both programs' activities. Additional laboratory space is required for building component and subsystems testing in support of the residential and commercial buildings R&D activities.
- R&D on advanced window testing and materials development is conducted in the Field Test Laboratory Building. There is currently adequate space for the planned activities.

Facility Options. In considering facility needs, the following options should be included:

- Limit R&D at NREL to that which can be accomplished with the current facilities.
- Construct the proposed Facility for Integrated Renewable Systems Testing (FIRST), which would provide space for FreedomCAR activities currently in the Thermal Test Facility, allowing more space for Buildings research in the Thermal Test Facility.

Facility Recommendations.

Facility for Integrated Renewable Systems Testing (FIRST). This new 60,000-gross-square-foot facility would accommodate critical engineering, testing, optimization, and verification research needed for integrated engineering systems development for EERE programs. The FIRST is proposed as the "first of its kind" integrated test and validation facility for new technologies being developed by the EERE programs and industry research partners nationwide, including engineering performance and testing of renewable hydrogen systems, and fuels-related vehicle engineering and testing. Developing engineering-scale integrated energy system capability is critical to optimizing technology penetration into the energy market. The availability of an engineering scale integrated energy systems test facility for renewable energy technologies power production and stationary and transportation use will immediately benefit the U.S. renewable energy solar, wind, buildings, and transportation, and hydrogen industries. As envisioned at NREL, the FIRST will leverage technology developments from EERE's Solar Energy and Wind Technologies programs for renewable hydrogen generation. With multidisciplinary engineering experts (mechanical, electrical, thermal) working together in one location, the facility will encourage the development of enabling technologies such as advanced power electronics, electrical interfaces and connections, fuels and emissions systems, grid-connected hybrid propulsion systems, and environmental testing. Estimated cost is $40-$60 million in the FY2008 and FY2009 budgets. This includes $10 million for new capital equipment related to the facility.

Equipment Issues and Opportunities

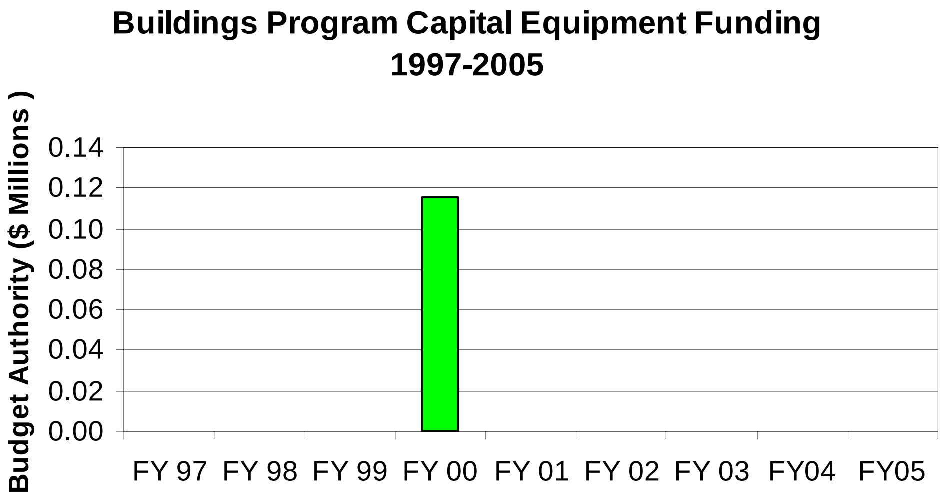
Buildings Capital Equipment Status (09/30/05)		
Estimated Cost Today (Full Use)	$2.1	million
Deferred Replacement Backlog	$0.4	million
Deferred Backlog (%)	17.3%	%
Average Useful Life	9.8	yrs
Average Age	9.1	yrs

The Building Technologies Program has invested very little in capital equipment at NREL over the past seven years. Some items currently need replacement and there are some additional capital items needed for new capabilities to meet program goals. The status of current capital equipment items for the Buildings Technology Program is summarized below.

To move forward in windows durability testing, additional equipment and/or replacement equipment is necessary in the 07/08 timeframe. These are outlined in our capital equipment spreadsheet and are accepted by DOE as program needs in future years.

A significant investment in NREL's Computational Sciences expertise and high performance computing capabilities would benefit the Building Technologies Program through enhancing the speed and efficiency to complete more detailed modeling and simulation. As tools such as EnergyPlus, whole building energy simulation program, the BeOpt optimization meta-program, and computational fluid dynamics modeling programs become more advanced and sophisticated, the computational power requirements increases dramatically. These tools would benefit significantly from additional high performance computing hardware. In addition, efforts to link ground heat transfer models and CFD models to whole building simulation models would also become much more viable with advanced computing hardware.

DOE and NREL discussed the possibility of NREL adding equipment for a Daylighting Test Laboratory within the Thermal Test Facility. While there are no current plans to move forward with this right now, NREL would like to keep it as a possible topic to revisit in future years. The Daylighting Test Lab would add the capability to measure and validate the light distribution, performance, and energy savings for daylighting options. For example, it will be able to quantify and measure side-by-side the performance of options such as a skylight with a fresnel lens, a light tube, and a light shelf. The primary cost of the Daylighting Test Laboratory will be program capital equipment. Some modification of the existing space, and possible roof penetrations will be required, but the cost of the modifications will be less than 20% of the cost of the equipment.


Buildings Program Capital Equipment Funding
1997-2005
Budget Authority ($ Millions)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
FY 97
FY 98
FY 99
FY 00
FY 01
FY 02
FY 03
FY04
FY05

5.7 NREL Capital Investment Strategy – FreedomCAR and Vehicle Technologies

Strategic Goals

EERE Goal: Dramatically reduce or even end dependence on foreign oil

Mission: Develop more energy-efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum

FreedomCAR Partnership: Enable the full spectrum of light-duty passenger vehicles to operate without using petroleum or producing harmful emissions while sustaining freedom of mobility and vehicle choice.

21st Century Truck Partnership: Dramatically improve the energy efficiency and safety of trucks and buses while maintaining a dedicated concern for the environment.

Current Activities at NREL

FreedomCAR FY06 Financials and FTEs		
FY06 Budg Auth - Operating	$19.5	million
FY06 Budg Auth - Capital Equipment	$0.2	million
FY06 Inhouse Costs	$11.5	million
FY06 Average FTEs	43	FTEs

- Partnerships with industry, other federal agencies, and other national laboratories
- Advanced vehicle systems research
- Technology integration and utilization
- Fuels performance research

Planned R&D Activities

Advanced Component and Vehicle Simulation and Validation
- Work with industry to simulate and validate advanced components for fuel-efficient vehicles.
- Provide the technical foundation and tools for developing and evaluating advanced vehicle concepts including plug-in hybrid electric vehicles, advanced control system concepts for predictive and/or adaptive controls using GPS or route-based data, and optimized thermal management including applications to energy storage, climate control, and power electronics.
- Use the Electrical Systems Laboratory to support industry in thermal management aspects of power electronics.
- Use the Energy Storage Laboratory to develop and evaluate unique characteristics of energy storage systems for advanced vehicle technologies.

Technology Integration & Utilization

- Evaluate the performance of new vehicle and fuel technologies as they move into commercial use, and work with industry to develop technical solutions and support to overcome problems that may result.
- Analysis of technology and market trends helps shape future technical programs and identify promising opportunities and supports DOE in policy review relative to transportation sections of EPAct.
- On-line tools, technical assistance, knowledge management, and training help fleets, local officials, and consumers make informed choices that help increase the nation's energy and environmental security.

Fuels Performance

- Apply expertise in fuels, lubricants, and emission control system technologies to guide relevant R&D in support of activities such as the Advanced Petroleum Based Fuels project. NREL also works on renewable fuels and lubricants, alternative fuel vehicle, engine, and infrastructure R&D, demonstration, and deployment. NREL has a facility (the ReFUEL laboratory) to support fuels research as well as the capabilities to evaluate the environmental impacts of conventional and advanced vehicles.

Facility Issues and Opportunities

New Opportunities and Thrusts

- Plug-in hybrids are gaining a lot of attention and will represent one of the greatest opportunities for fuel switching to electricity if the batteries and the power electronics and the IEEE standards all come together. There are many program and project connections with Plug In hybrid vehicles at NREL. NREL is well positioned to add value in this larger systems context, specifically as it relates to the energy transfer from the vehicle to the grid. Our state of the art electrical test bed at the NWTC builds upon the related work funded in the distributed power program for utility interconnection and associated standards for such an interconnect. Furthermore, connections of vehicles to buildings for net zero energy is likely even further out, but again an area of interest to NREL in future systems modeling and system testing as renewable energy technologies are connected to the infrastructure.
- Test procedures in the heavy hybrid area are being discussed. Many hybrid vehicles for various applications will have significantly different duty cycles and we understand how this impacts fuel economy. It is essential that NREL is involved to work with the EPA and others to understand the impacts of fuel economy on these applications so that industry moves toward successful deployment and implementation of new test procedures for various classes of heavy hybrids. Our Refuel facility along with our analytical techniques will be used to achieve these goals.

Current activities – opportunities for co-location

- FreedomCAR research is done in several different facilities at NREL: Building 16 is a leased office building that has been partially converted to laboratories; it houses all activities of Technology Integration and Utilization, as well as program management, analysis, and modeling. Building 16 also houses the Vehicle Climate Control Laboratory which houses the solar simulator and focuses on improving fuel economy and reducing emissions by decreasing vehicle climate control loads while maintaining passenger comfort; the Heat-Generated Cooling Laboratory which is used to develop vehicle air-conditioning from waste heat; the Thermal Comfort Laboratory which includes a climate control chamber for testing with ADAM, the thermal comfort manikin; the Electrical Systems Laboratory which evaluates thermal management of automotive components and validation of advanced control system concepts; and the Fuels Chemistry Laboratory, which focuses on characterizing the effect of molecular structure on the ignition properties of various fuel molecules.

- The ReFUEL (Renewable Fuels and Lubricants) Laboratory is a unique high-altitude, heavy-duty engine and vehicle laboratory located in a leased building 15 miles from the primary NREL campus. This is a unique DOE laboratory in the United States dedicated to researching and developing renewable and synthetic fuels and lubricants for heavy-duty transportation applications.
- The Thermal Test Facility provides space for Energy Storage research to assist battery and ultra-capacitor developers and automobile manufacturers improve energy storage module and pack designs by enhancing performance and extending battery life.

Fragmented Locations
Because NREL's unique capabilities in transportation-related research have evolved in the past several years, there has not been capital investment in long-term, dedicated facilities for this work. As a result, today's pressing needs are being accommodated with creativity, but having the various R&D activities scattered over several miles and multiple locations creates management and productivity inefficiencies and discourages research integration and synergy.

Full Utilization and Inflexibility
The research labs in the ReFUEL, TTF, FTLB, and SERF are fully and continuously in use, compared to the desired practical utilization rate for research labs of 90%. This 100% utilization rate results in no practical flexibility to quickly respond to changing research priorities or directions, or accommodate the additional research activities of students, visiting professionals, or industry partners. In addition, the four currently unassigned laboratory spaces in DW Building 16 have significant restrictions on ventilation, floor loading, and physical access because of their location in a leased office building, and would be unsuitable for much of the work of the FreedomCAR program.

Facility Recommendations

Energy Systems Integration Facility
This new facility would provide a very useful research test platform for plug-in hybrid vehicles for the FreedomCAR program, because the focus of this facility is on integrated systems including buildings and distributed generation via renewables. This DOES NOT duplicate other National Laboratory testing as it's focus would be at the larger system thinking and not only on the vehicle itself. Integration and load matching from car to grid is especially challenging and would be the area of most interest and exploration in this facility.

Biological and Chemical Research Facility
NREL proposes this new facility primarily for foundational science, but it would have sufficient space to accommodate, for the near-term, advanced fuels chemistry and formulation. Currently fuels chemistry research is conducted in leased office space, so the addition of this laboratory facility would greatly benefit NREL's work in this area for FreedomCAR.

Renewable Fuels and Vehicle Systems Facility
NREL proposes this new facility for initial funding in FY2011, to provide the space necessary for advanced vehicle testing and fuels formulation and testing, to support the FreedomCAR program in achieving its goals. This would also be a convenient time to co-locate the transportation-related researchers, creating a more effective critical mass in this research area and improving research productivity. Although this is not essential, it supports the idea of getting out of leased facilities for the long term.

Equipment Issues and Opportunities*

FreedomCAR Capital Equipment Status (09/30/06)		
Estimated Cost Today (Full Use)	$1.0	million
Deferred Replacement Backlog	$0.0	million
Deferred Backlog (%)	0.0%	%
Average Useful Life	10.0	yrs
Average Age	3.2	yrs

* Equipment investments have also been made that do not appear in the table or graphs because they are not technically program capital equipment for various reasons. However, this equipment is very important to the success of the research program, and includes experimental equipment such as the manikin, general purpose equipment purchases important to the program such as ABC 1000, or equipment gained from hybrid subcontract closeouts with the automotive companies such as calorimeters.

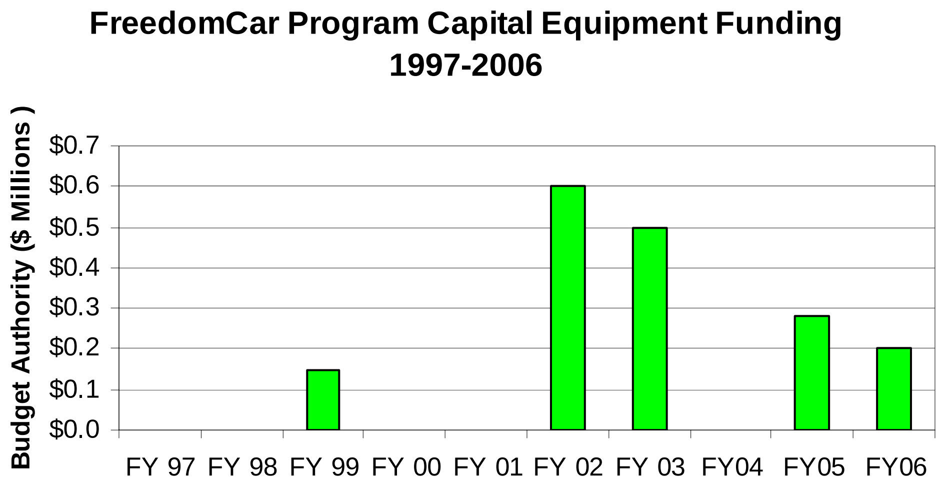
The DOE FreedomCAR Program invested in over $1 million of capital equipment to enable research in the ReFUEL facility. ReFUEL is a test facility for advanced fuels in heavy-duty engines and vehicles and advanced heavy hybrid vehicles, and houses the following specialized testing and measurement equipment:

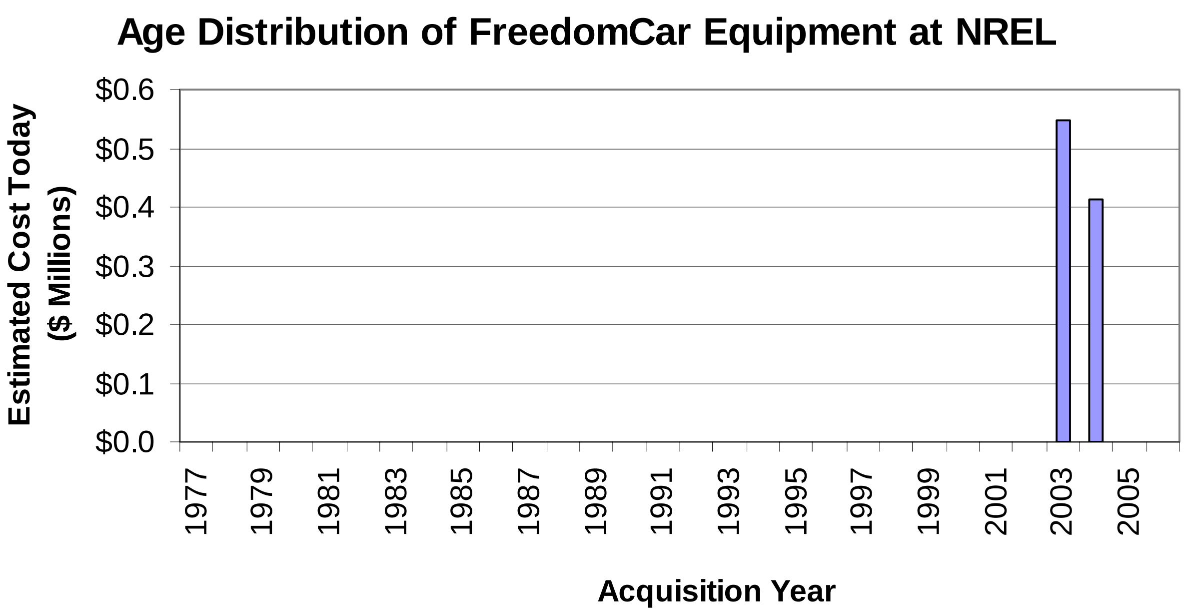
- Heavy-duty chassis dynamometer for testing advanced trucks and buses, simulation capability from 8,000 - 80,000 lbs
- Heavy-duty engine transient test cell (up to 400 hp) for fuels research and development
- Emissions measurement capability sensitive enough to be compliant with Federal certification procedures required in 2007.

NREL acquired the lab in 2002 and this equipment in 2002 and 2003 to increase the use of renewable diesel through research and development that removes barriers to a wider use of these non-petroleum based fuels. The investment made by NREL and DOE in the ReFUEL facility makes the lab available to the research community that is capable of testing advanced fuels, prototype engines, and hybrid powertrains in development for the next ultra-clean generation of heavy-duty vehicle technologies. It has been fully booked for it's testing schedule since it opened and work to support program activities could be expanded if the facility had additional space.

As we think about new emission regulations coming in 2010, this equipment needs to be upgraded and sometimes replaced by newer equipment, and new equipment added, as research priorities change. These are documented in multi-year DOE program plans.

A significant investment in NREL's Scientific Computing expertise and high performance computing capabilities would benefit the FreedomCAR & Vehicle Technologies Program through more fluid dynamics research and development. It would enable more detailed 3-D, transient modeling of airflow and thermal loads in vehicle cabins to improve air-conditioning effectiveness and reduce vehicles auxiliary loads. It would also provide computing capability to study components used in more fuel efficient hybrid vehicles such as spray cooling for high power electronics in heavy hybrid vehicles and improved road load prediction simulations with an accurate tire model to assists in reducing vehicle weight while maintaining a durable vehicle structure.


FreedomCar Program Capital Equipment Funding
1997-2006
Budget Authority ($ Millions)
$0.7
$0.6
$0.5
$0.4
$0.3
$0.2
$0.1
$0.0
FY 97 FY 98 FY 99 FY 00 FY 01 FY 02 FY 03 FY04 FY05 FY06


Age Distribution of FreedomCar Equipment at NREL
Estimated Cost Today ($ Millions)
$0.6
$0.5
$0.4
$0.3
$0.2
$0.1
$0.0
1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005
Acquisition Year

5.8 NREL Capital Investment Strategy – Geothermal Program

Work described in this plan is consistent with current NREL support for the Geothermal program. We recognize that the continuation of the Geothermal Program is in review by DOE and by the congress, and that the program has been proposed for termination.

Strategic Goals

DOE: Strengthen America's energy security by developing technologies that foster a diverse supply of reliable, affordable, and environmentally sound energy by providing for reliable delivery of energy, guarding against energy emergencies, exploring advanced technologies that make a fundamental improvement in our mix of energy options, and improving energy efficiency.

EERE:
- Increase the viability and deployment of renewable energy technologies
- Increase the reliability and efficiency of electricity generation, delivery, and use

Current Activities at NREL

Geothermal FY06 Financials and FTEs		
FY06 Budg Auth - Operating	$2.0	million
FY06 Budg Auth - Capital Equipment	$0.0	million
FY06 Inhouse Costs	$1.7	million
FY06 Average FTEs	5	FTEs

- Research to enhance the performance and decrease the cost of air-cooled condensers via air side surface alteration with tabs or other protuberances to disrupt and renew the boundary layer on the heat transfer surface, while maintaining or even reducing the energy expenditure on the air side. These developments can substantially enhance geothermal energy production.
- Development and field-testing of advanced doped polymeric coatings that can be applied to inexpensive base metals to provide the corrosion and abrasion resistance of exotic metals, while reducing the cohesion of fouling layers. The coatings can substantially reduce the cost of geothermal equipment such as piping and heat exchangers.
- Define and develop advanced conversion technology to increase the efficiency and decrease the cost of geothermal power. This includes analytical evaluation and field-testing of conversion processes and components.
- Provide technical integration support to the Geothermal Technologies Program, with activities ranging from planning and managing, to analysis, to outreach.

Planned R&D Activities

- The heat transfer developments will be perfected and will be taken to large scale field-test at a geothermal operating facility.
- Field-testing of doped polymeric coatings will be expanded, with continued development of polyphenylene sulfide based coatings, and development and testing of organo-metallic type coatings. One area of emphasis will be to provide fouling and corrosion efficient coatings that are thermally conductive for use on the air side of air-cooled condensers that are sprayed with brine in the summer to significantly enhance the rate of condensation and to reduce the condenser pressure to increase turbine output.

- Enhance the adoption of new processes and components for geothermal energy conversion via field-testing, with emphasis on development of the conversion technology necessary to make enhanced geothermal systems technically feasible and economically viable.

Facility Issues and Opportunities

The NREL Geothermal Technology Program will continue to use the current facilities in the TTF and the FTLB.

Equipment Issues and Opportunities

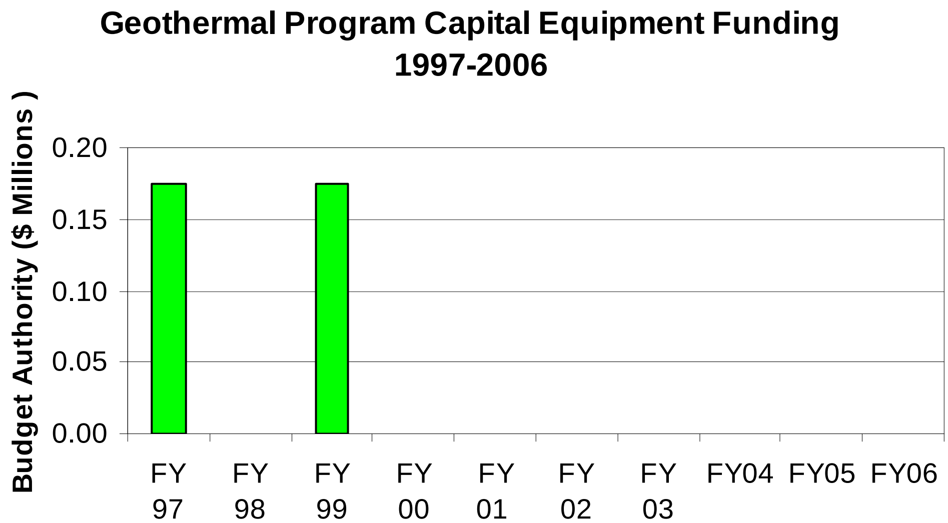
Geothermal Capital Equipment Status (09/30/06)		
Estimated Cost Today (Full Use)	$0.7	million
Deferred Replacement Backlog	$0.4	million
Deferred Backlog (%)	63.2%	%
Average Useful Life	10.0	yrs
Average Age	9.1	yrs

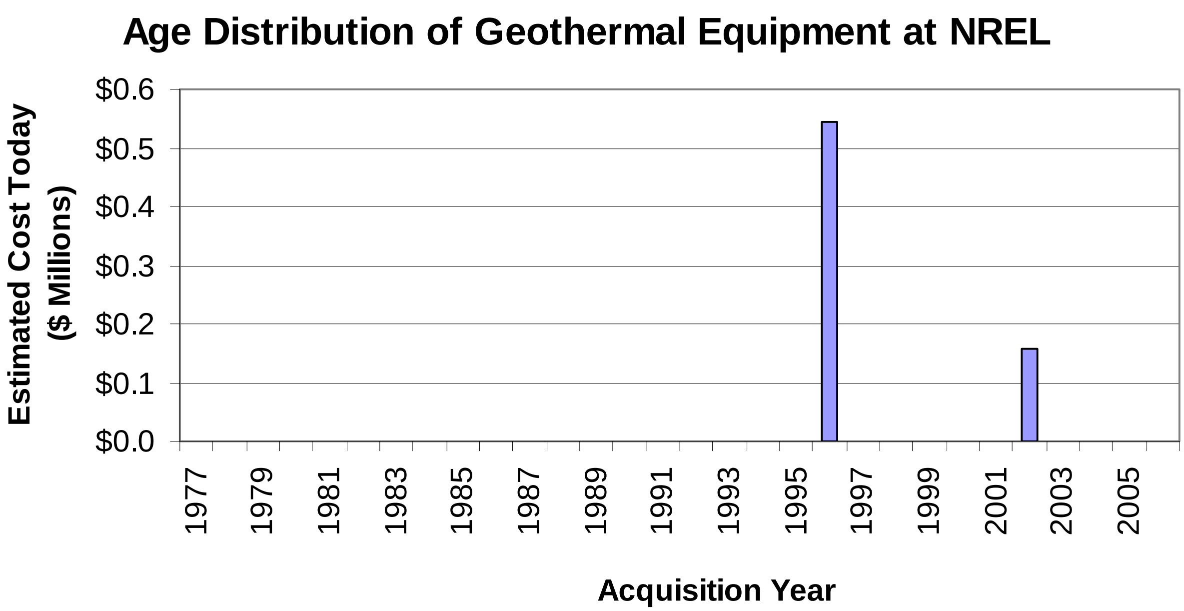
The existing capital equipment is barely adequate to perform the required work in heat transfer and materials testing. The existing heat transfer equipment needs to be upgraded to allow more efficient fabrication of test items, more cost-effective testing, and more rapid and in some cases in-situ analysis of materials performance.

The enhanced heat exchanger test module fabrication will require a numerically controlled punch coupled with an automated positioning table for formation of fin specimen. The transient and the steady state heat transfer test apparatus need to be upgraded with better data collection devices and with better auxiliaries to enable closer control of variables. The materials testing will require a dedicated boroscope to allow in-situ visual inspection of piping and tubing interiors, along with a fouling instrument to characterize the deposition of salts and corrosion products on the surfaces of geothermal equipment. Field-test of the enhanced air-cooled condenser will require a full-scale air-cooled condenser, essentially 1 bay of an industrial condenser located on a geothermal power plant. The air-cooled condenser test specimen will be a custom fabrication.

These are documented in multi-year program plans.

A significant investment in NREL's Computational Sciences expertise and high performance computing capabilities would benefit the Geothermal Technologies Program through more fluid dynamics research and development. For example, it would help reduce cost of geothermal electricity via research and development to identify and simulate improved, innovative air-cooled heat exchanger designs in collaboration with industry partners.


Geothermal Program Capital Equipment Funding
1997-2006
Budget Authority ($ Millions)
0.20
0.15
0.10
0.05
0.00
FY 97
FY 98
FY 99
FY 00
FY 01
FY 02
FY 03
FY04
FY05
FY06


Age Distribution of Geothermal Equipment at NREL
Estimated Cost Today ($ Millions)
$0.6
$0.5
$0.4
$0.3
$0.2
$0.1
$0.0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Acquisition Year

6.0 Detailed Budget Tables

Data

Budget tables included in this plan reflect NREL's proposals for its facilities and infrastructure. While the Ten-Year Site Plan attempts to align to the budget, it does not directly reflect the budget currently in development. This Ten-Year Site Plan is coordinated with EERE Program Managers. It reflects both known facility and equipment requirements (general purpose and program specific), and optional facilities needs. Cost estimates generally require further development and validation.

NREL Facilities and Infrastructure Investments for FY2009 - FY2013 Budget Formulation

Proposed Project/Investment	GSF	Funding Profile ($1000) FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	Total
Strategic Investments										
S&TF Research Equipment Initiative		$1,800	$12,800	$6,500	$7,800	$0	$0	$0	$0	$28,900
Integrated Biorefinery Research Facility	26,900	$0	$0	$16,500	$3,000	$0	$0	$0	$0	$19,500
Energy Systems Integration Facility (note b)	129,014	$0	$0	$0	$6,600	$48,400	$22,000	$0	$0	$77,000
Biological and Chemical Research Facility (note b)	165,000	$0	$0	$0	$11,400	$83,600	$39,700	$0	$0	$134,700
Renewable Fuels & Vehicle Systems Facility (note b)	100,000	$0	$0	$0	$0	$0	$5,760	$42,240	$19,200	$67,200
Solid-State Research Facility (note b)	135,000	$0	$0	$0	$0	$0	$0	$8,160	$59,840	$68,000
Total Strategic Capabilities		**$1,800**	**$12,800**	**$23,000**	**$28,800**	**$132,000**	**$67,460**	**$50,400**	**$79,040**	**$395,300**
Supporting Investments										
Research Support Facilities (Phase I)	48,000	$9,900	$0	$0	$0	$0	$0	$0	$0	$9,900
Research Support Facilities (Phase II) (note c)	244,000	$0	$0	$7,800	$57,200	$0	$0	$0	$0	$65,000
Research Support Facilities (Phase III)	36,000	$0	$0	$0	$0	$26,000	$0	$0	$0	$26,000
FTLB Expansion/Energy Efficiency Upgrade	100,000	$0	$0	$0	$4,500	$0	$0	$0	$0	$4,500
Data Infrastructure Modernization	8,000	$0	$0	$0	$2,100	$0	$0	$0	$1,000	$3,100
Research Support Facilities (Phase IV)		$0	$0	$0	$0	$0	$0	$0	$0	$0
STM Site Infrastructure Development		$0	$2,500	$0	$12,442	$3,000	$0	$27,029	$0	$44,971
Institutional Facilities and Infrastructure -- New Capabilities		$1,646	$0	$1,138	$1,022	$1,083	$1,635	$1,748	$5,441	$13,712
Institutional Capital Equipment -- New Capabilities		$1,492	$1,838	$2,353	$3,975	$5,000	$2,890	$2,828	$3,299	$23,674
Program Capital Equipment -- New Capabilities		$1,772	$1,500	$1,500	$3,000	$3,000	$3,000	$3,000	$3,000	$19,772
Total Supporting Investments		**$14,810**	**$5,838**	**$12,791**	**$84,239**	**$38,083**	**$7,525**	**$34,605**	**$12,740**	**$210,630**
Maintaining Existing S&T and Operational Capabilities										
Maintaining EERE's Existing Real Property Asset Base										
Direct Funded										
Real Property Reinvestment (Non-Overhead Portion of 2% RPV)			$0	$1,802	$2,554	$2,708	$4,087	$4,369	$6,802	$22,322
Real Property Deferred Reinvestment (0.5% of RPV)			$1,457	$901	$1,022	$1,083	$1,635	$1,748	$2,721	$10,566
Total Direct			$1,457	$2,704	$3,576	$3,791	$5,721	$6,117	$9,523	$32,888
Indirect Funded (NREL Operating)										
Real Property Reinvestment (Overhead Portion of 2% RPV)			$2,000	$2,202	$2,043	$2,166	$3,269	$3,496	$5,441	$20,619
Total Indirect			$2,000	$2,202	$2,043	$2,166	$3,269	$3,496	$5,441	$20,619
Total Maintaining EERE's Real Property Asset Base			$3,457	$4,906	$5,620	$5,957	$8,991	$9,613	$14,964	$53,507
Maintaining EERE's Equipment Asset Base										
Institutional Equipment Reinvestment (Equipment Portfolio Maintained at 50% Remaining Life)		$1,459	$1,303	$2,126	$7,638	$6,427	$8,296	$8,008	$8,666	$43,923
Institutional Equipment Deferred Replacement Backlog Worked to $0 by 2013		$4,961	$5,808	$6,656	$4,964	$3,208	$1,453	$726	$0	
Program Equipment Reinvestment (Equipment Portfolio Maintained at 50% Remaining Life)		$1,182	$1,000	$1,000	$13,902	$6,302	$7,402	$7,902	$8,602	$47,292
Program Equipment Deferred Replacement Backlog Worked to $0 by 2013		$19,538	$20,274	$21,010	$16,808	$12,606	$8,404	$4,202	$0	
Total EERE's Science and Support Equipment Reinvestment		$2,640	$2,303	$3,126	$21,540	$12,730	$15,698	$15,910	$17,268	$91,215
Grand Total Maintaining the Existing Real Property and Equipment Asset Base		**$2,640**	**$5,761**	**$8,032**	**$27,159**	**$18,686**	**$24,688**	**$25,523**	**$32,232**	**$144,722**

Assignments

Assignments to Categories for FY2009-FY2013 Budget Formulation										
Proposed Project/Investment	**Suggested Funding Category**						**Appears in What Documents?**			
	CLI	**PED**	**Plant Projects (GPP)**	**Capital Equip (GPE)**	**Program Operating (PCE)**	**NREL Operating**	**IFI**	**F&I Chapter**	**Program Plans**	**NREL Indirect Cost Plan**
Strategic Investments										
S&TF Research Equipment Initiative					x		x	x		
Integrated Biorefinery Research Facility	x									
Energy Systems Integration Facility (note b)	x	x								
Biological and Chemical Research Facility (note b)	x	x								
Renewable Fuels & Vehicle Systems Facility (note b)	x	x								
Solid-State Research Facility (note b)	x	x								
Supporting Investments										
Research Support Facilities (Phase I)	x						x	x		
Research Support Facilities (Phase II) (note c)	x	x					x	x		
Research Support Facilities (Phase III)	x	x					x	x		
FTLB Expansion/Energy Efficiency Upgrade			x				x	x		
Data Infrastructure Modernization			x				x	x		
Research Support Facilities (Phase IV)	x	x					x	x		
STM Site Infrastructure Development	x		x				x	x		
Institutional Facilities and Infrastructure -- New Capabilities			x				x	x		
Institutional Capital Equipment -- New Capabilities				x				x		
Program Capital Equipment -- New Capabilities					x				x	
Maintaining Existing S&T and Operational Capabilities										
Maintaining EERE's Existing Real Property Asset Base										
Direct Funded										
Real Property Reinvestment (Non-Overhead Portion of 2% RPV)			x							
Real Property Deferred Reinvestment (0.5% of RPV)			x							
Indirect Funded (NREL Operating)										
Real Property Reinvestment (Overhead Portion of 2% RPV)						x				x
Maintaining EERE's Equipment Asset Base										
Institutional Equipment Reinvestment (Equipment Portfolio Maintained at 50% Remaining Life)				x				x		
Institutional Equipment Deferred Replacement Backlog Worked to $0 by 2013				x				x		
Program Equipment Reinvestment (Equipment Portfolio Maintained at 50% Remaining Life)					x				x	
Program Equipment Deferred Replacement Backlog Worked to $0 by 2013					x				x	

Sums

Supplement to Facilities and Infrastructure Investments for FY2009-FY2013 Budget Formulation									
Proposed Project/Investment	Funding Profile ($1000)								
	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	Total
Budget Formulation Funding Category									
Construction Line Item (including essential capital equipment) + Project Engineering Design		$9,900	$2,500	$24,300	$90,642	$161,000	$67,460	$77,429	$433,231
Plant and Capital Equipment		$9,558	$12,907	$14,977	$40,217	$22,509	$19,994	$46,456	$166,617
Plant Projects Component		$1,646	$3,957	$3,841	$23,640	$7,874	$7,356	$34,894	$83,208
Capital Equipment Component		$7,912	$8,950	$11,135	$16,576	$14,636	$12,638	$11,562	$83,409
Program Capital Equipment		$0	$2,000	$2,202	$2,043	$2,166	$3,269	$3,496	$15,177
Operating Funding		$24,292	$35,574	$30,010	$41,510	$21,908	$18,806	$15,104	$187,205
EERE Investments by Major Categories									
Total Construction Line Item & Plant and Capital Equipment		$19,458	$15,407	$39,277	$130,859	$183,509	$87,454	$123,885	$599,848
Total Program Capital Equipment		$0	$2,000	$2,202	$2,043	$2,166	$3,269	$3,496	$15,177
Grand Total Construction Line Item & Plant and Capital Equipment & Prog Cap Equipment		$19,458	$17,407	$41,479	$132,902	$185,675	$90,724	$127,380	$615,025
Total Operating		$24,292	$35,574	$30,010	$41,510	$21,908	$18,806	$15,104	$187,205
Grand Total EERE Master Table		**$43,749**	**$52,981**	**$71,489**	**$174,413**	**$207,584**	**$109,530**	**$142,484**	**$802,230**
Cross Referencing EERE Master Table to DOE Budget Formulation Documents									
Total Appearing in EERE Master Table		$43,749	$52,981	$71,489	$174,413	$207,584	$109,530	$142,484	$802,230
Total Appearing in the NREL Line Item Facilities and Infrastructure Budget Chapter		$19,458	$15,407	$39,277	$130,859	$183,509	$87,454	$123,885	$599,848
Total Appearing in the Integrated Facilities and Infrastructure (IFI) Crosscut (Attachment M)		$35,838	$42,031	$58,152	$155,793	$190,782	$93,622	$127,427	$703,644
Total Appearing in the Corporate Program Review Integrated Priority List		N/A	N/A	N/A	$130,859	$183,509	$87,454	$123,885	$525,707
DOE Corporate Goal - Maintaining Real Property Infrastructure									
Real Property Replacement Plant Value (RPV as of the First Day of the Fiscal Year)		$170,032	$180,234	$204,348	$216,609	$326,935	$349,551	$544,146	
Real Property Deferred Reinvestment as % RPV		0.86%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	
Real Property Reinvestment as % RPV		1.18%	2.22%	2.25%	2.25%	2.25%	2.25%	2.25%	
Total Real Property Reinvestment as % RPV		2.03%	2.72%	2.75%	2.75%	2.75%	2.75%	2.75%	
DOE Corporate Goal - Maintaining Institutional Equipment Asset Base									
Institutional Equipment (Original Acquisition Cost)	$13,795	$15,686	$18,307	$22,825	$28,352	$31,791	$35,188	$39,106	
Remaining Institutional Equipment Value	$6,869	$6,682	$6,763	$11,462	$14,190	$15,919	$17,591	$19,537	
Remaining Institutional Equipment Portfolio Value (EERE Goal = 50% Remaining Value)	49.8%	42.6%	36.9%	50.2%	50.0%	50.1%	50.0%	50.0%	
Institutional Equipment Deferred Replacement Backlog	$4,961	$5,808	$6,656	$4,964	$3,208	$1,453	$726	$0	

Appendix A: Laboratory Overview

NREL Mission
NREL develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals.

The National Renewable Energy Laboratory (NREL) is a science and technology facility whose mission is to advance renewable energy, energy efficiency, and related technologies and practices. In this vein, NREL, a Federally Funded Research and Development Center (FFRDC) is operated under a management and operating contract (M&O) by the integrated Midwest Research Institute and Battelle team on behalf of the Department of Energy. While the Office of Energy Efficiency and Renewable Energy (EERE) is the primary sponsor of work at the Laboratory, NREL also performs work for or with other DOE programs; federal, state, or local government entities; private sector companies or research institutions; or academic institutions related to DOE's mission at NREL.

In delivering on its mission, NREL conducts a broad spectrum of research and development programs and makes its government-funded scientific and technical research results broadly available to the public. NREL also serves as a technical advisor, offering guidance to DOE in support of policy development, program planning, and other DOE activities, while advancing recommendations for new research and development programs designed to achieve DOE mission goals.

Work at the Laboratory promotes the nation's energy security while minimizing environmental impacts – all in a manner that supports enhanced economic productivity. Highly skilled staff support multi-disciplinary work to rapidly translate energy-related scientific discoveries into new knowledge and technical innovations.

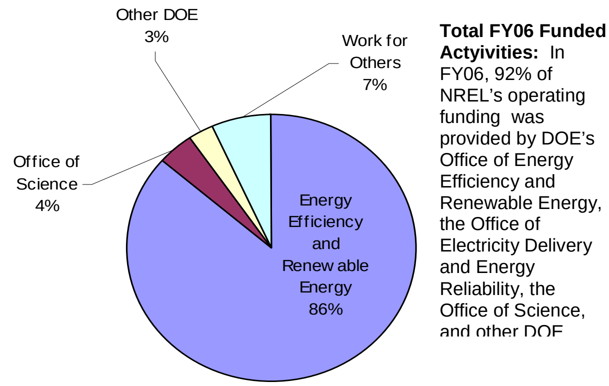
NREL's major emphasis is on the advancement and adoption of renewable energy, energy efficiency, and related technologies and practices. NREL activities include efforts to advance and transfer renewable energy and energy efficient end-use technologies in support of DOE's mission. The *DOE Business Plan for The Office of Energy Efficiency and Renewable Energy – National Renewable Energy Laboratory (December 2006)* further describes the Laboratory.

A.1 Funding Portfolio

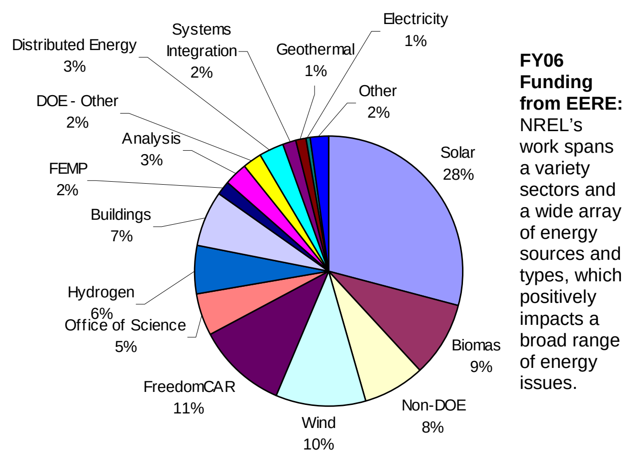
As DOE's primary laboratory for renewable energy and energy efficiency science and technology, NREL provides expertise across the continuum of research, development, and demonstration, as well as supporting implementation strategies to promote market adoption. These efforts are underpinned by highly effective program management, yielding significant outcomes that advance the EERE mission. In partnership with EERE, the Laboratory's steward and primary sponsor, NREL delivers expertise spanning eleven Science and Technology (S&T) programs. In FY2006, NREL's work with DOE's Office of Science promoted research in areas that will lead to breakthrough technologies and scientific advances in energy efficiency and renewable energy, with a particular emphasis on Solar, Biomass, and Hydrogen. Work for other government and non-government organizations and commercial firms completed the Lab's total FY2006 budget.

A key strength of the Lab is its ability to work with, and for, a broad range of groups outside of DOE, including industry, universities, state and local governments, other federal agencies, and domestic and international nongovernmental organizations. This is accomplished through Technology Partnership Agreements and subcontracting efforts that promote transfer of the knowledge and technologies produced at NREL. Through these partnerships, DOE's return on investment is realized as the knowledge created is put to use in relevant markets and sectors locally, nationally, and internationally. Through cost-sharing partnerships, NREL also leverages the federal funds that DOE invests at the Laboratory with corporate and university resources.

In FY2006, 92% of NREL's operating funding was provided by DOE. The Office of Energy Efficiency and Renewable Energy provides the majority of NREL's annual funding. For EERE, NREL's major research programs are in Solar, Biomass, Wind, and FreedomCAR, but other areas are vitally important to NREL's mission as well. Hydrogen technologies have been important at NREL since the early 1990s, and are currently a major emphasis under the President's Hydrogen Fuels and FreedomCAR Initiatives. Distributed Energy has gained importance in the last several years to address the technical issues of integrating distributed energy technologies such as renewables into the nation's electricity solutions. Geothermal technologies have also been a small but steady part of NREL's expertise. Building energy efficiency has been a strong program for many years in specific areas of expertise, and FreedomCar technologies are a growing area of expertise at the Laboratory.



NREL FY2006 Funding = $211 million



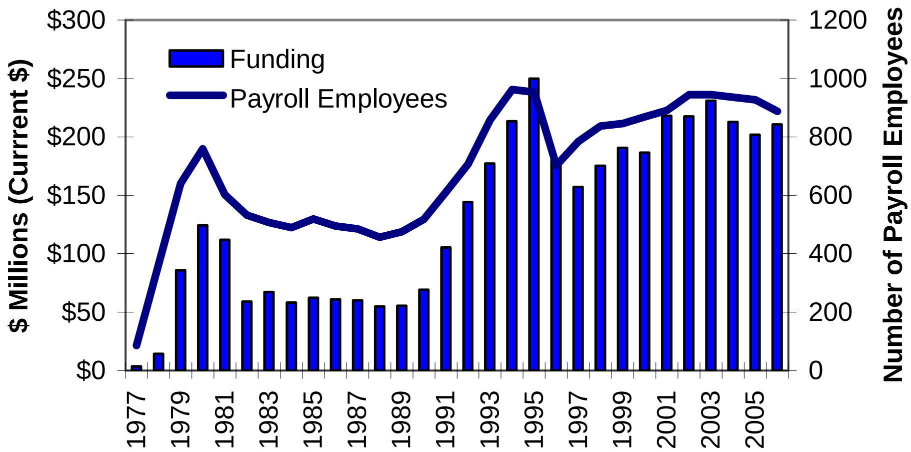
Total Operating Funding, FY2006: $181 million

Fig A.1 Sources of NREL Funding

NREL is also funded by the Office of Science in key areas related to EERE applied technologies, including materials science, chemical sciences, and biological sciences. NREL prides itself on demonstrating effective working relationships and collaborations at the interface between the fundamental research mission of the Office of Science and the applied research mission of the Office of Energy Efficiency and Renewable Energy, and is working to increase its contributions at this vital interface.

NREL also has strong efforts with The Federal Energy Management Program and Weatherization & Intergovernmental programs. This work is directed towards transferring technical successes in renewable energy and energy efficiency to widespread use, working in partnership with industries, government energy users and policy makers, and the general public.

NREL's work for other DOE offices includes work for the Office of Electricity, complementing Distributed Energy work in EERE. Non-DOE sources of mission-related work include various organizations in the Department of Defense, Environmental Protection Agency, U.S. Agency for International Development, and major companies such as Xcel Energy and DuPont. NREL expects work for others to grow in the future as the Laboratory continues to embrace an ever-widening circle of partners.



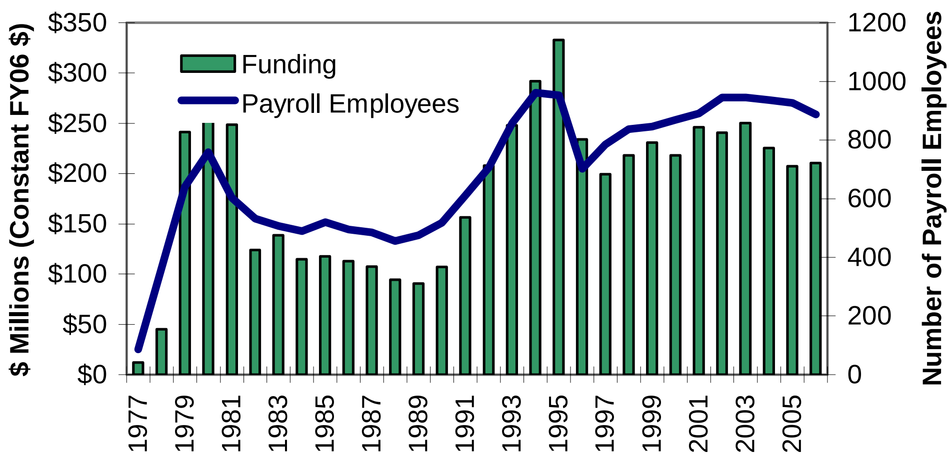
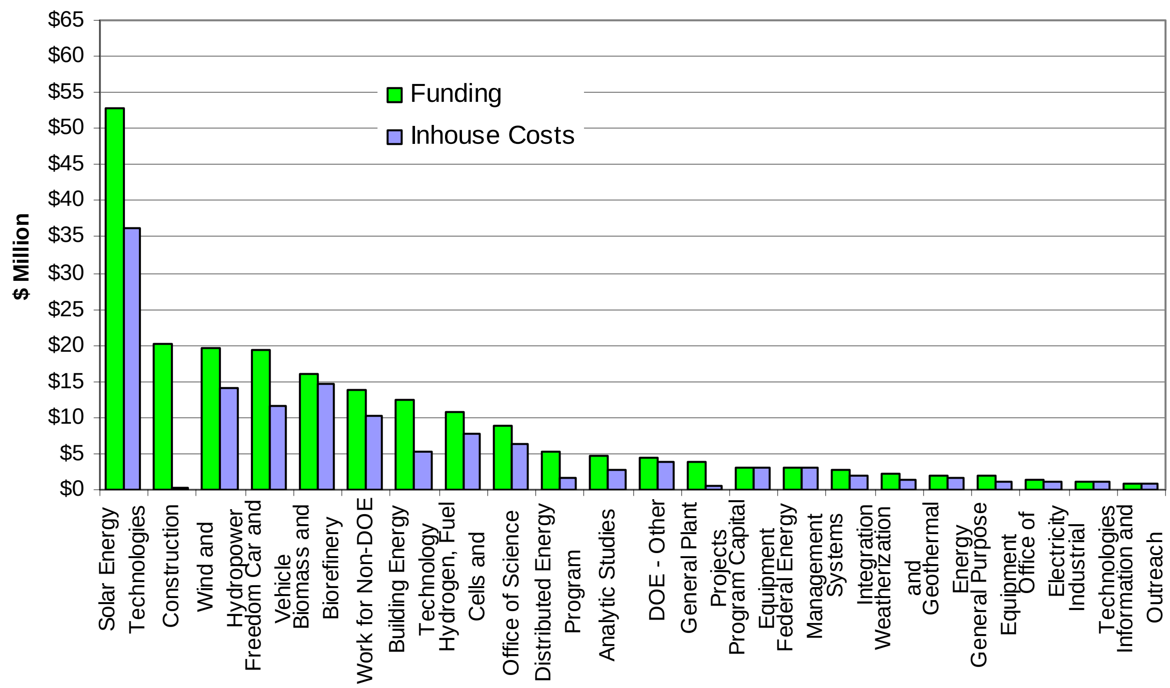


Figure A.1.2. NREL Funding (in Current and Constant FY2006) and Staffing

A.2 Partnerships

One of NREL's primary mechanisms for encouraging research that is truly relevant to industry's needs is to partner with companies in subcontracted research. NREL also subcontracts research with many U.S. universities, drawing upon the best minds to work collaboratively with the Laboratory's scientists. In FY2006, 34% overall of NREL's operating costs were subcontract research. Other partnership mechanisms, such as cooperative research and development agreements, complement NREL's subcontracted research.

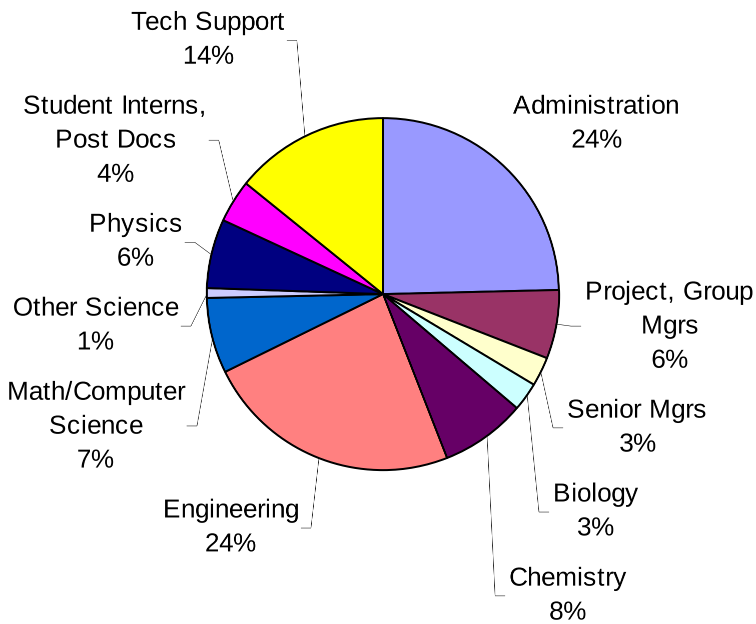
Figure A.2 NREL FY 2006 Funding and In-house Costs by Program

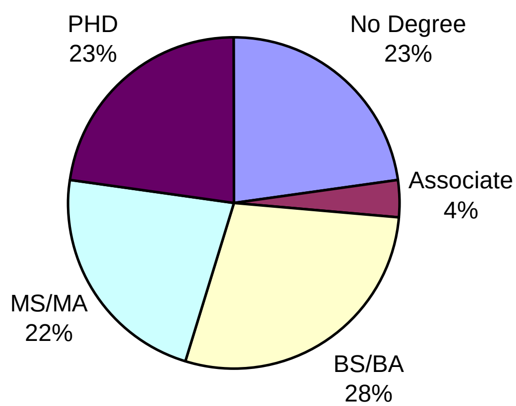


A.3 Staffing Portfolio

Roughly one-quarter of NREL's payrolled staff hold a bachelor's degree, one-quarter have master's degrees, and one-quarter have Ph.D.s. In terms of disciplines or job families, half of the staff are scientists and engineers, one-quarter provide technical support or technical management, and one-quarter are administrators.

Figure A.3.1 Staffing Portfolio





Appendix B: Current Facility, Infrastructure, and Equipment Overview

B.1 Sites and Space Overview

NREL operates in five separate locations in the Denver, Colorado, metropolitan area (Figure B.1.1). DOE-owned sites include the South Table Mountain (STM) site in Golden and the National Wind Technology Center (NWTC) site near Boulder, about 20 miles north of the STM site. Denver locations also include leased facilities in the Denver West Office Park where about half the staff are housed, the Joyce Street Facility warehouse, and the ReFUEL Facility (a small testing facility used for vehicle engine/fuel research). Lastly, NREL maintains a small office in leased space in Washington, D.C. In total, NREL occupies a little more than 735,000 square feet of DOE-owned or leased space. Of this total, 37% is leased (Figure B.1.2). NREL staff are housed about equally between leased and DOE-owned facilities (Figure B.1.3). NREL's sites have no chemical or radiological legacy.

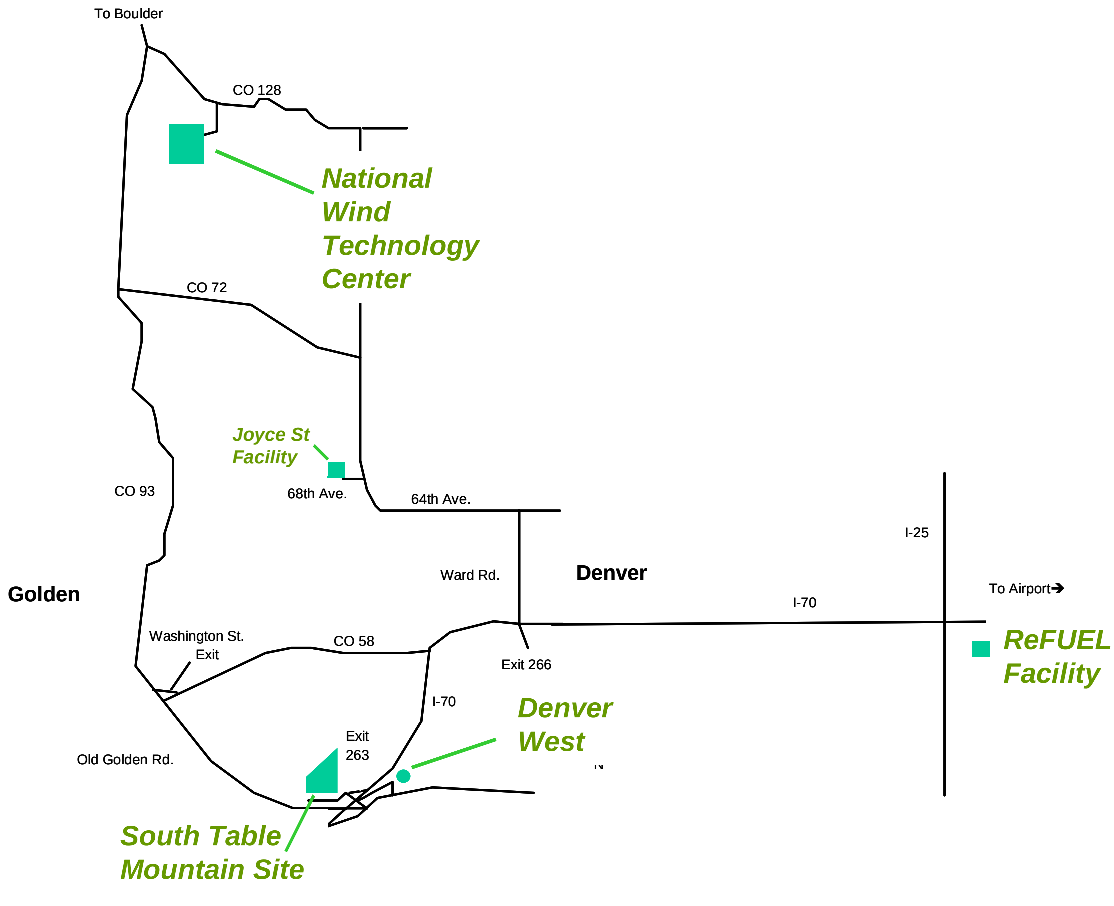


Figure B.1.1 Location of NREL Sites in the Denver Metro Area

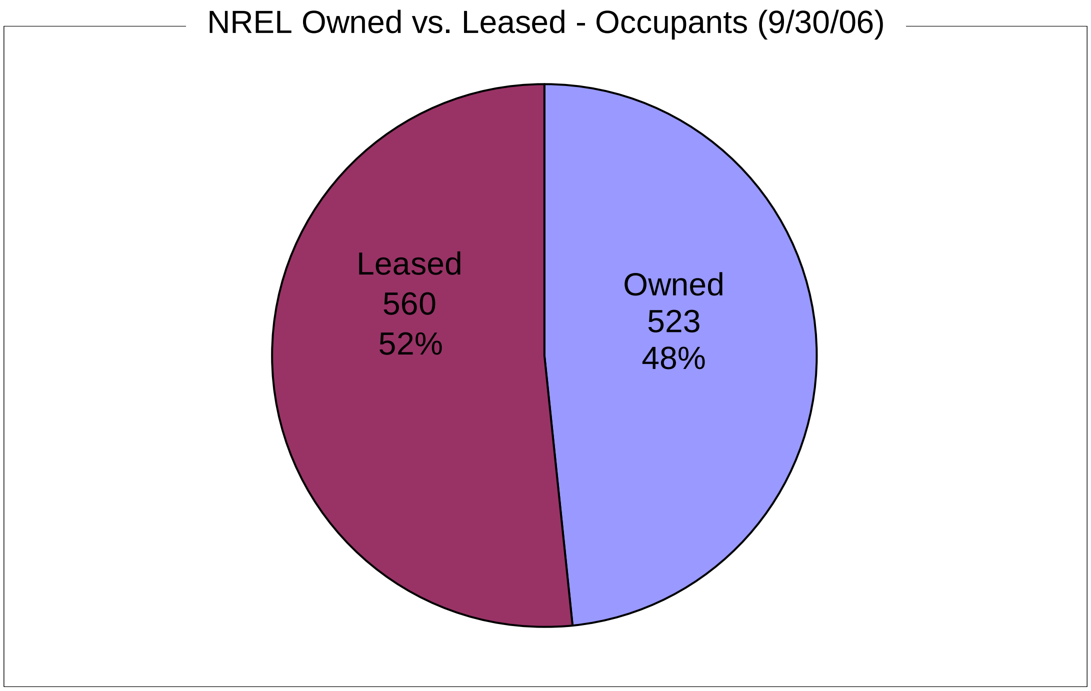


Figure B.1.2 Owned vs. Leased- Occupants

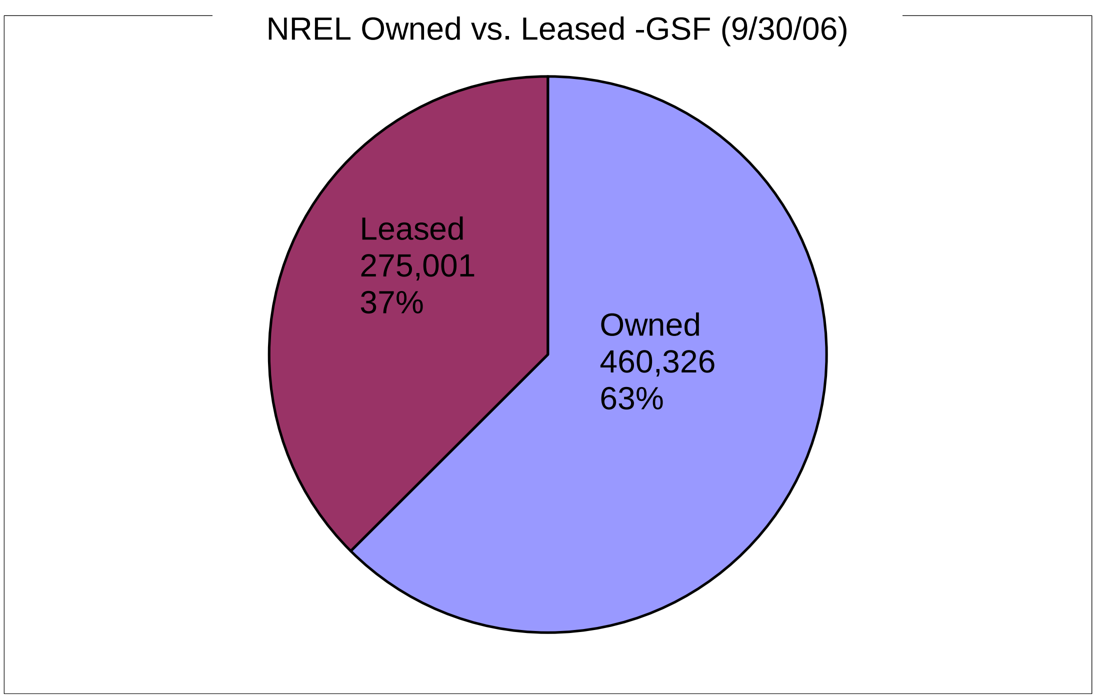


Figure B.1.3 Owned vs. Leased- Square Footage

Table B.1.4 NREL Sites (as of 09/30/06)

	Acres	Total GSF	Ownership	Occupants as of 09/30/06	Distance from STM site
South Table Mountain*	327	404,242	Owned	430	---
National Wind Technology Center	305	56,084	Owned	93	20 miles
Denver West Office Park**	na	207,247	Leased	541	1.2 miles
Joyce Street Facility	na	56,000	Leased	0	8 miles
ReFuel Facility	na	4,576	Leased	5	15 miles
Washington, D.C.	na	7,178	Leased	14	---
Total***	632	735,327		1083	

* Approximately 136 acres of the site can be developed; the balance is in easements.

** Does not include DOE Golden Office and Regional Office space.

*** Includes space tracked in FIMS database (incl. bldgs and trailers) as well as property not tracked in FIMS (e.g. small sheds.)

Table B.1.5 Summary of Issues and Opportunities for NREL Sites

Opportunities

- No environmental legacy issues
- Exceptional physical attractiveness adjacent to western mesa and mountains
- Space available for further development, if capital was available
- Located in Denver, easily accessed by the entire country
- Strong opportunities for collaborations with local universities and governments
- In the Rocky Mountain foothills, sites have six life zones within thirty miles, allowing environmentally specific research and testing (advanced vehicles, building design, etc)
- Sites have excellent solar and wind resources, and access to forest thinnings for biomass
- General Development Vision (2003) delineates land use plans
- Commitment to, and excellent technical expertise in, sustainable development

Issues

- Current facilities are highly utilized, with virtually no research flexibility
- Multiple sites and undesirable separation of activities decrease efficiency and productivity and increase operating costs
- High percentage (50%) of staff in leased facilities
- Primary site (STM) is landlocked
- Secondary site (NWTC, 93 occupants) is far from core NREL activities, with no water or sewer

B.2 Facilities and Infrastructure Historical Funding Summary

NREL's institutional facilities and infrastructure encompasses all the real property assets of the Laboratory. All of the facilities and infrastructure at NREL have been funded through the Laboratory's Lead Program Secretarial Office, the Office of Energy Efficiency and Renewable Energy. As the Lead Program Secretarial Office, EERE is responsible for maintaining and sustaining the institutional capital assets such as roads, utilities, and all buildings, as well as providing the facilities and infrastructure needed for new mission needs.

Real property assets (facilities and infrastructure) must be managed in a manner that promotes operational safety, worker health, environmental compliance, property preservation and cost-effectiveness while meeting the program missions. This requires a balanced approach to managing the assets and also providing for their modernization. Three types of funds are used for all institutional facility and infrastructure projects, whether for maintenance of existing assets, or construction of new assets: NREL operating, general plant projects, and construction line items.

- NREL's building maintenance and minor construction overhead operating budgets are used to maintain existing assets.
- Individual projects under $1 million, whether existing or new, are funded from the Small General Plant Project pool. While the size of the pool is planned two years in advance as part of the DOE budget cycle, the individual projects are prioritized and selected at the start of each fiscal year. The use of this pool for small projects gives the Laboratory flexibility to respond to immediate needs.
- Individual construction projects over $1 million but less than $5 million, termed Large General Plant Projects, are identified and planned individually two years in advance in the budget cycle.
- Construction line item projects are more than $5 million, and are planned through the project management process of the DOE Office of Engineering and Construction Management (DOE Order 413.1).

Over the 29-year history of the Laboratory, capital funding for facilities and infrastructure has totaled $102 million: $73 million for construction line items and $29 million for general plant projects (Figures B.2.1 and B.2.2). The initial 1979-1980 construction line item funding was used to build the first road and utilities and the first two buildings, the older portion of what is now the Alternative Fuels User Facility and the Field Test Laboratory Building. The SERF was built from funding in 1991-1992, and the Alternative Fuels User Facility in 1993. In 1995, DOE invested in an expansion of infrastructure on the STM site. New office space and laboratories were built in part of the FTLB with 1996-1997 funding, while 1998 funding was used to upgrade NREL's information architecture. Funding in 2003-2006 was used to build the Science and Technology Facility. General plant projects funds have been used to maintain, replace, and upgrade existing buildings and infrastructure, and to build new small, general usage buildings.

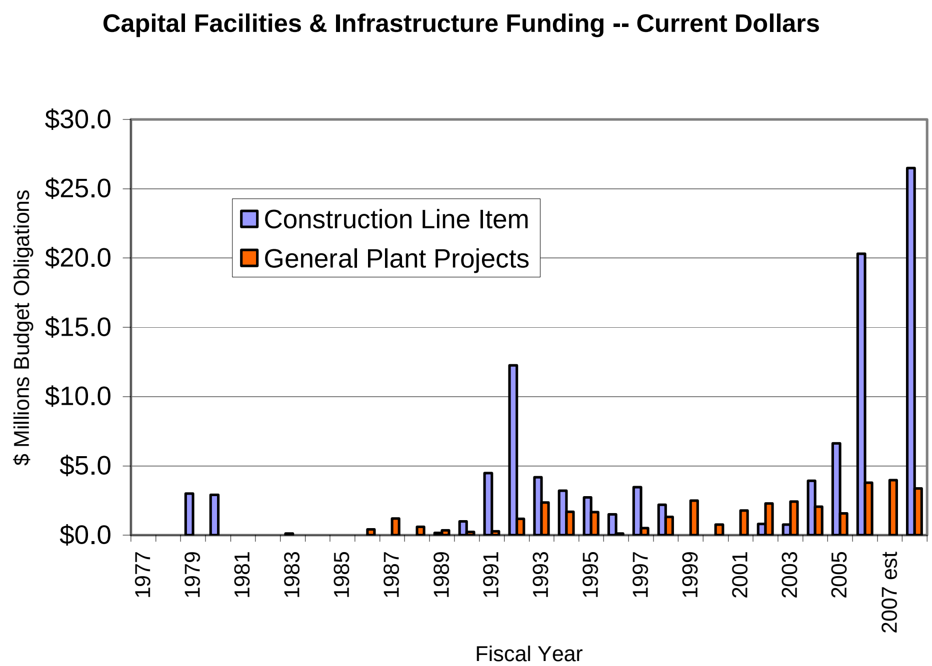


Figure B.2.1 Capital Facilities & Infrastructure Funding – Current Dollars

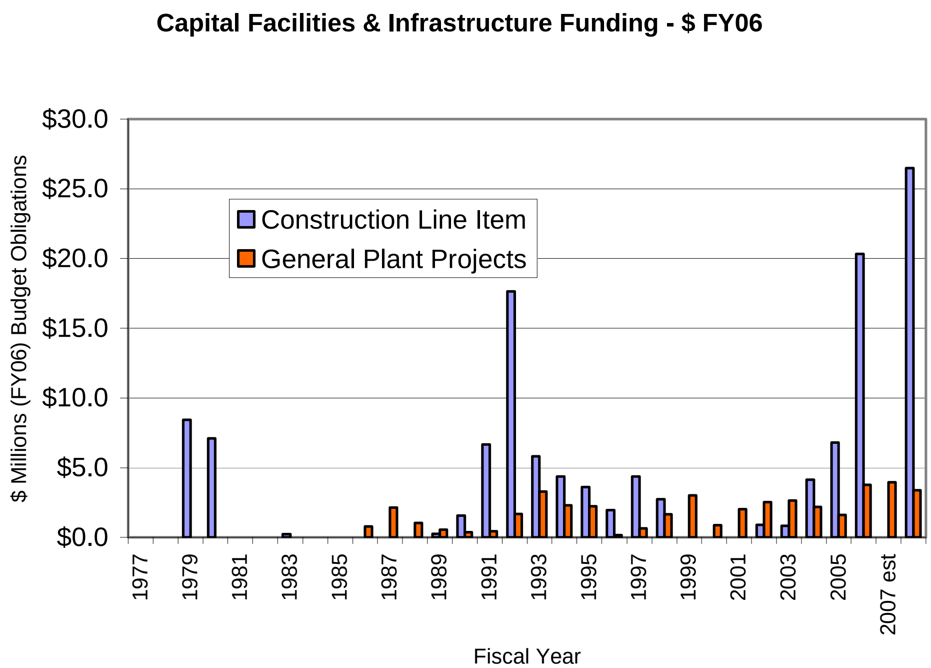


Figure B.2.2 Capital Facilities & Infrastructure Funding – FY2006 Dollars

B.3 Facilities and Infrastructure Overview

NREL uses the DOE Facility Information management System (FIMS) for real property asset information. The research facility portfolio today includes two major (more than 100,000 gsf) laboratory buildings on the STM site (the Solar Energy Research Facility and Field Test Laboratory Building), along with three additional research buildings ranging from 10,000 to 30,000 gsf (Alternative Fuels User Facility, Thermal Test Facility, and Outdoor Test Facility), and a Visitor Center and Shipping and Receiving Building. The Science & Technology Facility (71,000 gsf) was occupied in July 2006. The NWTC site includes the 22,000-gsf Administrative Building 251, which includes computer modeling labs and testing areas; the 5,500-gsf 2.5-MW Dynamometer building; and the 11,000-gsf Industrial User Test Facility.

Condition Assessment Process. NREL periodically contracts with an independent and experienced firm to perform an on-site, Comprehensive Condition Assessment Survey (CAS) consisting of inspections for all DOE-owned facilities and Other Structures and Facilities (OSF). The assessments also update the real property Replacement Plant Value (RPV) for NREL's buildings, mainline utility systems, and other structures and facilities. These assessments are performed consistent with the guidance provided in the DOE Real Property Asset Management (RPAM) Order 430.1B. The condition assessment data, including estimates of replacement plant value, are entered into the DOE Condition Assessment Information System (CAIS). The CAIS provides a comprehensive evaluation that is used to make informed facilities management decisions. Deficiency data, optimum replacement forecasts, facility, built-in equipment, and system condition are entered in CAIS for all NREL facilities, systems, and site infrastructure.

Deferred Maintenance Backlog. The deferred maintenance backlog is the list of replacements that were not completed when they should have been or were scheduled to be performed, and which were deferred or delayed for a future period. The total NREL deferred maintenance backlog as of 09/30/06 is $3,080,000. A two-year plan to eliminate the deferred (replacement in kind) maintenance backlog is shown in Table B.3.1.

Table B.3.1 Deferred Maintenance Backlog Reduction Plan

YEAR	FY2008	FY2009	TOTAL
National Wind Technology Center	$491,000		$491,000
South Table Mountain Site		$2,589,000	$2,589,000
TOTAL	$491,000	$2,589,000	$3,080,000

Facility Condition Index (FCI). The Facility Condition Index (FCI) is the ratio of the current deferred maintenance backlog in dollars divided by the current real property replacement plant value in dollars. The goal is for the FCI to approach zero as the backlog of deferred maintenance decreases at a site. Therefore, the smaller the FCI, the more favorable the maintenance condition (Table B.3.1). The NREL FCI is 1.8% (Table B.3.2).

Table B.3.2 DOE Facility and Asset Condition Index Ratings		
FCI Range	ACI Range	Rating
0% - 1.9%	0.98 – 1.00	Excellent
2.0% – 4.9%	0.95 - 0.98	Good
5.0% - 9.9%	0.90 - 0.95	Adequate
10.0% - 24.9%	0.75 - 0.90	Fair
25.0% - 59.9%	0 - 0.75	Poor
60.0% - 99.9%		Fail

Reference: DOE Order 430.1B

Asset Condition Index. The Asset Condition Index (ACI) is the Department's corporate measure of the condition of its facility assets. The ACI reflects the outcomes of real property maintenance and recapitalization policy, planning, and resource definitions. The Asset Condition Index is one (1) minus the Facility Condition Index (FCI) expressed as a fraction. Ratings are assigned to ACI range measures. The goal is for the ACI to approach unity (1). The ACI increases and approaches unity as the condition of facilities improves at a site (Table B.3.2). NREL's ACI is (1.0 – 0.017) = 0.98 or Excellent (Table B.3.3)

Table B.3.3 NREL Facility and Asset Condition Indices		
	Replacement Plant Value ($ millions)	Deferred Maintenance ($ millions)
South Table Mountain Site	$132	$2.589
National Wind Technology Center Site	$38	$0.491
Overall	$170	$3.080
NREL Facility Condition Index = $3.080 / $170 = 0.018 or 1.8%		
NREL Asset Condition Index = 1 - 0.018 = 0.98		

Replacement Plant Value. Table B.3.4 lists the major NREL buildings individually, and indicates the RPV of all NREL facilities and infrastructure. The RPV for all facilities and infrastructure (as of 09/30/06) was determined to be $170.4 million. The FY2006 NREL total RPV decreased slightly from the FY2005 RPV due to changes in the DOE cost model and the use of a different NREL site factor. In the past NREL had been using the DOE default site factor in calculating the RPV. A revised NREL site factor was calculated for the major buildings based on the recommended site factor algorithm provided by DOE in FY2006.

Table B.3.4 NREL's Facilities and Infrastructure (as of 9/30/06)

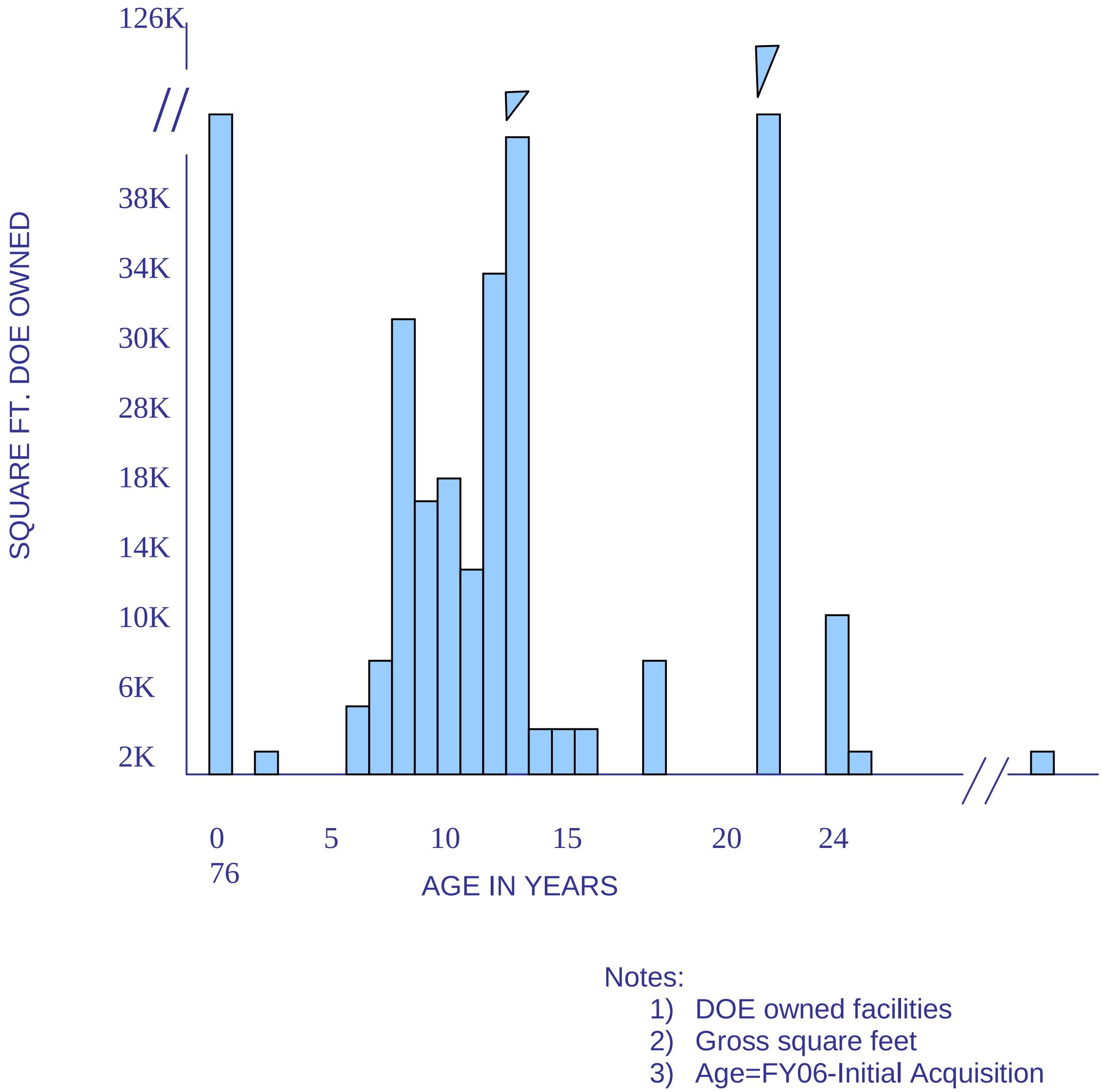
Site	Building	Year Acquired	GSF	# Occupants	FY2006 Replacement Plant Value ($ millions as of 11/24/06)
Leased	DW Building 16	1980	85,906	194	N/A
	DW Bldg 17	1979	87,774	264	N/A
	DW Bldg 15		29,100	72	N/A
	DW Bldg 7	2005	4,467	11	N/A
	REFUEL	2002	4,576	5	N/A
	Joyce St Warehouse	1989	56,000	0	N/A
	Washington DC	2000	7,178	14	N/A
	Other DW Structures and Facilities				
STM	STM Support Facilities	various	30,871	27	$7.48
	Alternative Fuels User Facility	1993	32,751	27	$10.89
	Field Test Laboratory Building	1984	126,572	130	$42.22
	Outdoor Test Facility	1994	11,247	14	$3.48
	Science & Technology Facility	2006	71,347	47	$24.03
	Solar Energy Research Facility	1992	115,890	172	$39.03
	Thermal Test Facility	1995	10,682	6	$3.55
	Mesa Top Facilities	various	4,882	7	$1.62
	Other STM Structures and Facilities	various	n/a	n/a	$13.58
NWTC	NWTC Bldg 251	1982	22,026	54	$6.90
	NWTC Industrial User Facility	1994	11,394	13	$3.68
	NWTC Other Facilities	various	22,664	26	$4.56
	Other NWTC Structures and Facilities	various	n/a	n/a	$9.01
	Total		*735,327*	1083	$170.03

Replacement Plant Value and Maintenance Investments. The actual NREL expenditures for facilities and infrastructure over the last five years are shown in Table B.3.5. DOE Order 430.1 on Real Property Management recommends that 2% - 4% of the replacement plant value be invested annually in maintenance of facilities and infrastructure. In the last four years, NREL's expenditures have totaled 1.5% to 2.5% of RPV. Of these expenditures, typically about one-half is overhead operating funds, and about one-half is general plant projects capital funds.

Table B.3.5 Historical Recapitalization Expenditures ($ millions)

	FY2002	FY2003	FY2004	FY2005	FY2006
Replacement Plant Value as Start of Fiscal Year	$176	$176	$176	$176	$170
NREL Overhead Maintenance Expenditures	$1.99	$2.02	$2.28	$2.08	$2.205
GPP Recapitalization Expenditures	$1.02	$0.65	$1.40	$1.39	$2.061
Subtotal Expenditures	$3.0	$2.7	$3.7	$3.5	$4.266
Expenditures as % of RPV	**1.71%**	**1.51%**	**2.09%**	**1.97%**	**2.50%**

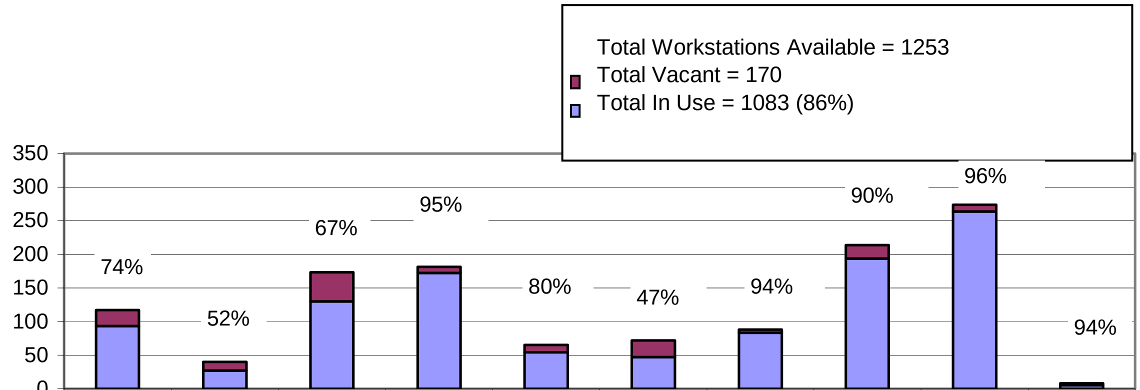
Age of Facilities. Established in 1977, NREL's facilities are younger, on average, than other larger national laboratories, which were established following World War II. NREL therefore has the opportunity to properly maintain these buildings as they age and avoid the problems other national laboratories have with decaying structures after decades of deferred maintenance. However, NREL's oldest major building, the FTLB, is now 22 years old and at the point where significant investments are needed to repair HVAC systems, and other building systems at or nearing their optimal periods of service. The average age of the rest of NREL's space is slightly over 13 years old, including the SERF and other smaller research buildings (Figure B.3.6).



B.3.6 Age of NREL Facilities (as of 9/30/06)

Workstation (Office) and Laboratory Utilization. The utilization of NREL facilities, in terms of both laboratories and workstations (offices and cubicles), can be seen in Figures B.3.7 and B.3.8. Ideal utilization rates for workstations, to allow practical flexibility for changing research directions, support needs, and visitors, is 85%. NREL's overall rate is 86%. If only standard workstations were included in the count, and substandard workstations were excluded, the overall utilization rate would be 98%. Ideal utilization rates for laboratories, again to allow practical flexibility for changing research directions and new research opportunities is 90%. NREL's overall rate is 96%, with only five modest laboratories not currently in use located in Building 16, a leased building in an office park.

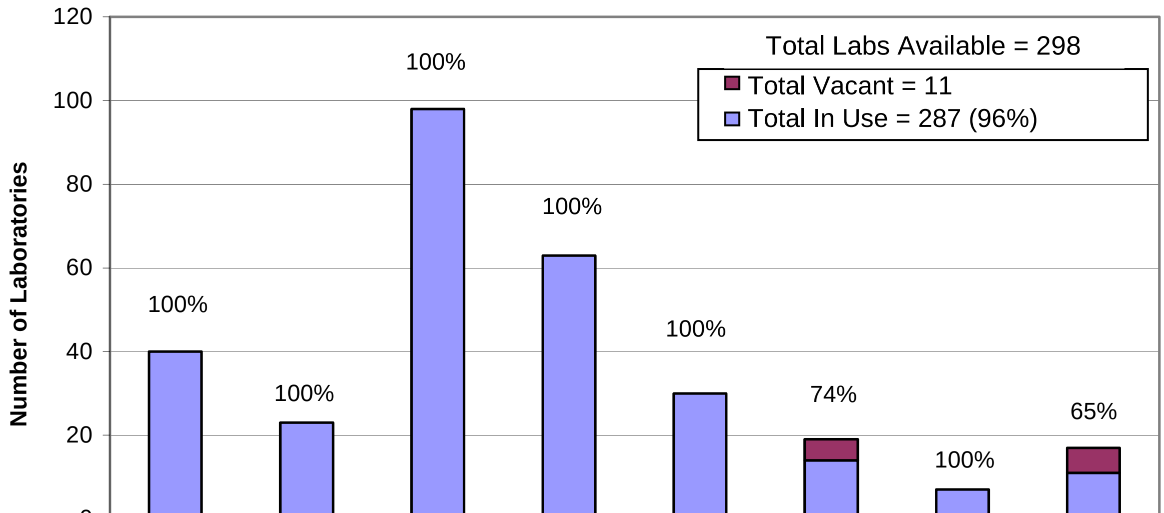
NREL Workstation Utilization



	NWTC	AFUF	FTLB	SERF	STM (Misc.)	S&TF	DW 15+7	DW 16	DW 17	ReFUEL
Vacant	24	13	43	9	11	25	5	20	10	3
In Use	93	27	130	172	54	47	83	194	264	5

Figure B.3.7 NREL Workstation Utilization (as of 09/30/06)

NREL Laboratory Utilization



	NWTC	AFUF	FTLB	SERF	STM	DW 16	ReFUEL	S&TF
Vacant	0	0	0	0	0	5	0	6
In Use	40	23	98	63	30	14	7	11

Figure B.3.8 NREL Laboratory Utilization (as of 09/30/06)

Table B.3.9 lists the opportunities and issues for NREL's facilities. NREL conducts no nuclear work, no classified work, and has no remediation legacy, either nuclear or toxic.

Table B.3.9 Summary of Issues and Opportunities for NREL Facilities

Opportunities

- Facilities relatively new compared to other national laboratories
- No environmental legacy
- Facility condition index rating is "Excellent"
- Several unique facilities not available anywhere else in U.S.
- Showcase facilities for energy efficiency
- Commitment to, and excellent technical expertise for, sustainable building design

Issues

- Current laboratories are 96% utilized, with virtually no flexibility for research changes
- Current workstations are 86% utilized, compared to the target of 85%, limiting flexibility to house students and co-locate functional groups with ~6% of workstations being substandard.
- Multiple sites and undesirable separation of activities limit efficiency and productivity and increase operating costs
- High percentage of staff are in leased facilities, which separates them from researchers on campus, increases redundancy and inefficiency in operations, and increases risk from rent increases after the current lease term.

B.4 Capital Equipment Historical Funding Summary

NREL's capital equipment assets consist of a portfolio of capital equipment that has been purchased, and may be replaced by, three principal sources of funding: EERE programs, Office of Science programs, and institutional (general purpose) equipment funding. As the Lead Program Secretarial Office, EERE is responsible for maintaining and sustaining the EERE program and institutional equipment, as well as providing the equipment needed for new mission needs.

Capital equipment must be managed in a manner that promotes excellence in all areas of mission and meets program milestones and expectations. This requires a balanced approach to managing the assets and also providing for their modernization. Three types of funds are used for all capital equipment, whether for maintenance of existing assets or construction of new assets: NREL operating, institutional (general purpose) equipment, and program capital equipment.

- NREL operating funds have been, and as of December 2006 are still being, used to pay for service contracts on all capital equipment, regardless of current ownership or purpose.
- Institutional (general purpose) equipment funds are used for four categories of equipment that support the entire Laboratory or multiple programs: scientific research equipment, scientific computing equipment, administrative information equipment, and other (safety, security, site operations).

- Program capital equipment funds are used for scientific research or computing equipment that is dedicated to individual programs.

Over the 29-year history of the Laboratory, capital funding for equipment has totaled $133 million: $113 million for program capital equipment and $20 million for institutional capital equipment (Figures B.4.1 (current dollars) and B.4.2 (FY2006$). The historical trends by program are shown in Figures B.4.3 and B.4.4.

Figure B.4.1

Capital Equipment Funding -- Current Dollars

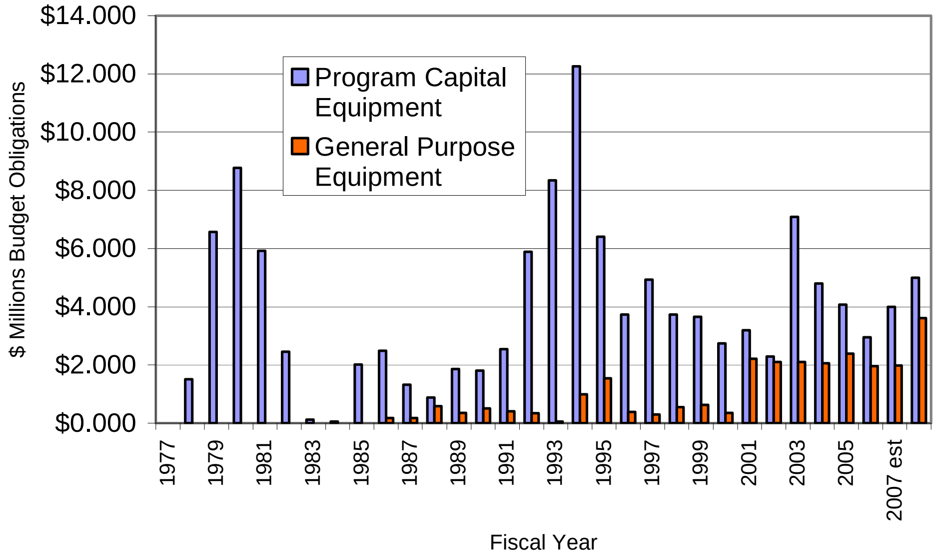


Figure B.4.2

Capital Equipment Funding - $ FY06

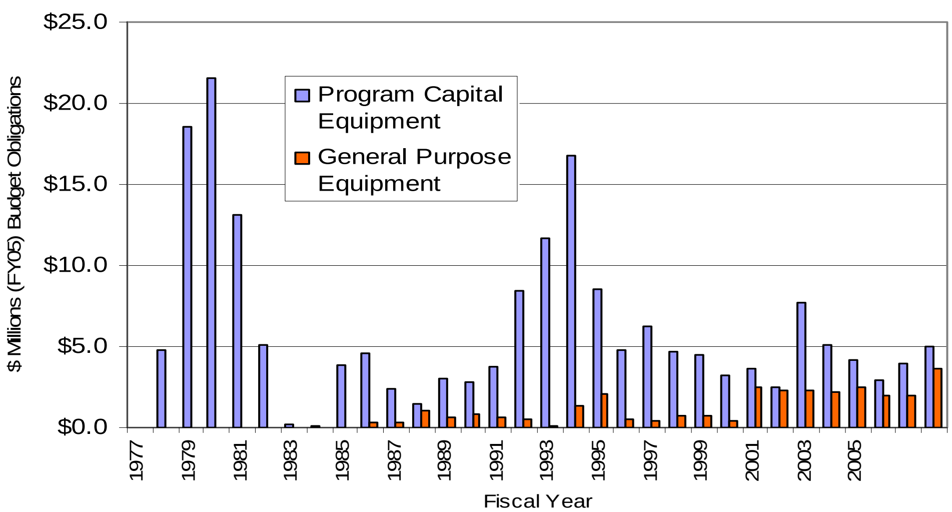


Figure B.4.3

Program Capital Equipment Funding
By Year By Program, 1997-2006 (Current Dollars)

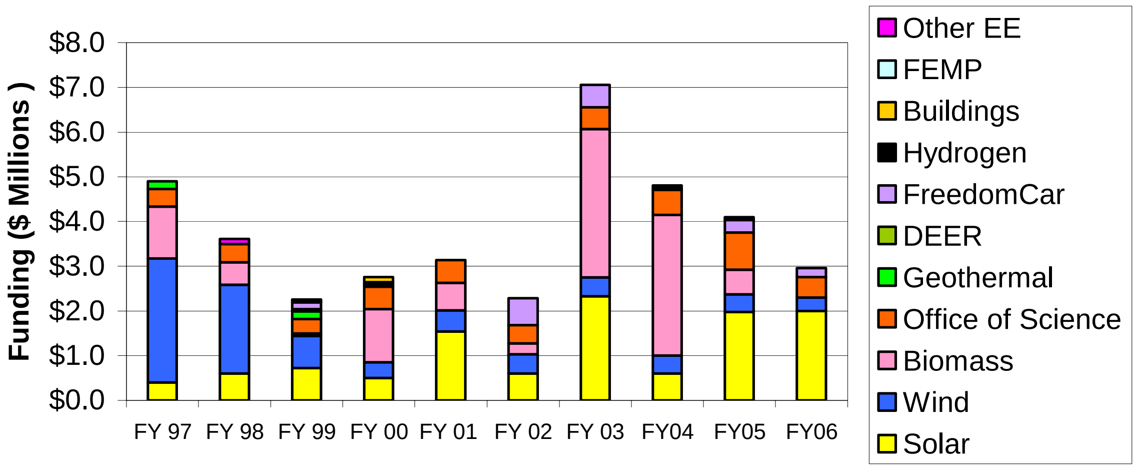
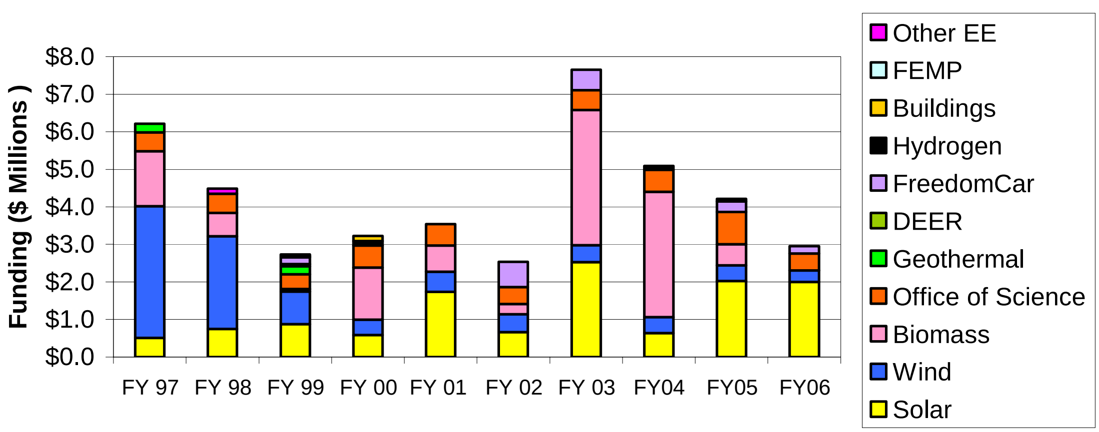


Figure B.4.4

Program Capital Equipment Funding
By Year By Program, 1997-2006 (FY06$)



Appendix C: Capital Investment Principles and Process

C.1 Objective and Scope of the TYSP

The NREL TYSP is the product of a comprehensive planning process. In coordination with NREL's strategic planning processes, the objective of the ten-year site planning process is to reach a shared understanding among NREL and DOE managers of the future goals and expectations of research and development at NREL, and identify the capital investments (facilities, infrastructure, and equipment) that are needed to successfully meet those objectives. The objective of the TYSP itself is to document and communicate these recommendations and the many factors that go into these decisions.

The TYSP is the overarching strategic link between the mission of NREL and the physical assets that make that mission possible. As such, it is a key management tool for developing and communicating the integrated investment rationale – the business case – for capital investments. It also is intended to respond to requirements of DOE Order 430.1B, Real Property Asset Management and fulfills the TYSP requirement of RPAM 430.2.

The scope of the TYSP includes all facilities (buildings), infrastructure (roads, walkways, utilities, etc.), and capital equipment (program-specific and general). It addresses investments necessary over the next 10 years to sustain DOE assets at NREL at the current level of functionality, as well as investments necessary to enhance mission capabilities. While it focuses on capital investments, related operating costs are also discussed where relevant.

C.2 Leadership

The Assistant Secretary for the DOE Office of Energy Efficiency and Renewable Energy is the Lead Program Secretarial Officer for NREL, and as such "owns the site, manages its own program projects, and acts as a host for tenant program secretarial officers by providing facility and/or infrastructure support." (DOE Order 430.1B) (The DOE Office of Science, Office of Energy Transmission and Distribution, and other DOE offices conduct research at NREL. These offices are tenant program secretarial officers.)

Determining capital investment strategy requires involvement and leadership from both technical managers and institutional managers, at both NREL and EERE. The program managers at NREL include the Technology Managers and Center Directors. The institutional managers at NREL include the NREL Office Directors in Site Operations; Information Services; Environment, Safety, Health and Quality; and Finance. NREL's Associate Director for Science & Technology and Associate Director for Laboratory Operations jointly lead the planning process. NREL's Director and all the Associate Directors together make the final decisions on capital investment recommendations to DOE. The integrated team of MRI and Battelle, who manage and operate NREL under contract to DOE, advise on NREL's plans and in some cases provide the means to implement the plan, such as using innovative financing and partnership models as necessary.

C.3 Capital Investment Goals and Outcomes

Goals and Outcomes

Effective planning for capital investments requires clear understanding of the outcome desired. NREL has identified four goals for its capital investments, and several specific outcomes related to those goals:

Goal 1: Accomplish the mission with adequate facilities, infrastructure, and equipment:

- Existing facilities and infrastructure will be maintained in a condition to accomplish its original functionality.
- Existing facilities will be modified, and new facilities and infrastructure will be constructed as necessary, to meet mission requirements and provide enhanced capabilities that will sustain the viability of the Laboratory well into the future.
- Facilities will efficiently and effectively meet specific mission needs, but will also be flexible to adapt to changing research requirements and technologies.

Goal 2: Promote mission excellence through the working environment:

- Activities and organizations will be logically co-located to improve productivity, while cross-program interactions and interdisciplinary science will be encouraged.
- Capital equipment will be added or replaced as necessary to maintain technological relevance and avoid technological obsolescence.
- The laboratories, offices, campus, and research equipment of NREL will significantly contribute to attracting and retaining high-quality staff in a competitive technological job market, and will encourage scientific creativity and discovery.
- State-of-the-art scientific and engineering equipment will be available and maintained. Collaborative use of more expensive items will be encouraged.
- The Laboratory will employ the latest advances in information technology to encourage scientific discovery, enhance worker productivity, and enable convenient interactions with other scientists.
- Visiting professionals and students will be encouraged by providing adequate research and office space.

Goal 3: Demonstrate sustainable design and practices:

- The Laboratory sites and facilities will demonstrate the best principles of sustainability by being cost-effective (efficient to operate and maintain), having minimal impact on the environment, and promoting human wellbeing among the staff and with the surrounding community.
- The Laboratory will be viewed as a good community neighbor.

Goal 4: Maintain safe and secure facilities and operations:

- The Laboratory will provide a safe, healthy, and secure working environment for employees and visitors.
- The visibility of security measures will be minimized to maintain a campus atmosphere consistent with NREL's mission and education and outreach activities.

C.4 Integration and Linkages

Capital investment decisions are integrally linked to many other aspects of an organization's planning and operations. The linkages pertinent to the formulation of NREL's capital investment strategy, and appropriate documents, are enumerated here.

DOE Plans and NREL Performance-Based Management

NREL's performance-based management system, which includes capital planning and management, is guided by programmatic strategy as conveyed through documents such as:

- The National Energy Policy
- The DOE Strategic Plan
- The EERE Strategic Plan
- Multiyear program plans for each of EERE's programs

In addition, NREL is guided by the R&D Budget Priorities articulated by the Office of Science and Technology Policy each year, and the current presidential initiatives such as the Hydrogen Fuel Initiative, Networking and Information Technology R&D, and the National Nanotechnology Initiative.

For investment criteria, management practices and expectations, the guiding federal documents include:

- The President's Management Agenda
- Circular No. A 11 Part 7: Planning, Budgeting, Acquisition, and Management of Capital Assets
- DOE Order 430.1B Real Property Asset Management
- DOE Order 413.3 Program and Project Management Policy for the Planning, Programming, Budgeting, and Acquisition of Capital Assets

NREL's performance-based management system provides the overall framework, tools, and systems to define desired outcomes, focus and align Lab resources on these outcomes, provide evidence of performance, and foster organizational learning and improvement. This system results in Laboratory planning documents including the NREL strategic Roadmap, annual plans, and five-year plans. Figure C.1 shows the linkages among the elements of NREL performance-based management, including NREL strategy, the General Development Vision, and Ten-Year Site Plan, and the dependence on DOE programmatic direction.

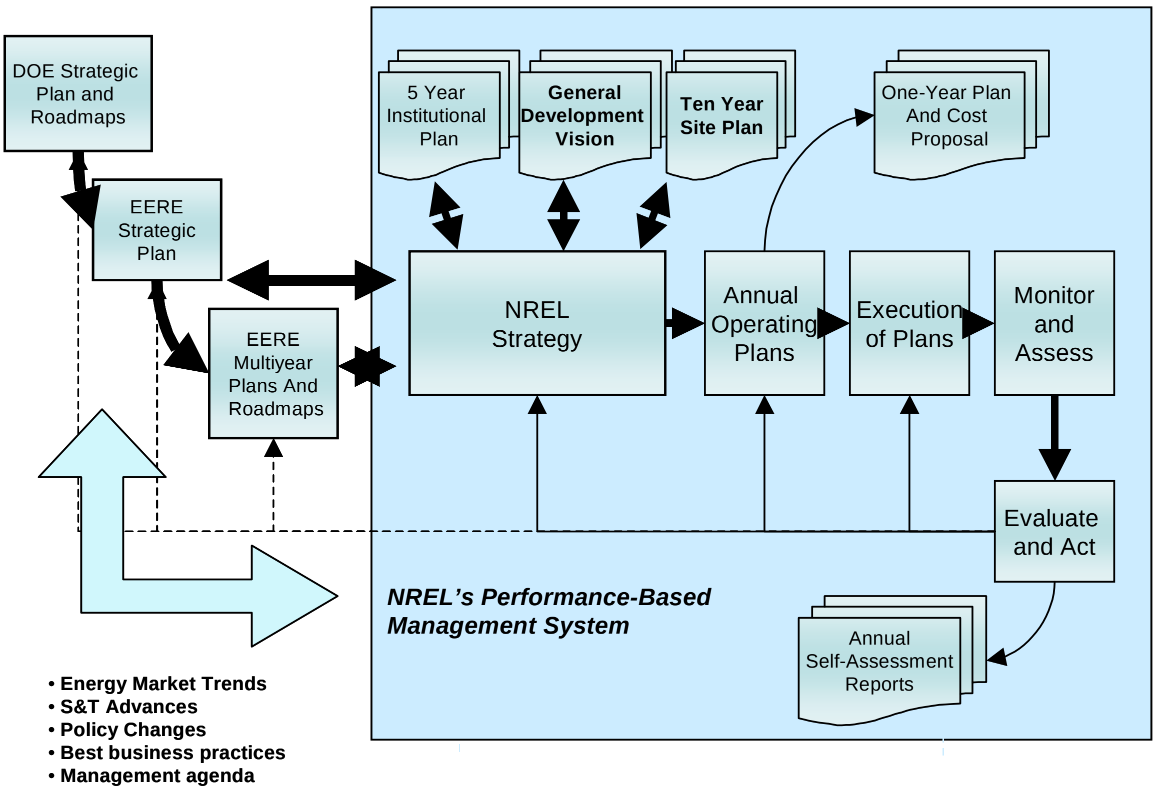


Figure C.4.1. Integration and Linkages in NREL Planning

DOE Order 430.1B

On September 24, 2003, DOE Order 430.1B Real Property Asset Management was issued which put the Department of Energy on the path to improve the management of its real property assets. The new order integrates various management elements and practices into a holistic, performance-based approach to the life-cycle management of the Department's real property assets. It links real property asset planning, programming, budgeting, and evaluation to the Department's multi-faceted missions. Successful implementation of the Order will enable the Department to better carry out its stewardship responsibilities, and will ensure that its facilities and infrastructure are properly sized and in a condition to meet the DOE mission requirements today and in the future.

DOE Order 413.3

On October 13, 2000 the DOE Order 413.3 *Program and Project Management for the Acquisition of Capital Assets* was issued which provides the Department of Energy project management direction for the acquisition of capital assets that are delivered on schedule, within budget, and fully capable of meeting mission performance and environmental, safety, and health standards. The order integrates various project management requirements and practices to provide appropriate guidance and critical decision points during the lifecycle of a project in order to ensure the project meets the established budget, schedule, and scope criteria. Successful implementation of the Order will enable the Department to better carry out its responsibilities and will ensure that its facilities and infrastructure are properly designed and constructed to meet the DOE mission requirements today and in the future.

NREL Design Guidelines

The NREL Design Guidelines are a general overview of the codes, standards, and requirements that NREL follows designing new, or modifying existing, facilities and infrastructure. NREL incorporates International Building Code 2003 as the overarching code. In addition, discipline-specific codes and local codes are utilized in all designs. Safety and functionality are the driving factors for design; however, NREL strives to incorporate maximum energy efficiency, the use of renewable energy, and sustainability. To these ends, NREL policy is to exceed the Federal model Energy Code requirements by 30%, achieve at least a LEED® Silver Rating for all its major new buildings, and utilize the principles of the laboratories for the Twenty-First Century program in the design of its new laboratory buildings.

NREL Design Advisory Board

The Design Advisory Board (DAB), established in 1993, provides advice and counsel to NREL Executive Management with regard to site planning and facility and infrastructure design and planning. This involves review of building placement and exterior physical environments to develop and facilitate an orderly and architecturally cohesive buildout of the South Table Mountain and National Wind Technology Center sites. DAB members consist of individuals external to NREL, DOE, and EERE who provide advice and counsel. The current members include a leading architect and site developer in the Denver area; a landscape architect and urban planner; a member representing the adjacent community; and a representative from Bechtel, an international construction company. Regular participants also include individuals internal to NREL, DOE, and EERE who provide information as required to the members and address the Board’s recommendations.

NREL Governing Board

The NREL Governing Board provides oversight, policy direction, and assistance to the Director of NREL to ensure that high-quality research is performed by the Laboratory, including requirements for facilities, infrastructure, and equipment; that NREL is operated in a cost-effective manner; that NREL remains a world leader in renewable energy and energy efficiency programs; and that NREL meets the policy, program, and management objectives of DOE. The members consist of a small number of senior executives mainly from NREL’s operating contractors.

NREL Technical Staff

NREL technical staff members will assist with the design of NREL site and buildings as planned and budgeted for in their respective programs.

Sustainable NREL Master Plan

Sustainability means the simultaneous and balanced pursuit of economic viability, environmental health, and public responsibility over the long term through appropriate investment decisions and operating practices. As such, sustainability is inherently a centerpiece of the work of the Laboratory. It is the Laboratory's stated objective to become more sustainable in its site planning, facilities and infrastructure design and construction, and operations, in synergy with the Laboratory's mission.

The Laboratory’s focal point for sustainability is the Sustainable NREL program. The Laboratory’s goal is to “institutionalize” sustainability. The Sustainable NREL Master Plan describes the Laboratory's sustainability activities and serves as the annual planning document for these activities (http://www.nrel.gov/sustainable_nrel/), and it includes and addresses the Federal and Congressional mandates that pertain to the sustainability of Laboratory operations and sustainability impacts of capital investment decisions. These mandates are listed below and are supplemented by internal Laboratory goals.

- Executive Order 13123, Greening the Government Through Efficient Energy Management
- DOE 430.2A, Departmental Energy and Utilities Management
- Energy Policy Act of 1992
- Energy Policy Act of 2005
- Executive Order 13148, Greening the government Through Federal Fleet and Transportation Efficiency
- DOE Compliance Strategy for Executive Order 13149
- Executive Order 13101, Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition
- Resource Conservation and Recovery Act of 1976
- EPA Comprehensive Guidelines
- Executive Order 13146 (DOE Order 450.1) Greening the Government Through Leadership in Environmental Management

This Plan sets Laboratory-wide performance objectives, supporting goals, specific implementation strategies, and an overall management plan. Several of these objectives and goals are directly related to facility planning and building operation, including energy use reduction, water use reduction, new building construction and retrofits, greenhouse gas emissions, and transportation.

Environment, Safety, Health and Quality

Environmental, Safety, Health and Quality (ESH&Q) planning and management is conducted via an integrated ESH&Q risk assessment process that utilizes proactive mechanisms to identify risks presented by planned activities on NREL sites. Based on the risk assessment appropriate controls are identified and implemented to maintain the risk presented by these activities at an acceptable level. The acceptable level of risk is established for all NREL activities via NREL policy.

Components of the risk assessment process may be site wide or activity specific, with significant overlap and interaction between the two types of processes. Site wide activities result in periodic reports such as environmental assessments, fire protection assessments, and security vulnerability analyses that provide ESH&Q considerations necessary for effective mid to long-range planning. These reports are used in conjunction with other Laboratory planning processes and reports to make informed decisions concerning site development and are updated on a regular basis. Activity specific processes include development of Hazard Analysis Reviews and Fire Hazard Analyses for major facilities, and Safe Operating Procedures for individual research and support tasks. These processes and resultant documentation promote effective planning and management of the ESH&Q aspects of immediate to mid-term activities and facilities, and are coordinated with the ESH&Q considerations identified via the site wide processes. Other Environment, Safety, Health and Quality Considerations for DOE-Owned Sites are:

- Conservation easements, environmentally sensitive areas, and other no-build zones are identified in the NWTC Environment Assessment, the STM Environmental Assessment, and in Appendices B and C of this TYSP.
- Environmental Permitting – There may be caps on air emissions, the types and quantities of wastewater discharged, etc., and these are addressed via the ESH&Q risk assessment processes with necessary permits being obtained.

- Fire Protection –Surveys have been conducted internally and by third-party experts with a determination that there is no unusual threat presented by wildfires on NREL sites, a particular DOE concern after the Los Alamos fires. Fire department services are readily available for both sites.
- Off-Site Exposures – There are no undue threats presented to the NREL sites by neighboring operations. The greatest threat was presented by the Rocky Flats nuclear weapons operations of earlier decades, but NREL lies both upstream and upwind of those activities, and carries no environmental legacy. Limitations on NREL development and operations due to the proximity of neighbors are well known and addressed in the various NREL planning processes.

To facilitate proper integration of ESH&Q considerations in Laboratory-level planning the ESH&Q Office has direct representation and involvement in all of the planning and management processes described in this section. Conversely, representatives of other Laboratory-level planning processes directly participate in the risk assessment processes managed by the ESH&Q Office.

ESH&Q planning is, and will continue to be, an integral part of all capital investments considered at NREL. ESH&Q active involvement begins when a new construction project is in the earliest stages of conceptual discussion, and continues as projects develop. ESH&Q staff reviews all GPP and GPE requests before they come before serious consideration by NREL management. The Laboratory will continue this strong and pervasive involvement by ESH&Q staff in all capital investment projects.

With regard to the specific projects proposed in this Ten-Year Site Plan, the appropriate and necessary level of ESH&Q risk assessment has been conducted for all potential facilities and operations. More detailed assessments will be conducted as the development of these facilities and operations proceed. All ESH&Q hazards presented by the proposed operations already exist within current NREL facilities to some degree. Some limitations may be imposed on specific proposed facilities and operations, such as their location relative to site borders or quantities of hazardous materials allowed, in order to maintain an acceptable level of risk. However, no ESH&Q hazards have yet been identified that cannot be controlled by application of appropriate codes, standards, and NREL procedures. The acceptable level of risk established by NREL policy can be maintained in all cases, as the proposed projects are understood at the time of publication of this report.

Security

Security and Emergency Preparedness Office (Security) planning and management is conducted via an integrated threat assessment process that utilizes proactive mechanisms to identify vulnerabilities presented by site growth and planned business/research activities. Based on the Threat/Vulnerability Assessment, appropriate controls are identified and implemented to maintain the risk presented at an acceptable level for current and long range planning. Security will utilize the threat and vulnerability assessment process to establish effective protection measures for current and long range planning.

To facilitate proper integration of Security considerations in Laboratory-level planning, the Security Office has direct representation and involvement in all of the planning and management processes related to facility and site planning. Security reviews all relevant GPP and GPE requests before serious consideration by NREL management. Security recommendations are consistently integrated into the NREL site planning process.

Specific physical security requirements include:

- Parking areas should be located 90 feet from buildings and appropriate vehicle barriers should protect the building's perimeter from moving vehicles.
- Trashcans, thick shrubbery, or anything that might provide concealment may not be adjacent to the building's exterior.
- Property boundaries will be marked with fencing and/or signage to deter trespassing.
- Appropriate interior and exterior electronic surveillance equipment will be installed.
- Appropriate exterior lighting (building and parking areas) will be included.
- Major entrances should be limited to as few as practicable.
- All windows must be sealed or alarmed.
- Security Alarms and electronic Access Control systems and devices must be compatible with current systems and all exterior hinges must be welded.
- Interior access to utility/power plant rooms must be controlled (locked doors).
- Air intakes must be sufficiently inaccessible (roof mounted or adequately sealed from mischief).

Community Interactions

NREL strives to demonstrate its value as a corporate citizen within the community by interacting positively with community organizations and citizens. The Laboratory's South Table Mountain site is bordered by several neighborhoods whose residents have a direct line of sight to its buildings and daily operational activities. Regular communications with these neighbors, especially about changes on the STM campus that will be visible to the neighbors, is of paramount importance in sustaining NREL's reputation as a good neighbor. This communication occurs through community meetings and newsletters, an information hot line, and public access to NREL's Visitors Center where information is provided about facilities, construction projects, technologies, and special public events at NREL. Thus, the Pleasant View community is given multiple opportunities to participate in NREL's site planning process.

Beyond the local neighborhoods, NREL participates in regional long-range planning activities, neighborhood association meetings, and responds to county information requests about its facilities plans. The Laboratory works with regional developers, providing technical consultation on sustainable or "green" building projects in nearby cities. NREL technical staff also collaborates with regional governmental entities to facilitate adoption of renewable energy technologies through construction and implementation of renewable energy demonstration projects that benefit local communities.

At the National Wind Technology Center, NREL's interactions with the community include hosting tours and special briefings for community leaders and special interest groups.

C.5 Capital Planning Processes

Planning Process for Construction Line Items and Large General Plant Projects

NREL's capital planning process begins with the mission needs of its Lead Program Secretarial Office, EERE. With the guidance and input from the DOE documents listed in section 5.4, and ongoing interchanges among NREL and EERE managers, NREL's programmatic facility and equipment strategies and needs are identified. Simultaneously, with guidance and inputs from the NREL Institutional Plan and strategic discussions, the NREL General Development Vision, condition assessments, and consideration of the factors affecting site development, NREL's institutional needs for facilities, infrastructure, and equipment are identified. Joint meetings are then held of technology managers representing each EERE and the Office of Science Program at NREL, Center Directors managing the people and capital resources to carry out programmatic work, and Laboratory Operational Managers (including the General Development Vision Leader, Site Operations, Environment, Safety, Health & Quality; Finance; and Information Technology) to develop facility and infrastructure solutions to meet mission requirements. These forums bring together the individuals needed to work out integrated and practical options and recommendations for the facility and infrastructure challenges facing the Laboratory. Through a series of discussions at various levels, the most critical proposals are identified, sequenced, and prioritized by NREL Executive Management for discussion with DOE Management.

Planning Process for Small General Plant Projects and General Purpose Equipment
Condition assessments are conducted for facilities, infrastructure, and capital equipment. These assessments are key to developing the Laboratory's deferred maintenance backlog reduction plan, and other plans for facilities, infrastructure, and equipment. These assessments are also key to identifying the individual projects that require upgrade or replacement to sustain functionality. NREL managers also propose projects to provide new capability to support evolving missions. The individual projects proposed by managers are reviewed by Executive Management, who determines the priorities for available funding at the start of each fiscal year.

Planning Process for Program Capital Equipment
The need for capital equipment replacements is informed by the equipment condition assessment information, prepared each July and October. In addition, items are identified during the preparation of the programmatic AOP to extend, expand, or add technical capability. The requests are reviewed and approved by the Technology Managers, in consultation with the Center Directors.

DOE Project Management Processes of the DOE Office of Engineering and Construction Management
NREL's construction line item projects are managed in accordance with the DOE Project Management Process directed by the DOE Office of Engineering and Construction Management. Table C.5.2 describes the steps of that process, and Figure C.5.1 gives an indication of the timing and duration of the steps.

Figure C5.1 depicts conceptually the life cycle cost of ownership of an asset. In this example the time in years on the x-axis and the cost on the y-axis are not quantified, since each asset will have a different cost curve. When a new asset is acquired, maintenance costs initially are low. As the asset becomes older, maintenance costs begin to rise. The design or service life of the asset, or optimum period as defined in the Real Property Asset Management (RPAM) order, is eventually reached. Ideally, at the end of the design life, the asset is replaced, and the initially low maintenance cost profile begins anew.

When the old asset is replaced, the rising long-term maintenance cost of the old asset is avoided. If the asset is not replaced the maintenance costs continue to rise. Assets not replaced at the end of their design life become deferred maintenance as defined in the RPAM order. The implication to management is to minimize the total area under the cost curve. The area under the cost curve over the life of the asset represents the total cost of ownership.

Figure C5.1 Life Cycle Cost curve for an Asset with Replacement

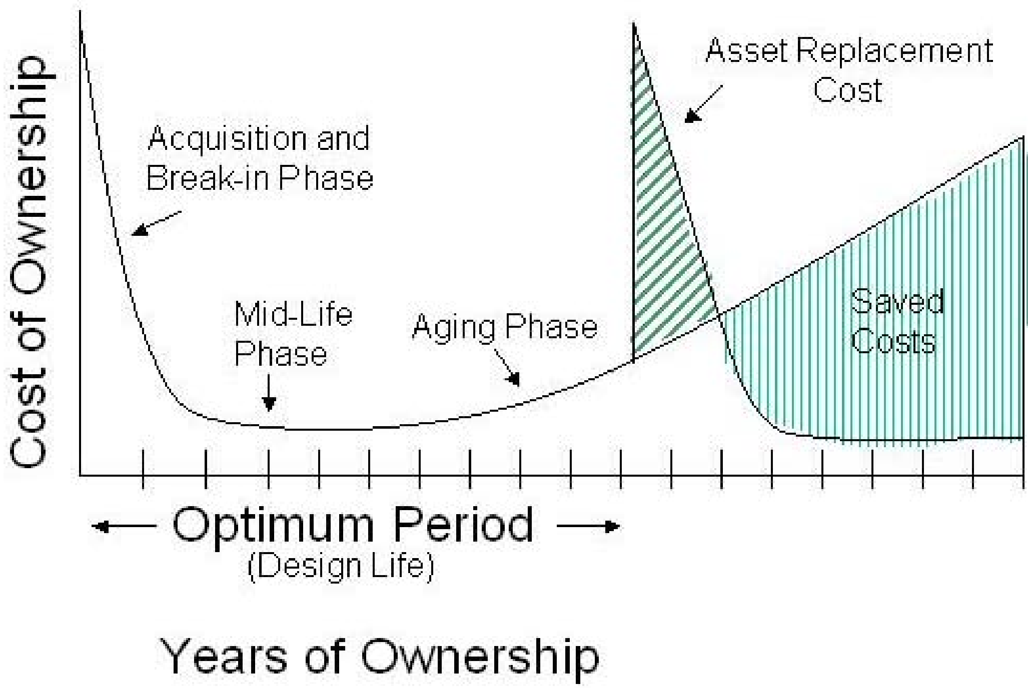


Table C5.2 Project Management Process (DOE Order 413.3)

	CD-0	CD-1	CD-2	CD-3	CD-4
Approves	• Mission Need	• Preliminary Baseline Range	• Performance Baseline	• Start of Construction	• Project Acceptance
Launches	• Conceptual Design • Budget Request for PED funds	• Preliminary Engineering Design	• Final Design • Construction Budget Request	• Construction	• Operations
Deliverables	• Conceptual Design Package • Preliminary Project Execution Plan • Preliminary Hazards Report • Preliminary Design Phase Budget & Schedule • NEPA Documentation • Project Data Sheet • Acquisition Plan • Preliminary Baseline Range (cost/scope/ schedule)	• Preliminary Engineering Design Package • Final Project Execution Plan • Construction Project Data Sheet • Independent Cost Estimate • External Independent Review (OECM) ** • Performance Baseline (cost/scope/ schedule)	• Final Design package (Construction Design Documents) • Updated Project Execution Plan • Internal Project Review with OECM ** Review	• Completed Facility Turnover & Startup Plan • O&M Manuals • As-Builts • Operational Readiness Review	
Next Decision	• CD-1 Package to AE* for Decision	• CD-2 Package to AE* for Decision	• CD-3 Package to AE* for Decision	• CD-4 Package to AE* for Decision	
Funding	• Operating Funds	• Capital Project Engineer Design Funds	• Capital Project Engineer Design Funds	• Capital Construction Funds	

*Acquisition Executive
**Office of Engineering & Construction Management

Appendix D: Replacement Plant Value Detail and NREL Building Summary

Table D.1

NREL Replacement Plant Value (November 2006)
Summary

South Table Mountain Buildings	$132,762,505
National Wind Technology Center Buildings	$15,138,655
South Table Mountain Other Structures and Facilities	$13,638,390
National Wind Technology Center Other Structures and Facilities	$8,077,915
Denver West Other Structures and Facilities	$414,959
Total	**$170,032,423**

Table D.2
NREL Replacement Plant Value (November 2006)
South Table Mountain Buildings

Name-Bldg #	Sq Ft*	FY06 RPV	R.S Means Model Description	R.S Means Base Model SF Cost	Denver Geo Factor	NREL Site Factor	Adj.Model SF Cost
	Col A	Col B	Col C	Col D	Col E	Col F	Col G
Alternative Fuels User Facility	32,751	$10,889,218	Labs-Bio/Envir (80/20)	228	1	1.45800	$332
Bulk Storage Building	4,000	$312,096	Warehouse/Storage	53	1	1.45800	$77
Facilities Building	3,786	$895,718	Maintenance Shops	161	1	1.45800	$235
FETA Ammo Bunker	361	$218,588	Bunkers/Magazines	402	1	1.45800	$586
Field Test Laboratory	127,000	$42,222,948	Labs-Bio/Envir (80/20)	228	1	1.45800	$332
High Flux Solar Furnace-7117	261	$22,169	Warehouse/Storage	53	1	1.45800	$77
High Flux Solar Furnace-7118	184	$17,218	Warehouse/Storage	53	1	1.45800	$77
Concentrated Solar Flux Furnace	730	$249,863	Lab-Physics/Comp. (80/20)	231	1	1.45800	$337
Historical Bunker-4317	386	$237,241	Bunkers/Magazines	402	1	1.45800	$586
Outdoor Test Facility	11,247	$3,482,403	Labs-Bio/Envir (80/20)	212	1	1.45800	$309
Shipping & Receiving Facility	14,206	$3,997,483	Hardened Storage	193	1	1.45800	$281
Site Entrance Building	814	$127,055	Security/Badging	102	1	1.45800	$149
Solar Energy Reseach Facility	115,891	$39,034,857	Lab-Physics/Comp. (80/20)	231	1	1.45800	$337
Solar Industrial Mesa Test Area-7421	1,220	$96,274	Warehouse/Storage	53	1	1.45800	$77
Solar Industrial Mesa Test Area-7521	576	$178,680	Lab-Physics/Comp. (50/50)	208	1	1.45800	$303
Thermal Test Facility	10,682	$3,554,953	Labs-Bio/Envir (80/20)	228	1	1.45800	$332
Visitor's Center	6,459	$1,445,987	Auditorium/Meeting	127	1	1.45800	$185
Waste Handling Facility	1,165	$329,824	Hardened Storage	193	1	1.45800	$281
Science and Technology Facility	71,347	$24,139,527	Lab-Physics/Comp (80/20)	231	1	1.45800	$337
SRRL/Metrology-7225	2,684	$924,966	Lab-Physics/Comp (80/20)	231	1	1.45800	$337
SRRL-7315	513	$187,777	Lab-Physics/Comp (80/20)	231	1	1.45800	$337
Stone Face Bunker-FETA	327	$197,660	Bunkers/Magazines	402	1	1.45800	$586
Subtotal	**406,590**	**$132,762,505**					

NOTES: Column B = Column A x Column G
Column G = Column D x Column E x Column F

*Square footage differs from Table page D-7 because of rounding and other minor differences

Table D.3
NREL Replacement Plant Value (November 2006)
National Wind Technology Center Buildings

Name-Bldg #	Sq Ft*	FY06 RPV	R.S Means Model Description	R.S Means Base Model SF Cost	Denver Geo Factor	NREL Site Factor	Adj.Model SF Cost
	Col A	Col B	Col C	Col D	Col E	Col F	Col G
Admistrative Bldg-251	22,033	$6,906,685	Labs-Hard Engn (80/20)	215	1	1.45800	$313
Blade Test Facility-252	2,563	$803,424	Labs-Hard Engn (80/20)	215	1	1.45800	$313
Switchgear Bldg-253	803	$62,051	Warehouse/Storage	53	1	1.45800	$77
IUF-254	11,735	$3,678,570	Labs-Hard Engn (80/20)	215	1	1.45800	$313
Dynomometer-255	2,452	$493,352	High Bay Facility	138	1	1.45800	$201
Modal/Elex Test-256	5,600	$1,755,432	Labs-Hard Engn (80/20)	215	1	1.45800	$313
Hybrid Power Test H-1	1,790	$561,111	Labs-Hard Engn (80/20)	215	1	1.45800	$313
Data Shed - 1.1	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Data Shed - 1.2	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Data Shed - 1.3	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Data Shed - 2.25353	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Data Shed - 1.8	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Data Shed - 1.9	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Data Shed - 3.2	188	$14,528	Warehouse/Storage	53	1	1.45800	$77
Data Shed - 3.4	188	$14,528	Warehouse/Storage	53	1	1.45800	$77
Data Shed - 4.2	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Building M1A	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Building M1B	50	$3,864	Warehouse/Storage	53	1	1.45800	$77
Building M1C	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Research Tower M2	100	$7,727	Warehouse/Storage	53	1	1.45800	$77
Research Tower M3	200	$15,455	Warehouse/Storage	53	1	1.45800	$77
Pumphouse	452	$34,928	Warehouse/Storage	53	1	1.45800	$77
Trailer-248	1843	$239,151	Office-Small	89	1	1.45800	$130
Trailer-249	1843	$239,151	Office-Small	89	1	1.45800	$130
Trailer-257	1843	$239,151	Office-Small	89	1	1.45800	$130
Subtotal	**54,583**	**$15,138,655**					

NOTES: Column B = Column A x Column G
Column G = Column D x Column E x Column F

*Square footage differs from Table page D-7 because of rounding and other minor differences

Table D.4
NREL Replacement Plant Value (November 2006)
South Table Mountain Other Structures and Facilities (OSF)

OSF Usage	Size Capacity	Unit of Measure	Replacement Value
1129 Sidewalks	5000	FEET	$97,112
1729 Primary Roads	1	MILES	$1,404,574
1739 Secondary Roads	1	MILES	$933,997
1749 Tertiary Roads	1	MILES	$6,228
1789 Parking (Vehicular)	2,022	SQYD	$870,893
2009 Catchall	4	EACH	$2,898,181
2429 Fencing (Security)	18,122	FEET	$1,099,970
2809 Flood Control and Navigation	551	EACH	$327,224
3009 Other, Research and Development	10	EACH	$6,808
6271 Pol Services for Vehicles	2	PMP	$145,094
6929 Security Lights	4,515	EACH	$489,081
7007 Communications System Lines	12	EACH	$71,840
7231 Cables, Under Ground (Voice/Data)	18,488,100	FEET	$3,110,938
7281 Switching Stations (Voice/Data)	1	EACH	$253,877
7321 Cables, Above Ground (Fire Alarm)	800	FEET	$16,683
7331 Cables, Under Ground (Fire Alarm)	6,000	FEET	$133,071
7509 Energy Management Control Systems	800	PTS	$141,114
8119 Water Lines	3,600	FEET	$307,586
8129 Piping (Potable Water)	4,800	FEET	$167,815
8129 Piping (Non-Potable Water)	3600	FEET	$307,587
8141 Piping (Fire Protection Water)	3,600	FEET	$328,323
8329 Piping (Natural Gas)	200	FEET	$2,156
8929 Electrical Cables Primary	6	MILES	$397,646
8988 Power Transformers	2,000	KVA	$120,594
		Total:	**$13,638,390**

Table D.5
NREL Replacement Plant Value (November 2006)
National Wind Technology Center Other Structures and Facilities (OSF)

OSF Usage	Size Capacity	Unit of Measure	Replacement Value
1129 Sidewalks	330	FEET	$7,337
1729 Primary Roads	2	MILES	$987,883
1739 Secondary Roads	1	MILES	$104,263
1749 Tertiary Roads	3	MILES	$36,596
1789 Parking (Vehicular)	23,363	SQYD	$212,479
2009 Catchall	2	EACH	$1,087,975
2429 Fencing (Security)	15,953	FEET	$515,461
3009 Other, Research and Development	1	EACH	$2,233,717
5906 Electric Generators	200	KVA	$130,165
6929 Security Lights	333	EACH	$34,752
7231 Cables, Under Ground (Voice/Data)	3,000	FEET	$21,613
7509 Energy Management Control Systems	0	PTS	$20,185
8119 Water Lines	950	FEET	$33,741
8129 Piping (Potable Water)	6,230	FEET	$302,631
8141 Piping (Fire Protection Water)	7,460	FEET	$654,821
8329 Piping (Natural Gas)	7,262	FEET	$153,419
8909 Electrical Distribution System	2	EACH	$1,540,877
		Total:	**$8,077,915**

Table D.6

NREL Replacement Plant Value (November 2006)
Denver West Other Structures and Facilities (OSF)

OSF Usage	Size Capacity	Unit of Measure	Replacement Value
2009 Catchall	1	EACH	$38,880
5729 Plants (Chilled Water)	70	TONS	$40,650
7007 Communications System Lines	1	EACH	$184,469
7279 Towers (Voice Data)	5	HGTFT	$99,400
7281 Switching Stations (Voice/Data)	1	EACH	$51,559
		Total:	**$414,959**

Table D.7

NREL Building Detail (as of 9/30/06)

Site	Bldg No.	Building Name	Fiscal Year Acquired or Constructed	Gross Sq. Ft.	No. of Occupants
LEASED					
	7	Denver West Bldg 7	2005	4,467	11
	15	Denver West Bldg 15	1979	29,100	72
	16	Denver West Bldg 16	1980	85,906	194
	17	Denver West Bldg 17	1980	87,774	264
		ReFUEL Facility	2002	4,576	5
	6800	Joyce Street Facility	1989	56,000	0
	901	Washington D.C. Office	2000	7,178	14
		Total - Leased		275,001	560
OWNED					
South Table Mountain	8606	Alternative Fuels User Facility	1985/1994	32,751	27
	9304	Bulk Storage Building	1988	3,792	
	9306	Facility Maintenance Building	1988	3,787	
	5923	FETA Ammobunker	1981	361	
	7603	MISR Power Distribution	1980	0	
	5308	Field Test Laboratory	1984	126,572	130
	7117	High Flux Solar Furnace	1990	160	
	7118	High Flux Solar Furnace	1990	184	
	7119	High Flux Solar Furnace	1990	730	
	4317	Historical Bunker	1981	386	
	7704	Outdoor Test Facility	1995	11,247	14
	4015	Science and Technology Facility	2006	71,347	47
	9400	Shipping and Receiving Facility	1997	14,207	12
	1802	Site Entrance Building	1994	814	13
	4515	Solar Energy Research Facility	1993	115,890	172
	7421	Solar Industrial Mesa Test Area	1992	544	
	7521	Solar Industrial Mesa Test Area	1992	576	
	4703	Stone Face Bunker - FETA	1981	0	
	8206	Thermal Test Facility	1996	10,682	6
	1904	Visitor's Center	1994	6,459	2
	4716	Waste Handling Facility	1991	1,065	
	7225	SRRL / Metrology	2000	2,688	7
		Total - STM		404,242	430
National Wind Technology Center	101	Guard Post	2003	160	1
	251	NWTC Administration Building	1982	22,026	54
	252	NWTC Blade Test Facility	1979	2,469	
	253	NWTC Building 253	1981	803	
	254	NWTC Industrial Users Facility	1996	11,394	13
	248	NWTC Trailer	1998	1,843	11
	249	NWTC Trailer	1998	1,843	5
	257	NWTC Trailer	1998	1,843	5
	255	Dynomomenter Spin Test Facility	1999	5,570	
	256	Modal Test Facility	1999	2,212	
	152	Pump House		495	
	1.1	Data Shed 1.1	1994	108	
	1.2	Data Shed 1.2	1994	252	
	1.3	Data Shed 1.3	1994	144	
	1.4	Data Shed 1.4	1994	150	
	1.7	Data Shed 1.7	1996	54	
	1.8	Data Shed 1.8	1998	105	
	1.9	Data Shed 1.9	1998	105	
	1E.2	Data Shed	1997	441	
	3.1	Wind Turbine	1994	300	
	3.2	Data Shed 3.2	1994	80	
	3.4	Wind Turbine Test Site & Shed	2000	225	
	4.2	Data Shed 4.2	1996	625	3
	H-1	Hybrid Power Test Bed	1997/2001	1,790	1
	M-1-A	Building M-1-A	1994	525	
	M-1-B	Building M-1-B	1994	150	
	M-1-C	Building M-1-C	1994	180	
	M-2	Research Tower	1994	96	
	M-3	Research Tower	1994	96	
		Total - NWTC		**56,084**	**93**
		Total - Owned		**460,326**	**523**
		Totals		**735,327**	**1083**

Appendix E: Sustainability and Campus Energy Strategy

E.1 Sustainability Goals

NREL relies upon its Sustainable NREL Master Plan to guide the design of individual buildings and infrastructure projects, and overall Lab operations, towards specific goals of environmental sustainability. Sustainability is defined as "the simultaneous and balanced pursuit of economic viability, environmental health, and public responsibility over the long term through appropriate investment decisions and operating practices." Sustainability goals are considered in the identification and development of all NREL construction projects and equipment purchases, whether to maintain the functionality of current assets or to acquire new assets for expanded capabilities. Sustainability goals include:

- Manage the impact on the environment caused by the placement and general design of Laboratory structures including buildings, roads, parking, storm water management, etc.
- Maintain, protect, and restore natural and landscaped environments to sustain natural and native ecological systems.
- Reduce water consumption and manage water discharges from the site.
- Reduce energy use in all building designs and operations.
- Reduce the impact of local Laboratory travel (within sites, between sites, or to local destinations) on the environment through choices leading toward pedestrian campuses, the use of advanced vehicles and bicycles, walking, and public transportation.
- Reduce the use of materials and the creation of waste by reducing, reusing, and recycling materials needed for Laboratory operations.
- Increase the purchase and use of environmentally sensitive products, such as products with the highest recycled content, bio-based products and products made from energy efficient materials and processes.
- Provide an environment, both indoors and outdoors adjacent to Laboratory facilities, that promotes efficiency and effectiveness, and encourages the creativity and personal motivation required for excellence in scientific, engineering, technology development, and support functions.

E.2 Campus Energy Strategy

Today the NREL campus is carbon neutral because the Laboratory purchases renewable energy credits to offset the carbon dioxide generated as a by-product of fossil fuel consumption. As NREL builds out its campus, the Laboratory will use every opportunity to demonstrate and showcase to other Federal, private and academic research campuses both how to plan for and significantly reduce conventional energy usage using both demand-side reduction and supply side techniques. This will provide the opportunity to move the latest energy efficiency and renewable energy technology from inside the lab to demonstration and showcasing outside the lab, further positioning NREL as both as a nationwide center of excellence for state-of-the-art renewable research and development as well as a state-of the-art campus for the application and demonstration of energy efficiency and the use of renewable energy. NREL's buildings, on-site and grid power supply, and transportation system will evolve to become one connected energy system through this campus energy strategy

The following concepts apply right now to the South Table Mountain Campus (STM), but with further planning, the same types of concepts can be applied to the National Wind Technology Center. Over time, building heating and cooling systems at the STM campus will be interconnected as a district heating system (utility distribution grid) using several central plants located near load centers on the campus. The central plants will be managed as an interconnected system through real-time energy use monitoring. This allows NREL to manage its energy demand throughout the campus. Renewable power supply technologies, such as biomass combustion, photovoltaics (PV), biomass gasification and renewable hydrogen production, will be able to be “plugged in” to the Laboratory utility distribution grid moving the laboratory toward the goal of a campus which uses on-site renewable energy to meet a significant portion of its energy needs over time.

Energy Efficient Design

The first priority in the NREL campus energy strategy is to invest in site design and building development to maximize energy efficiency, with building orientation and massing appropriate to take advantage of passive solar design for heating, cooling and natural lighting in all new building construction. NREL buildings are primarily a mix of laboratory and office buildings. Typical lab buildings use four to six times more energy per unit of area than typical office buildings. Since labs use energy differently than offices, the low-energy design strategies applied in offices are different than the set of strategies applied in lab buildings. Low-energy design strategies in office buildings focus primarily on reducing energy for lighting and cooling while strategies in laboratories focus on reducing energy needed to meet ventilation requirements.

In the next five years NREL plans to build several hundred thousand square feet of office buildings. The first module is currently under design. NREL has set an aggressive U.S Green Buildings Council (USGBC) Leadership in Energy and Environmental Design (LEED) goal of “Platinum” for the RSF which includes an energy design goal of 25 KBTU/ft^2/year. This target is 50% more energy efficient than a conventional building designed to the ASHRAE 90.1 (2004) standard. For the purpose of campus planning, it is assumed that NREL can meet this energy target in FY2006 and that all buildings planned on the NREL campus in the future can be designed to exceed this performance target by 1% per year. Office buildings designed on the NREL campus in 2026 will therefore require only 22.5 KBTU\ft^2\year of energy.

NREL completed the 71,000 ft^2 Science and Technology Facility (S&TF) in FY2006, and plans to build several hundred thousand square feet of new lab buildings in the next several years. The NREL energy target for lab buildings, based on the design of the S&TF, is 281KBTU \ft^2\yr. This is estimated to be 41% more energy efficient than a conventional lab building designed to the ASHRAE 90.1 1999 standard in 2006. It is assumed that all new lab buildings built on the NREL campus will also exceed this performance target by 1% per year.

District Heating System Concepts

Today, the NREL buildings are clustered on the north central and western portion of the STM site. There are two central heating plants on the STM campus, one located in the Field Test Laboratory (FTLB) and one located at the Solar Energy Research Facility (SERF). The central plant in the FTLB is connected to the buildings on the west portion of the site through a utility spine. This has been in operation since 1993 and working well. The central plant in the SERF is connected to the STF and will provide power for both buildings.

When specific building locations and load characteristics are better defined, NREL will determine whether the most effective energy strategy is one campus-wide district heating system where one central plant services the entire site through piping, or a set of three smaller district heating systems: north central, south central, and northeast - with piping to individual buildings in that section only. As shown in Table E.2.1, the energy loads on the north central, south central and eastern portion of the campus will be approximately equal over the 20-25-year time horizon.

Table E.2.1 - Shifting Energy Loads at the STM site over time

	2006 Loads (10^9 BTU)	2006 % by location	2016 Loads (10^9 BTU)	2016 % breakdown	2026 Loads (10^9 breakdown)	2026 % breakdown
No. Central and West	91	100%	111	45%	115	35%
South central			49	20%	121	37%
East Campus			86	35%	93	28%

Note: *Note: The purpose is to look to see where the major energy loads will be on campus in 10 years and 20 years out. Because office buildings use about 1/4 the energy of a lab building on a SF basis, even though RSF is large, proportionally energy use is small. In 2016, the major load is still north central and west campus; by 2026, energy loads are equally proportioned North, South and East. In 2016, this assumes 477,000ft^2 of office space and 150,000 ft2 of labs on the South Central campus and 341,000ft^2 of new labs on the east campus; in 2027 this assumes a total of 537,000ft^2 of office space and 285,000 ft2 of labs on the South Central campus and 341,000ft^2 of new labs and 36,000 in a new visitors center on the east campus. In addition, there would be 106,900 ft2 in new labs added to the north central and west area.*

If a campus-wide district heating system is determined to be the best choice in the future, NREL will need new sets of piping runs to connect 1) the north central campus to the south campus, and 2) the north central campus to the east campus.

Renewable Power Generation Concepts

NREL makes extensive use of its on-site renewable power generation sources. In FY2006, wind turbines used during research and development activities at the National Wind Technology Center (NWTC) generated enough electrical energy to simultaneously offset approximately 45.8 MWh of the Lab's on-site electrical load. Photovoltaics also helped to decrease the Laboratory's electrical load through generation of approximately 66.5 MWh of electricity. Other on-site renewable thermal energy sources included solar hot water systems, ventilation air preheat systems, and extensive use of passive solar heating and daylighting. These thermal energy sources provide 10.2 MMBTU annually.

Biomass

The first major new renewable supply-side system that NREL will "plug into" its district heating system will be a Renewable Fuel Heating Plant (RFHP). This will supplement NREL's existing natural gas boiler capacity and offer dual fuel capability using locally available forestry wood thinnings. At current and projected wood and natural gas prices, a 15,000 MMBTU/hr RFHP would provide base load heating capacity during the 30-week heating season and displace 80% of the annual STM natural gas use at a savings of approximately $275,691 annually. Wood-fueled boiler technology and balance of plant equipment would be utilized since they are commercially available and suitable for STM heating requirements. There is a long-term supply of wood fuel in the form of forest thinnings available through the Federal Healthy Forest Initiative/National Fire Plan that supports the financial viability of the RFHP at a cost below natural gas. A suitable location for the RFHP has been identified, adjacent to the FTLB Central Plant. This is a central location that cost effectively accommodates pipe connections with the

SERF/S&TF and potentially the proposed RSF. A three-day supply of wood will be stored on-site, requiring approximately 180 truckloads of wood per year (increasing NREL truck traffic by approximately 20%).

The RFHP boiler, fuel system, building addition and the piping connection to the SERF/S&TF is estimated to cost approximately $2,255,500. The project will be implemented under an Energy Savings Performance Contract (ESPC). The ESPC contractor will pay for the design and construction of the RHFP and be repaid from savings generated by the project over the contract term of about 15 years.

For future central power plants needed in south or northeast sections of the STM campus, or on the NWTC campus, options will include an additional RFHP. Over the next 10 years, NREL will also assess the cost effectiveness of biomass gasification for the campus, (in the size range of 50KW - 200KW). Such a gasifier using wood chips would produce both electricity and heat (two units of heat for each unit of electricity produced).

Solar

In addition to the RFHP, NREL plans to provide at least 500 kW of photovoltaics or solar hot water on flat roofs of current and future structures, someday filling all available rooftop area with generating technologies. NREL is also planning to put one MW of PV at the NWTC.

Hydrogen / Advanced Vehicles

At the NWTC site, NREL is building a wind-powered electrolyzer to produce hydrogen, and plans to add a hydrogen fueling station for Laboratory vehicles. From a 100-kW wind turbine, the Laboratory will generate 50 kilograms (equivalent to 50 gallons) of hydrogen per day. Since a fuel cell vehicle is twice as efficient as a gasoline vehicle, vehicles fueled with hydrogen can travel 50-60 miles per gallon. The best use for this hydrogen is to power trucks at the wind site.

NREL also plans to use hydrogen from renewable energy in the future at the STM site. Several production options are possible, and the hydrogen can be used in a hydrogen-powered shuttle bus as well as other vehicles. In the long term NREL proposes to use a renewable-energy-powered hydrogen fuel cell at the STM site.

Besides an STM campus designed for encouraging pedestrian travel and discouraging individual vehicles for commuting, NREL envisions using plug-in hybrid vehicles as shuttles on the NREL campus. This will enable the use of battery capacity to help manage the energy loads and the ability to power vehicles from excess off-peak power.

NREL Projected Energy Use Through 2027

Figures E.2.2 and E.2.3 and Table E.2.4 show NREL's total planned energy use over the next 20 years and NREL's building energy use intensity (BTU/ft2/yr) for buildings on the STM campus from 2006 to 2027. These figures show that through the 1% efficiency gains per year coupled with a series of renewable offsets, as the NREL building stock increases five-fold, NREL's total energy use only doubles from the 2006 level.

Figure E.2.3 shows the result of this plan in terms of energy intensity of the NREL buildings. The energy intensity of the buildings after the offsets (BTU\ft2\year) declines dramatically over time by 36% between 2006 and 2027. This is the result of three factors:

- Over the 10 year period, the mix of lab to offices changes from almost 100% lab building in 2006 to 66% labs and 34% office in 2027; as NREL adds more offices to the building stock the energy intensity drops.
- By setting targets to reduce energy use in lab and office new construction, NREL plans to reduce energy use in each new building over time so that buildings constructed in 2026 are designed to use 20% less energy per ft^2 than buildings built in 2006;

- In this plan NREL included a series of renewable energy offsets to reduce the total campus-wide energy use over time.

NREL is exploring the requirements for a zero-energy campus. Assuming NREL's buildings are as energy efficient as stated above and all the renewable systems are used as stated above, using photovoltaics to meet the remaining load would require 55 MW, at an approximate cost of $43 million (without rebates). This would require 274 acres of land, pointing out the challenge of total onsite generation in a small community. A more realistic solution would be to offset the electrical load with PV and offset the thermal load with another option. If we assume that that electricity represents 50% of our energy loads, then the requirement for PV would be 27.5 MW and 137 acres. As a reality check, our STM electric load is currently 16,000,000 kWh. Meeting this load translates into 11 MW of photovoltaics, requiring 55 acres of land.

Figure E.2.2 Total Energy Use on the STM Campus Over Time

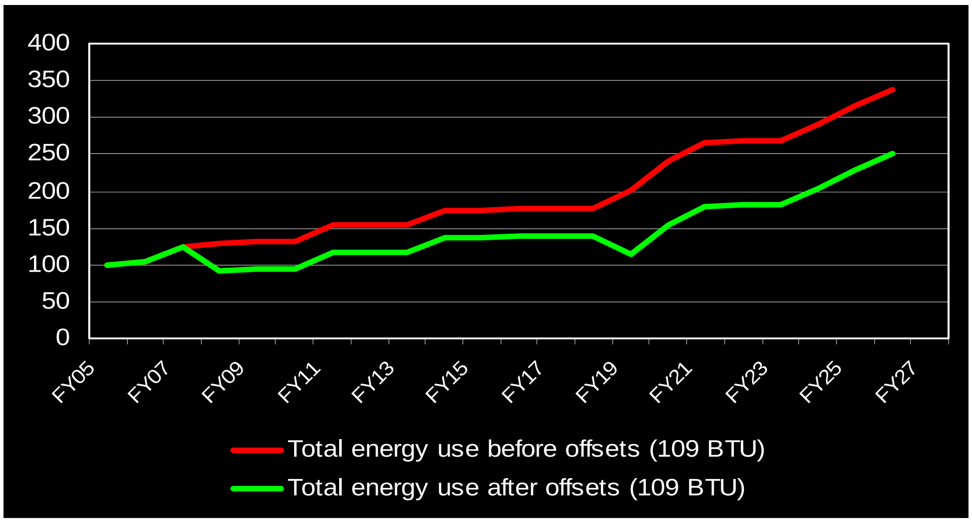


Figure E.2.3 Energy Use Intensity on the STM Campus Over Time

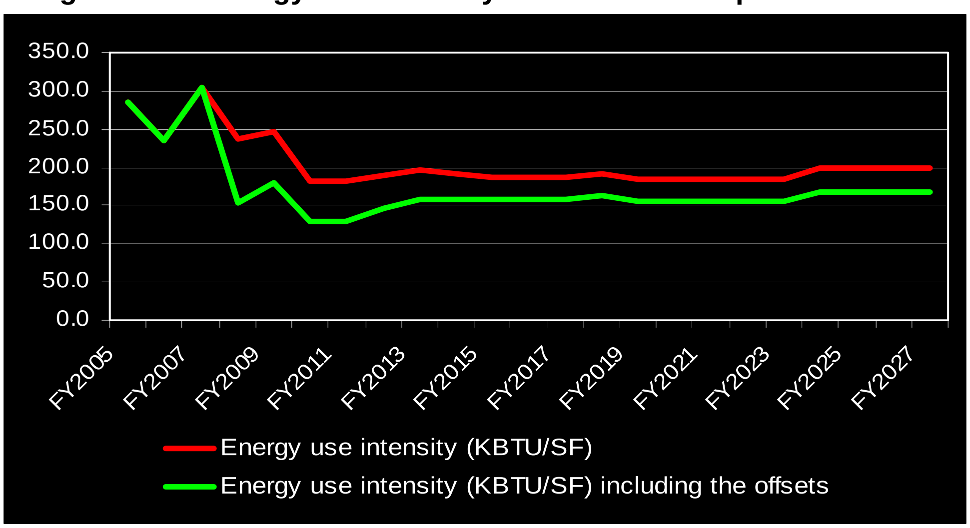


Table E.2.4 NREL STM Campus Energy Strategy

Objective of this chart is to look at energy intensity over the next 20 year on our campus taking into account added SF for labs and offices as per the GDV
as well as conventional energy offsets by RE such as the RFHP (sized to meet FTLB CP, SERF and 1/2 S&TF thermal), purchases of PV, biomass gasification and possibly a RE powered fuel cell
Energy intensity (BTU/SF/Yr for new office construction in FY06 is assumed to be 25 BTU/SF/yr (this is the aggressive standard set for the RSF --about 50% better than conventional)
Energy intensity (BTU/SF/Yr for lab construction in FY06 is assumed to be 281K BTU/SF/yr (this is the aggressive standard set for the S&TF --about 37% better than conventional)
For buildings built after 2006, a 1% improvement was planned for each year beyond 2006, so that in 2026, the assumption is new construction is 20% more efficient than 2006
The RE offsets are subtracted from the total energy use so the bottom line or "energy use intensity" reflects conventional energy only
The numbers in red are updates done Dec. 06 based on the most current info.

	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016
Base Level Annual Energy Use (2005)												
Electricity, MWH	13,195	14,659.0	16,272	16,272	16,272	16,272	16,272	16,272	16,272	16,272	16,272	16,27
Natural gas, billion BTU	50	45	43	43	43	43	43	43	43	43	43	4
Added Square Footage (SF)												
Labs (additional SF planned)		71,000		26,900	129,014			150,000	100,000	135,000	112,500	
Offices (additional SF planned)				48,000		244,000		30,000		100,000	85,000	
Total Building SF	333,271	404,271	404,271	479,171	608,185	852,185	852,185	1,032,185	1,132,185	1,367,185	1,564,685	1,564,68
Added loads (new facilities)												
S&TF Electricity (MWH) (added in 50% of annual S&TF because S&TF started up mid-2006)			2,020.0									
S&TF Natural Gas (billion BTU)			3.0									
S&TF Total energy use (billion BTU)		in base	9.9									
New Offices total energy use (billion BTU)				1.2	0.0	6.1	0.0	0.7	0.0	2.4	2.0	0
New Labs total energy use (billion BTU)				7.6	36.3	0.0	0.0	40.1	26.7	36.0	30.0	0
Total energy use before offsets (billion BTU)	**95.0**	**94.9**	**104.8**	**113.6**	**149.8**	**155.9**	**155.9**	**196.7**	**223.4**	**261.8**	**293.9**	**293**
Energy use intensity (KBTU/SF)	**285.2**	**234.8**	**304.2**	**237.0**	**246.4**	**183.0**	**183.0**	**190.6**	**197.3**	**191.5**	**187.8**	**187**
Note: EPACT Goal 389.6 KBTU/SF/yr - compare to NREL in FY2007												
Note energy use will go up in 2007.												
Energy use intensity of new labs(BTU\SF)		281,000	281,000	281,000	281,000	281,000	267,000	267,000	267,000	267,000	267,000	253,0
Energy use intensity of new offices(BTU/SF)		30,000	25,000	25,000	25,000	25,000	23,750	23,750	23,750	23,750	23,750	22,5
Renewable Energy Offsets (billion BTU)												
Renewable Fuels Heating Plant				-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40
Five 100KW increments of PV or wind						-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1
Biomass Gasification (200 kW)												
Transpired collector at AFUF												
Fuel cell												
Second RFHP										-40.0	-40.0	-40
1 MW of wind at NWTC						-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5
Total energy use after offsets (billion BTU)	**95.0**	**94.9**	**104.8**	**73.6**	**109.8**	**110.5**	**110.4**	**151.2**	**177.9**	**215.8**	**247.9**	**247**
Energy use intensity (KBTU/SF) including the offsets	**285.2**	**234.8**	**304.2**	**153.6**	**180.6**	**129.6**	**129.6**	**146.5**	**157.1**	**157.9**	**158.4**	**158**

Appendix F: South Table Mountain Site and Facilities

The 327-acre STM site is located on the southeast side of South Table Mountain near Golden, Colorado. The STM site supports all research and development areas except wind energy research. These R&D activities include low-bay and high-bay laboratories, process development and pilot-scale facilities, and research support spaces for R&D related to chemistry, biology, physics, thermal sciences and engineering, vehicle engineering, outdoor and field testing, and interdisciplinary activities. The STM site also houses research support facilities such as the Visitor Center, Site Entrance Building, Shipping and Receiving, and maintenance buildings.

Geographically, the STM site has many naturally attractive features. Located on the top, slope, and toe of a western mesa, it lies at the intersection of the natural open space of the mountain to the north and dense man-made developments to the south. The northern half of the site includes the mesa slope, with its pristine hillsides, rock outcroppings, deep drainage channels, and frequent sitings of deer and other wildlife. Most of this area is within a 177-acre conservation easement. With several more acres in utility and trail easements, only 136 acres of the 327-acre total are developable (Figure F.1).

Of the 136 developable acres, a long, narrow strip of 18 acres at the western end is only amenable to smaller buildings and field tests because of its difficult topography. The small 13-acre parcel on the mesa top is used only for activities that require unique access to the solar resource, such as concentrated solar research and solar radiation research. These activities involve a minimum number of people and low, unobtrusive buildings. Because the entire STM site is visible to the surrounding community for several miles, NREL is sensitive to the concerns of its residential neighbors, especially on the Mesa Top. Community action groups and local governments have been working to place the remaining mesa top property in conservation easements. The Laboratory seeks to ensure that research facilities have an acceptable appearance and that research activities on the Mesa Top have minimal visual impact.

The south, east, and west sides of the site are surrounded by a mix of old neighborhoods and rapidly changing residential and commercial development, with increasing growth and rising real estate costs. Further change is expected, including the development of a neighborhood park on NREL's southern border in 2005 and a research and development light industrial park in the southern area at some point in the future. The extent of development around NREL precludes any conceivable expansion of the current property, effectively landlocking the site.

Regional access to the site is excellent with an interchange to Interstate 70 less than a mile away. In the future, a light rail stop is planned a few miles from the STM site, and NREL has discussed shuttle links with NREL in its interactions with community planners and the regional transportation district. The on-going commercialization of the area with the increased traffic due to the number of local residents, office personnel, and shoppers will continue to increase the traffic load on bridges and highway exchanges around the STM site. The mesa top has long been a favorite area for hikers, and the public is allowed to access the mesa via trail easements along the NREL property borders.

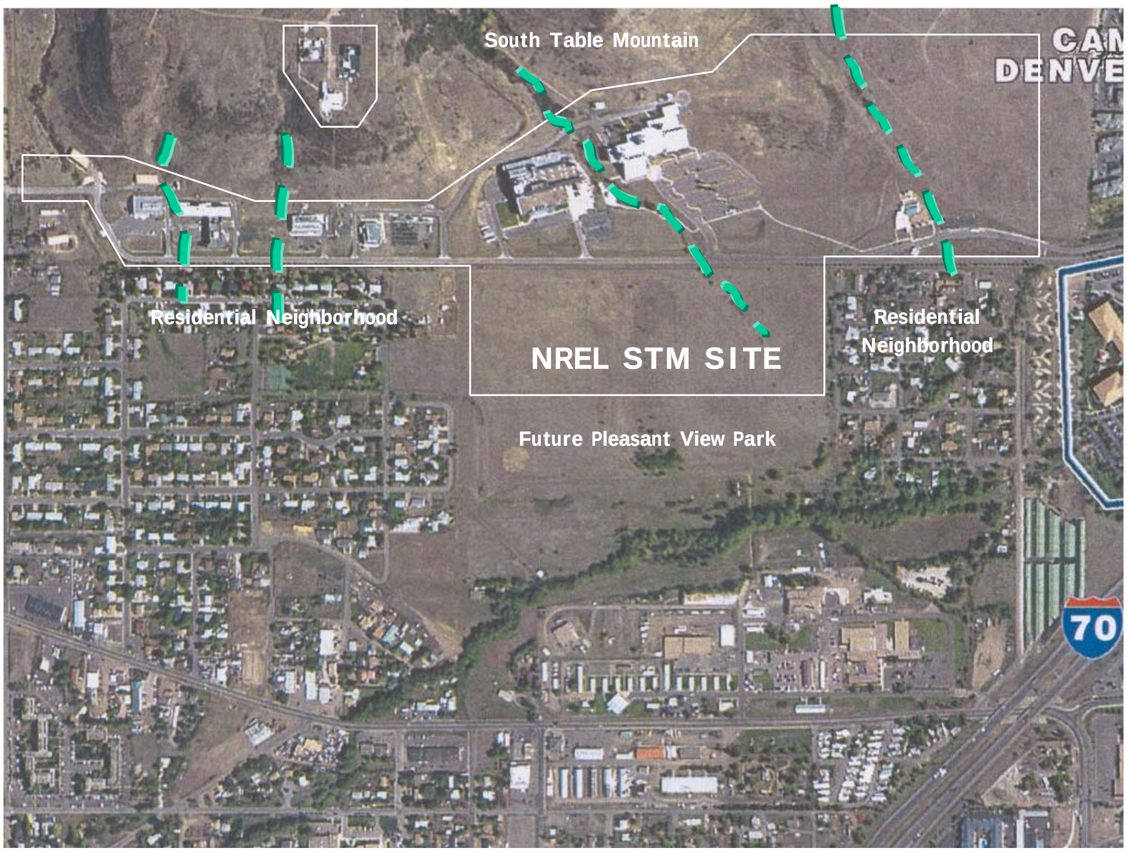


Figure F.1. Satellite View of South Table Mountain Site

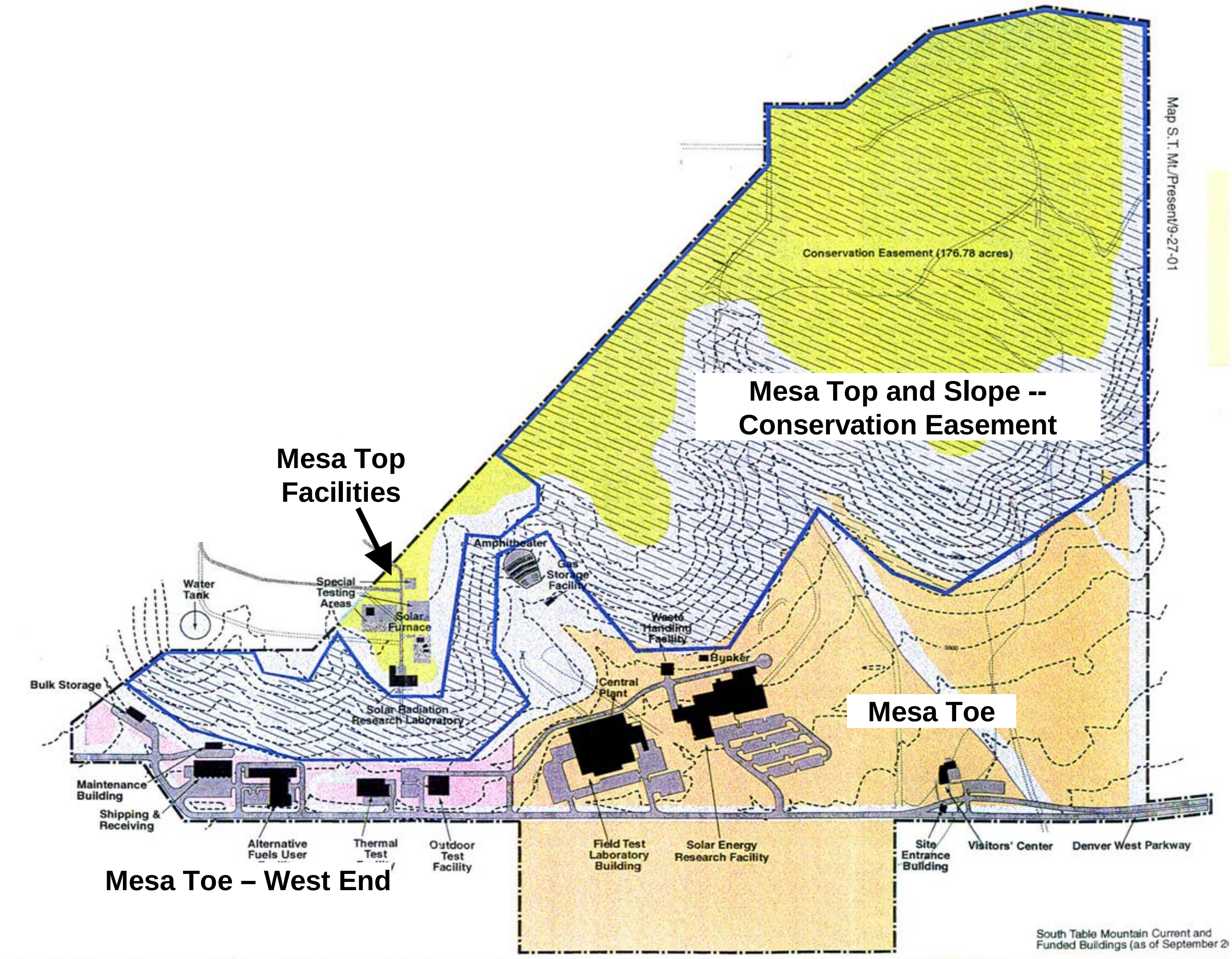


Figure 3. South Table Mountain Current and Funded Buildings

Figure F.2. Site Map

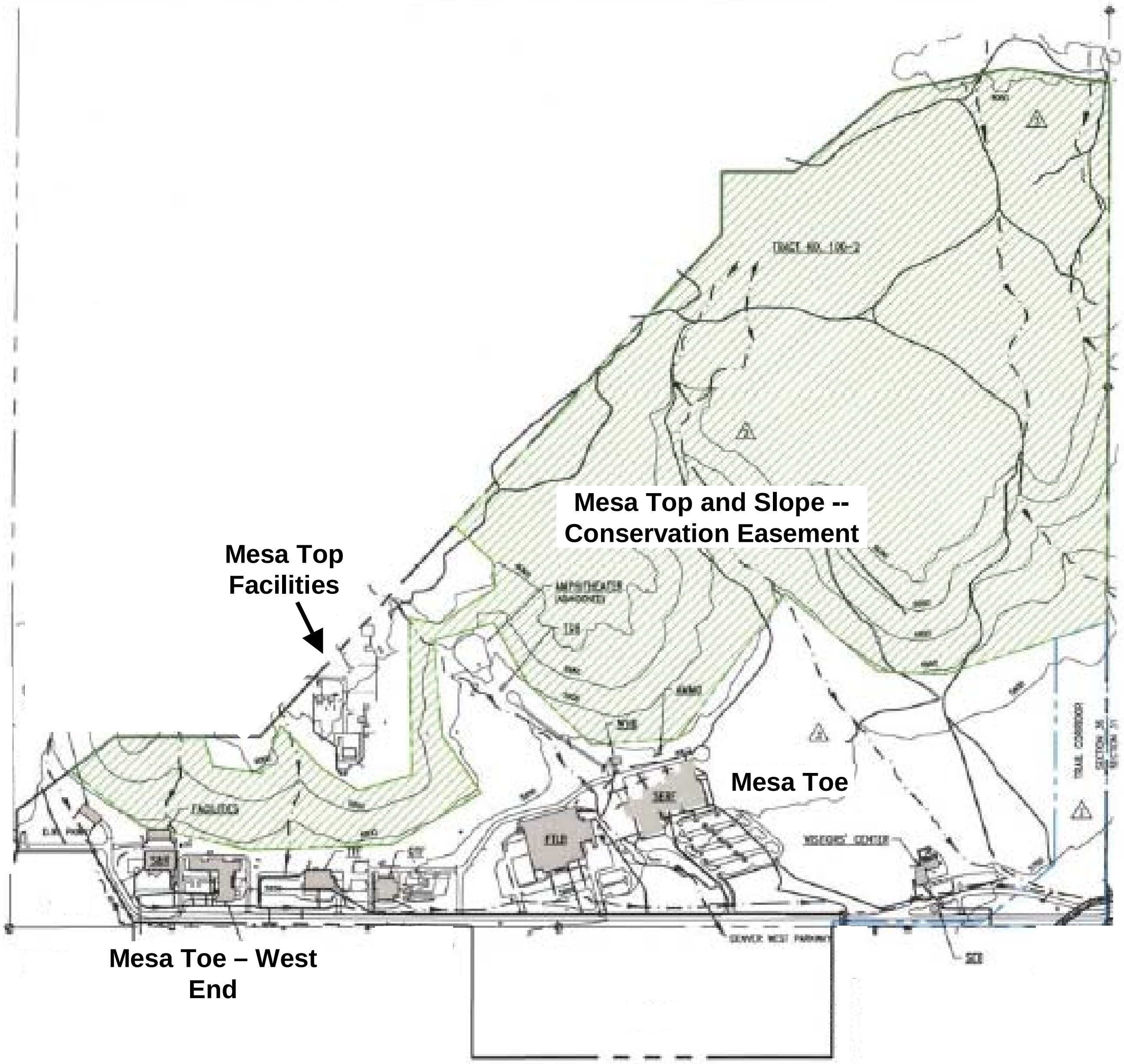


Figure F.3. Mesa Top Topographical Map

Figure F.4. South Table Mountain Site (looking from the east)

Figure F.5. South Table Mountain Site (looking from west)

F.1 Location, History, and Usage

The 327-acre STM site is located on the southeast side of South Table Mountain, north of I-70 and west of the I-70 and Denver West Boulevard interchange in unincorporated Jefferson County, near Golden, Colorado. A site map for the STM facility is presented in Figure F.2.

The STM site was formerly part of the Colorado National Guard facility, established between 1903 and 1924, at Camp George West (Figure F.1.1). The site was offered by the State of Colorado as part of its proposal to the Department to be the home for the proposed Solar Energy Research Institute. The excellent availability of sunshine in the high plains ecosystem of the Front Range of Colorado was one of the factors that contributed to the success of the state's proposal. DOE acquired the land in 1981, and ground was first broken in 1983 for the Field Test Laboratory Building.

In July 1999, the 25 acres south of Denver West Parkway were acquired from Jefferson County Open Space as part of a land exchange. As part of this agreement, DOE established a conservation easement of 177 acres and a trail easement of 10 acres that benefits Jefferson County Open Space. This action provided the DOE with additional acreage for site development and protected the slopes and most of the mesa top area within the STM site from any future development. NREL must initiate above ground site improvements within 20 years of acquiring the 25 acres or Jefferson County can exercise a 5-year option to designate the acreage as open space.

The South Table Mountain site is used for all areas of research and development excluding wind energy research. Most of the Laboratory's DOE-owned buildings are on the STM site, and its occupants (as of 9/30/06) total about 430. The site also houses NREL's shipping and receiving activity, and the NREL Visitors Center.

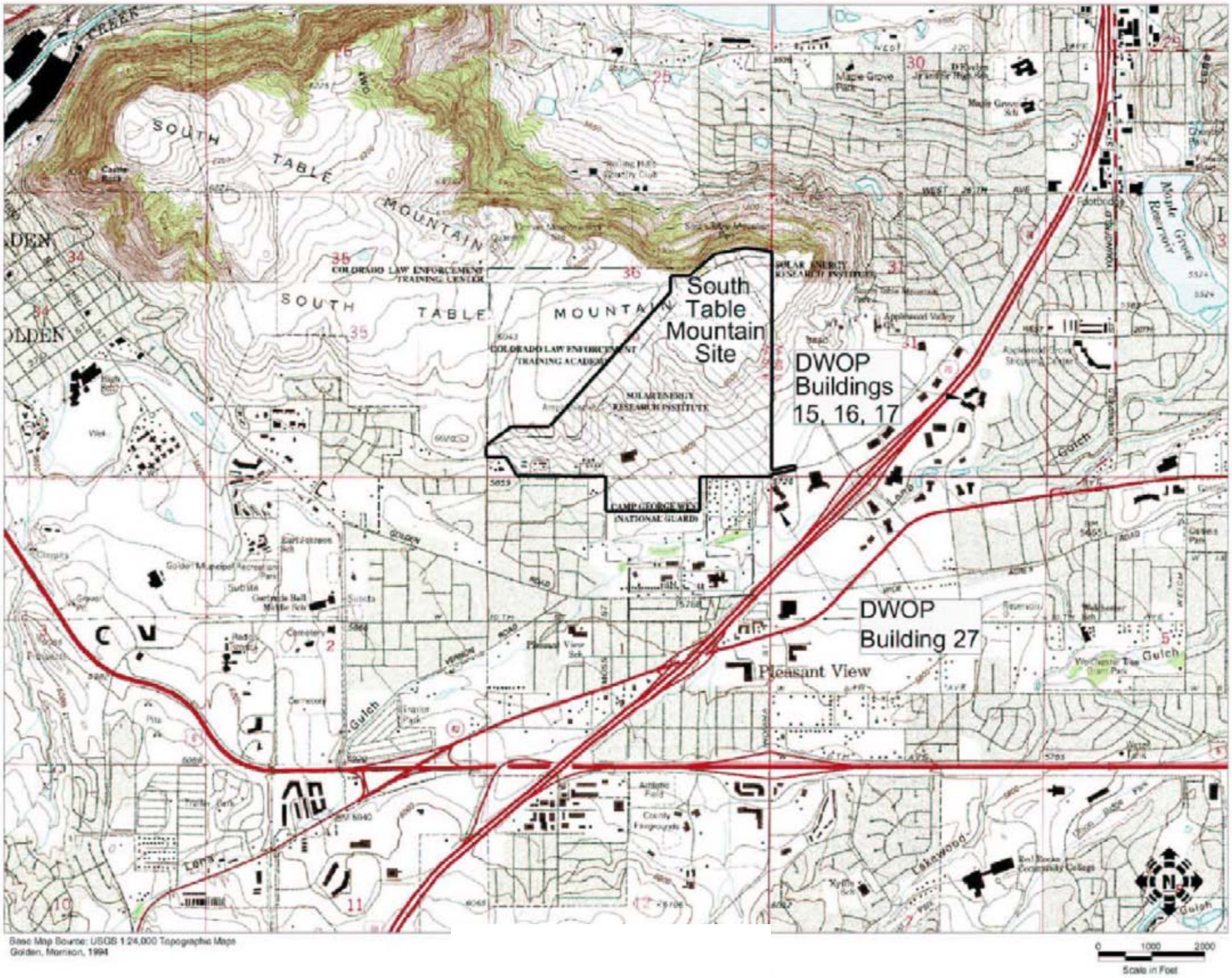


Figure F.1.1 South Table Mountain Vicinity Map

F.2 Surrounding Community

The areas surrounding the STM site are within portions of unincorporated Jefferson County, as well as the Cities of Golden and Lakewood municipalities within Jefferson County. The Pleasant View Metropolitan District, within unincorporated Jefferson County, overlays portions of each of these jurisdictions (Figure F.2.1).

Specific uses adjacent to the STM site include the following:

- Denver West Office Park
- Camp George West (state- and county-owned facilities; see below)
- Colorado State Highway Patrol Driver Training Track and Jefferson County open space land to the northwest, on the mesa top
- Camden Denver West multi-family residential development and office buildings to the east
- The community of Pleasant View, with single-family residences, a community park, and an area planned for a regional park (supposed to begin development in 2005), borders the STM site on the south.
- Offices and a nursery associated with the Colorado Division of Forestry, and residential development and a neighborhood park within Pleasant View to the west
- A Marriott Hotel is located east of the STM site, north of Building 27 and southwest of Buildings 15, 16, and 17.

Camp George West currently comprises approximately 100 acres located south of the STM site (Figure F.2.1). Camp George West was established in 1903 as the Colorado National Guard's (CNG's) permanent rifle and range facility. Lands associated with the Camp totaled 750 acres during the mid-1920s to late-1930s, including the acreage comprising the current STM site (DOE had been a tenant of the State of Colorado prior to acquiring the STM property in 1981). Jefferson County also acquired a significant portion of former Camp George West lands. In addition to providing storage, maintenance, and classroom space for the CNG, the remaining lands known as Camp George West currently provide land for a variety of tenants including the Colorado Office of Emergency Management, Colorado Department of Transportation, Colorado State Patrol, and the Colorado Correctional Center at Golden. However, the CNG is in the process of relocating space at Camp George West. The State of Colorado has received several requests for reuse of the site. The Camp George West Historic District, which includes portions of the present Camp George West site and the STM site, was placed on the National Register in 1993 (Colorado Department of Corrections, 2002).

Major office, residential, and retail developments within a one-mile radius of NREL have occurred steadily since 1995. The latest addition, in November 2002, was a regional mall called Colorado Mills, which lies just south of I-70 about a mile from the STM site. Traffic in the area has increased markedly, but several local access roads were also widened as a part of this development, minimizing detrimental impacts on access to NREL's facilities.

The Jefferson County Planning Commission issued a draft Central Plains Community Plan in August 2003 in which it recommended developing a research and development light industrial park area between Old Golden Road and I-70, south of the STM site; this is a concept that NREL fully supports.

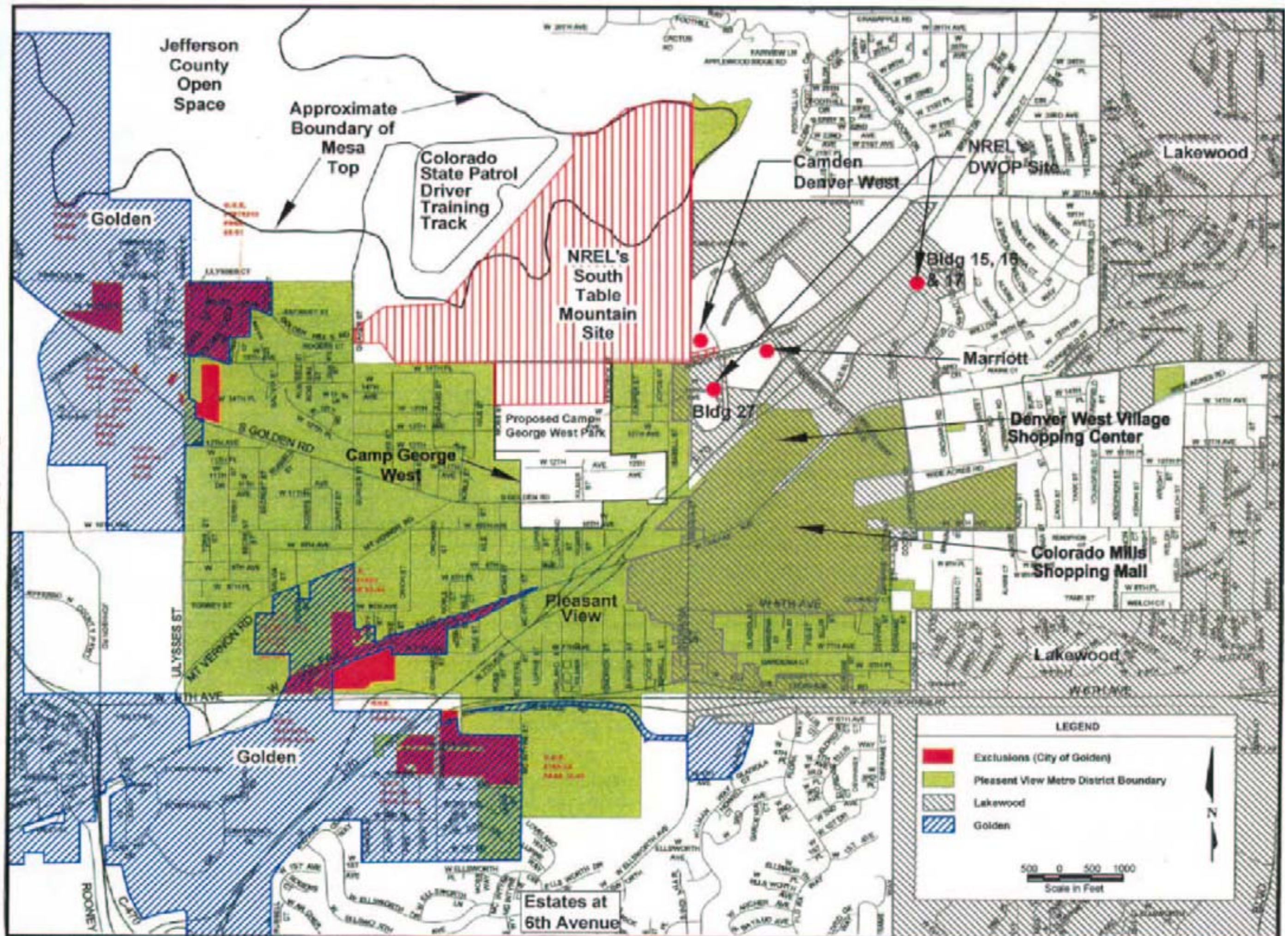


Figure F.2.1 STM Vicinity Map

F.3 Land Management

Topography

The site is located on the South Table Mountain top, slope, and toe, which limits site development (Figure F.3, F.4 and F.5). Although the mesa presents many unique design opportunities, a significant portion of the STM site has steep, erosive slopes; rock outcrops; deep drainage channels; and other physical constraints. The mesa slope has a grade greater than 20%, which prohibits construction, and the slope is unstable when disturbed. The rockfall zone, steep slopes, and major drainage ways is preserved as open space. Due to the topographical nature of the site it can only be partially developed.

- 136 acres are available for development. The central and east end of the mesa toe and the 25 acres south of Denver West Parkway (about 105 acres total) are the areas best suited for major research and administrative buildings. The two largest laboratory buildings and the Visitor Center are currently located in this area.
- 13 acres of the 136 developable acres are located on the mesa top. The mesa top has poor soil conditions and a shallow depth to bedrock resulting in difficult and expensive construction. Water, natural gas, and electrical service are accessible to the mesa top but it

has no sewer facilities. Access to the mesa top is via ~1 mile of unpaved road on an easement. Only low-impact activities are performed in low, unobtrusive buildings or as outdoor tests.

- 18 acres of the 136 developable acres comprise a narrow strip of land running along Denver West Parkway at the west end of the site. Numerous topographic factors make this more difficult to develop than the east end, and limit the size and placement of buildings. This area is used for small-scale buildings, field testing, pilot plants, maintenance activities, storage, and warehousing.
- 177 acres are protected by a conservation easement.
- 14 acres comprise a Jefferson County Open Space trail easement and utility easements for the STM site. The trail easement is located on the southeast corner of the STM site.

Climate and Ecology

The altitude of the site varies between 5750 ft. and 6050 ft. above sea level. The site is in the "foothills life zone," a transitional region between the grasslands of the plans life zone and the higher, tree-dominated montane life zone of the Rocky Mountains. With its location near the foothills, the weather conditions impact the facility designs and maintenance considerations due to the climate changes, snow loads, and high winds of the area.

STM site soils consist of mostly bedrock on the mesatop and mostly clay loam and cobbly clay loam in the areas where most of the development has occurred.

Vegetation on the STM site consists of a mixture of grasslands, shrublands, and a very small amount of wetlands. Some common wildlife found on the STM are coyote, fox, rabbit, muledeer, deer mice, numerous species of birds, bullsnakes, and rattlesnakes. Endangered species have been identified and handling of these endangered species, if found, is done in accordance with NREL and DOE Best Management Practices.

Visibility

The entire STM site is visible to the surrounding community for several miles. NREL is sensitive to the concerns of residential neighbors about minimizing the visual impact of research activities on the mesa top, and the appearance of all research facilities.

Storm Water Management

The STM resides in the Pleasant View Area watershed. There are three significant drainage basin – west, center, and east - that must be considered in site design, both overall and individually. These three basins are shown in Figure F.3.1. The storm water management plan that has been developed for this area recommends creating channels or improvements for the center and east drainage channels, including numerous drop structures. Also a 14-acre-foot pond is recommended for the east drainage basin.

As development occurs on the STM and to meet the intentions of the storm water management plan NREL plans to require provisions in the development plans to use landscape features as planted infiltration basins and trenches, porous pavement, and grassy swales to filter the runoff, along with localized detention ponds to slow down the runoff. This approach offers several advantages to NREL:

- It will not only slow down storm water runoff but also improve the quality of water leaving our site.
- The swales and planted basins will support added plant growth on the campus, and
- Land that would otherwise be needed for a regional detention pond can be used for another purpose.

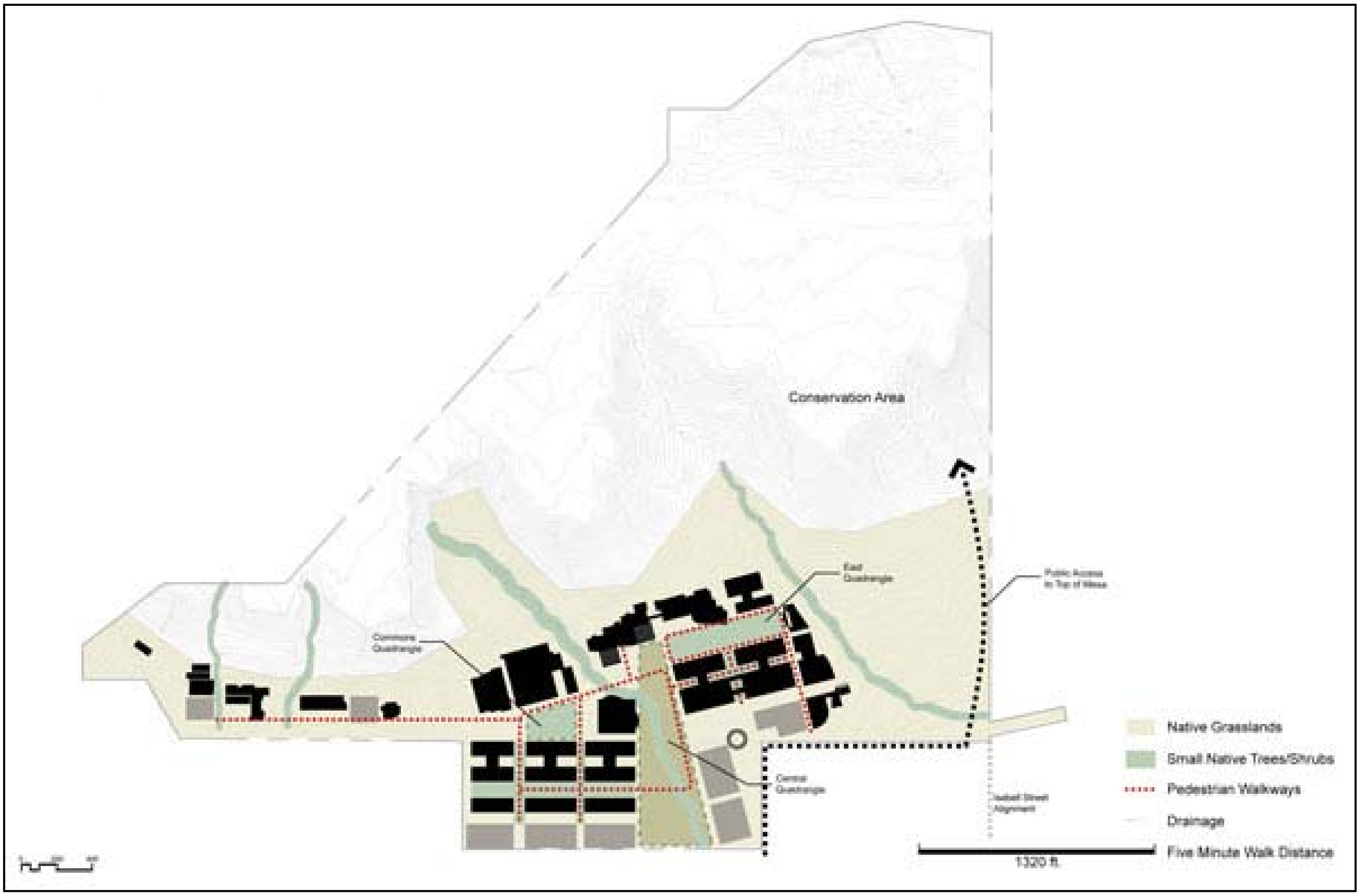


Figure F.3.1 Open Space Plan

F.4 Buildings

At the STM site, DOE owns approximately 404,200 gross square feet (gsf) of space, the total of all interior space. Table F.4.1 describes the primary facilities on the STM site.

Table F.4.1 Summary of DOE-Owned Research Facilities on the South Table Mountain Site

Solar Energy Research Facility – NREL's "signature" building, about 116,000 gsf and completed in 1993, contains low-bay laboratories (some with toxic gas capabilities) and offices to support basic and applied research in many different solid-state materials and devices, with a primary focus on photovoltaic solar cells and modules, hydrogen production and storage technologies, superconducting materials, electrochromic coatings for windows, and nanostructured materials of all types. The work encompasses theoretical studies, material science, device fabrication, process research, and analysis and characterization. The principle focus is on solid-state materials and surfaces, although some liquids and polymers are also studied. Programs supported include EERE programs in Solar; Hydrogen; Distributed Energy & Electricity Reliability; and Buildings; Office of Science programs in Chemical Sciences, Material Sciences, and Biological Sciences; and various CRADAs and work-for-others projects.

Science & Technology Facility – NREL's newest building, completed in August 2006, is approximately 71,000 gsf, contains low-bay laboratories (some with toxic gas capabilities), a Process Development Integration Laboratory (PDIL), and offices to support solar, hydrogen, buildings, solid-state lighting, and nanotechnology research. The PDIL will assist in moving the technology from the laboratory through integrated pilot-scale experiments to commercial-scale design.

Field Test Laboratory Building – NREL's largest and first building, about 126,000 gsf and initially completed in 1984, is a multi-purpose facility that has been modified several times in response to changing research programs. The combination of high-bay and low-bay laboratory space has made this building a versatile and flexible workhorse for virtually every program NREL has supported since its construction. Programs currently supported include Biomass, Hydrogen, Solar, Buildings, FreedomCAR, Geothermal, Industrial Technologies; Office of Science programs in Chemical Sciences, Biological Sciences, and Material Sciences; and various CRADAs and work-for-others projects. The future vision for this facility is to focus its use towards a biosciences research and development facility.

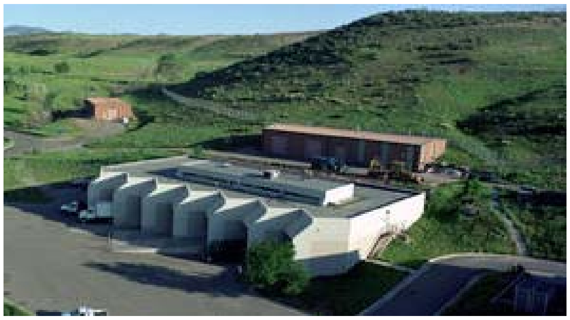
Alternative Fuels User Facility – This facility, about 33,000 gsf and completed in 1994, absorbed the earlier Biotechnology Research Facility built in 1985 and contains biological laboratory and office space, as well as the Biotechnology Process Development Unit. The structure supports the research and development of fuels, chemicals, and other materials from biomass using biological and biochemical conversion processes. Programs supported include EERE Biomass, Hydrogen, Industrial Technologies, and a variety of CRADA projects and work-for-others projects

Outdoor Test Facility -- This facility, about 11,000 gsf and completed in 1995, contains laboratories used to test the performance and reliability of many types of materials for solar applications, including photovoltaic cells and modules, solar films, and other product s. Researchers simulate outdoor conditions to analyze how various devices perform under prolonged exposure to extreme weather conditions. An open field adjacent to the laboratory building is used for outdoor testing. Programs supported include EERE Solar; and various CRADAs and work-for-others projects.

Thermal Test Facility – This facility, about 11,000 gsf and completed in 1996, serves both to house research activities and as a research instrument itself. This structure uses 70% less energy than a similar building of conventional design. Its extensive instrumentation and data collection capabilities help NREL building researchers test and monitor the performance of the building itself, as a research activity. As a functioning laboratory, researchers study advanced cooling, ventilation, ventilation pre-heat, and active solar systems for buildings. The open bay test area houses the Advanced Thermal Conversion Laboratory, which measures realistic performance of desiccant dehumidifiers; air-conditioning components, such as heat exchangers, heat pipes, and evaporators; and entire systems. The facility also houses the Battery Thermal Management laboratory and other transportation-related research activities. Programs supported include EERE programs in Buildings, FreedomCAR, and Distributed Energy & Electricity Reliability;

and various CRADAs and work-for-others projects.

Mesa Top Facilities -- The primary mesa top facilities include three small structures. At the Concentrated Solar Radiation User Facility, NREL researchers work with industry partners to discover new ways to reduce manufacturing costs, increase product quality, and reduce pollution using sophisticated equipment that includes a High-Flux Solar Furnace and a UV Concentrator. The High Flux Solar Furnace, completed in 1990, concentrates sunlight up to 50,000 times to study the potential applications of concentrated sunlight on material processing, industrial coatings and surface treatments, chemical synthesis, etc. The Concentrated Solar Test Area includes control rooms and staging areas and outdoor test areas for testing troughs, parabolic dishes, solar trackers, and related equipment. The Solar Radiation Research Laboratory, completed in 2000, supports instrumentation to collect and analyze solar radiation and meteorological data important to many different programs. Programs supported at the Mesa Top Facilities include Solar; Hydrogen; Industrial Technologies; DOE Initiative for Proliferation Prevention; and various CRADAs and work-for-others projects.



Shipping and Receiving Facility – This facility, about 14,000 gsf and completed in 1997, provides space for shipping and receiving functions and staff.

Visitor Center – This building, about 6,500 gsf and completed in 1994, was built by Midwest Research Institute and donated to DOE. At the east entrance outside the secured area of the Laboratory, it provides technology displays and meeting space. It is open to visitors from the general public and provides meeting space for NREL use.

Site Entrance Building – This small structure houses around-the-clock site security, visitor greeting and badging services, and alarm monitoring.

F.5 Utilities

The following discussions address electricity and gas, telecommunications, water, sewage service, emergency response and fire protection. Figure F.5.1 presents the locations of existing on-site utility lines.

Electricity and Gas

Electrical power for the STM site is delivered through an Xcel Energy overhead, 13.2-kilovolt (kV) electrical distribution line that enters the site via an easement from the west end of Denver West Parkway. The STM site features a 13.2-kV high voltage distribution system that features three loops to provide electricity to the buildings on site. This distribution system and the transformers associated with each of the on-site buildings are owned, maintained, and operated by NREL. It is anticipated that this electrical system is adequate to serve the STM site for the foreseeable future. In line with its mission, from 1999 through 2004 NREL committed to purchase "green power," in the form of wind power, from Xcel Energy. During 2005, NREL purchased approximately 97% of the electrical use of its DOE-owned buildings in renewable energy certificates (RECs). However, since the actual electrical consumption was higher than anticipated, the difference was purchased in RECs and retroactive in FY2005 to establish a 100% NREL purchase. Twenty three percent (23%) of this purchase was made through Community Energy, Inc. Seventy three percent (73%) of this purchase was made through the Western Area Power Administration Federal Agency Master Purchase Agreement. In 2006, NREL purchased 30,000 MWh of RECs through the Western Area Power Administration Federal Agency Master Purchase Agreement. This REC purchase offsets 100% of the total electrical consumption and 77% of the total gas consumption. From a GHG emissions standpoint, this REC purchase offsets 100% of the natural gas GHG emissions. NREL was able to secure twice the greenhouse gas emission reduction credits from the same investment with Community Energy compared to Xcel Energy.

Xcel Energy also provides natural gas to the STM site via a main pipeline located along the main site access road (Figure F.5.1). In addition, a 20-inch regional distribution line (1,000 pounds per square inch (psi)) passes through the site. This pipeline runs north-to-south through the site between the FTLB and OTF and up to the mesa top. The gas line that serves the site is adequate to meet natural gas needs at the STM site for the foreseeable future.

NREL has a central boiler and chiller plant in the FTLB that serves that building and the buildings in the western part of the campus through an underground pipe that runs along the north side of the buildings. Another central plant is located in the SERF and is designed to serve the planned S&TF, as well. Future development would require additional utility corridors and central plants to serve new facilities. The STM site energy strategy is discussed further in Appendix E.

Telecommunications

Qwest provides telephone and electronic communications services at the STM site. Although the existing telecommunications service at the site is considered adequate for current needs, NREL would increase the capacity of the system to meet increased needs in the future. The existing analog communications technology is being replaced with digital communications technology, and the Data System Infrastructure Project completed in 1997 with a budget of $2,925,000 installed fiber optic data and communications networks throughout the STM and DWOP sites to provide increased bandwidth of the data highway. It is anticipated that in the future, the capacity of these systems will need to be increased to allow access to high-performance computing capabilities at other laboratories. Two five-inch conduits are routed through Denver West Parkway to the west of the STM site for future use.

Water

The Consolidated Mutual Water Company (CMWC) provides domestic water to the STM site. The CMWC serves 85,000 people in Jefferson County within a 23 square-mile service area. The existing water system is considered adequate to meet current and future needs. Drought conditions in March of 2003 required substantial limitations on available water supplies.

Based on consultation with Consolidated Mutual on April 2003, the CMWC system is considered adequate in wet and normal years to meet existing and future water demands. During years of drought Consolidated Mutual would likely place substantial limitations on water use as was recently done in March 2003. While Consolidated Mutual has a tap moratorium in place that applies to new users only, NREL's STM complex is an existing user not subject to the tap moratorium.

Sewer Service

The Pleasant View Water and Sanitation District provides sewer service to the lower portions of the STM site. A septic tank and leach field system serves the one toilet, one hand sink, and one janitor's sink located within the existing mesa top facilities.

Wastewater from the sewer system is discharged to Denver's Metro Wastewater Reclamation District. This system is considered adequate for existing and anticipated future sewage needs.

Emergency Response and Fire Protection

Fire fighting equipment for buildings and facilities located below the mesa slopes includes a water supply (fire hydrant, dry hydrant, or another type of water supply) for every building except the Bulk Storage Facility and the PDU Emergency Generator buildings. Facilities on the mesa top do not have a water supply for fire protection. All facilities at the STM site have external horns and strobes that are activated when the fire alarm is triggered. Fire detection systems at the STM site are monitored by the West Metro Fire Protection District (West Metro), which receives the signal directly from the NREL system. With the exception of the Bulk Storage and PDU Emergency Generator buildings (which do not have any form of fire protection), all buildings on the lower STM site have multiple fire protection systems. The Visitor Center, Site Entrance Building, FTLB, OTF, TTF, S&R, and Facilities Shed all feature fire detection (fire or smoke detector heads), fire alarm, and fire sprinkler systems. In addition to these systems, the SERF also features a standpipe and fire pump, while the AFUF has multiple fire sprinkler systems, a foam deluge system, and a fire pump. The SERF, AFUF and the S&TF have fire detection systems in the elevator lobbies and the heating, ventilation, and air conditioning systems.

To protect the site from wildfire, NREL applies its Fire Protection Program to the site, which includes wildfire protection requirements. In 2001, Fire Mark Limited conducted an Updated Fire and Life Safety Analysis of NREL's FTLB, a Wildfire Hazard Assessment of the STM site, and an Assessment of the NREL Fire Protection Program. This assessment concluded that Fire Protection Program at the STM site is excellent. The Fire Mark Limited Wildfire Hazard Assessment concluded that the wildfire hazard potential for both the lower STM site and the mesa is low.

In the event of a fire on the STM, West Metro is under contract to provide emergency service equipment and personnel. West Metro would also provide ambulance service. In the event of an on-site injury, illness, or other situation requiring an ambulance, West Metro personnel and equipment would be dispatched to the site. Emergency services for adjacent properties are provided by several jurisdictions including West Metro and Pleasant View. West Metro staff and equipment capabilities are being expanded to address the new demand created by the Colorado Mills Mall and other new development within their service boundaries.

In the event of a crime or other issues requiring law enforcement assistance at the STM site, on-site security personnel would respond. If off-site support were required, the Jefferson County Sheriff would be contacted.

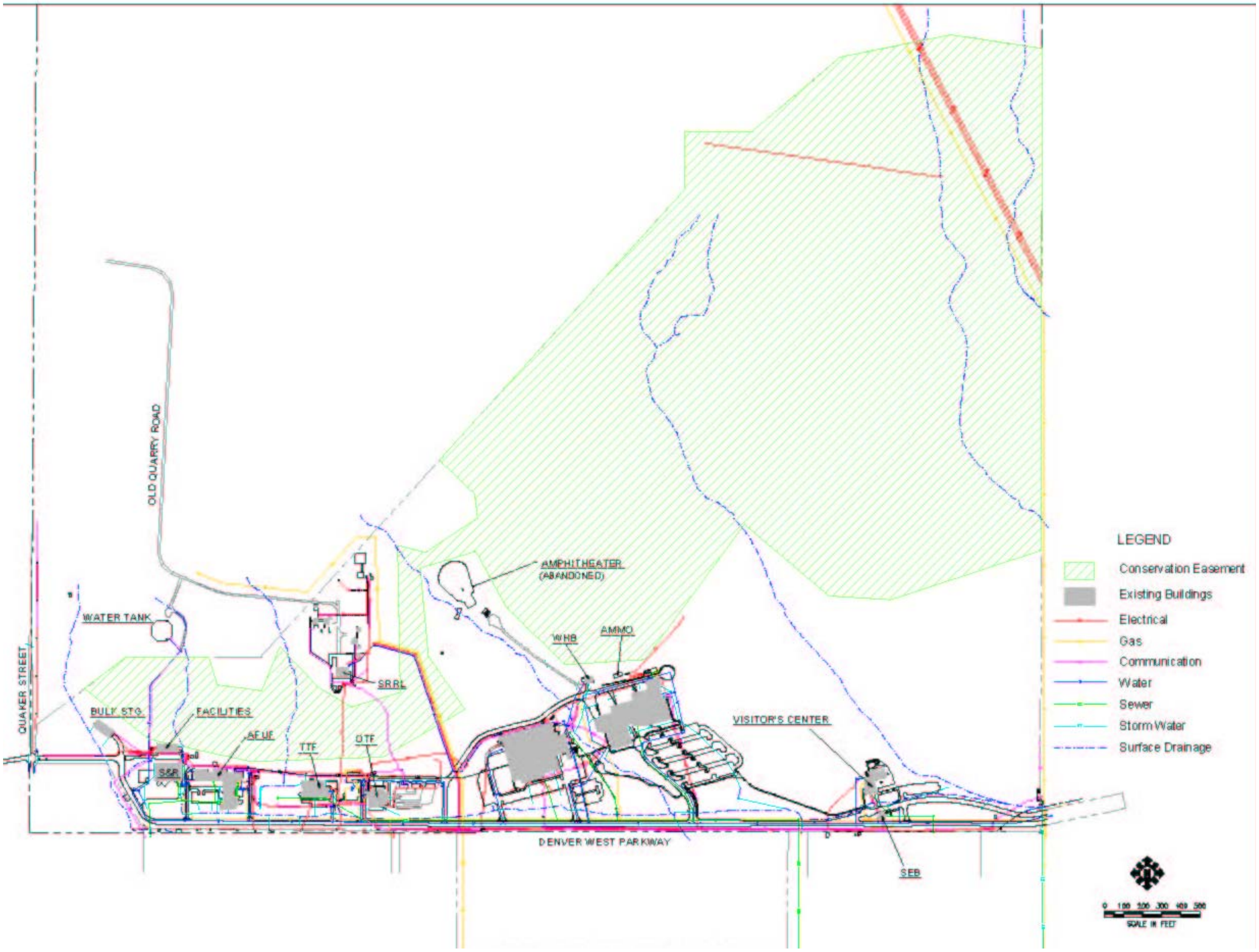


Figure F.5.1. South Table Mountain Utilities Map

F.6 Transportation

Interior Circulation

Within the STM site, the buildings are currently served by one two-lane, east-west primary road, with individual roads connecting to each facility. Parking is provided near each facility.

Pedestrian pathways are minimal on the site, connecting only the Visitor Center with the SERF and the S&TF, and the SERF with the FTLB. The inability to walk between other buildings is an ongoing issue currently being addressed by an NREL shuttle system that operates during normal business hours.

Access to the STM Site

The roadway network serving the STM is primarily composed of Denver West Parkway, Denver West Marriott Boulevard, West Colfax Avenue (U.S. 40), I-70, Cole Boulevard, and various local streets (Figure F.1.1).

The I-70/Denver West Marriott Boulevard interchange provides regional access to the STM. Denver West Marriott Boulevard is a 4-lane, divided roadway that extends between West Colfax Avenue and Denver West Parkway.

Denver West Marriott Boulevard intersects Denver West Parkway just north of the I-70/Denver West Marriott Boulevard interchange. Denver West Parkway is a four-lane, divided collector that parallels the north side of I-70 between the STM site and 20th Avenue. Denver West Parkway provides primary access to the STM site.

The main entry to the STM site is at the western terminus of Denver West Parkway about 2,000 feet west of the Denver West Parkway/Denver West Marriott Boulevard intersection. Gates control this entry point and a second entry point to the STM site off of Quaker Street. These entry points control interior access to roads within the lower portion of the STM site. Public access to parking areas near the Visitor's Center and security building is not controlled by the gate.

Quaker Street provides access to the STM facilities located on the mesa top. Quaker Street is paved to a point just north of the STM west gate. Beyond this point the road is unimproved. The unimproved portion of the road provides access to the mesatop for several users, including NREL, Consolidated Mutual, and the Colorado State Patrol. Maintenance of the road is provided as needed with cooperation between NREL and Consolidated Mutual. A gate is located at this location, but it is only closed and locked at night. The gate is open during the day because the road provides access to public open space. However, upon reaching the STM facilities on the mesa top, a security gate controls access to STM facilities. An access card is required to gain entry at the mesa top security gate and at the other two primary STM site gates.

Bus service to the project site is provided by the Denver Regional Transportation District's (RTD's) Route 20-125 bus line, which includes a stop at the STM Visitor's Center. The on-going commercialization of the Denver West area with the increased traffic due to the number of local residents, office personnel, and shoppers will substantively increase the traffic load on bridges and highway exchanges around the STM site. A Light Rail stop is planned in the Red Rocks Community College area along 6th Avenue, south of the STM site, in the future, and a shuttle to NREL has been discussed.

Pedestrian access to the STM site is provided via Denver West Parkway. Trail easements exist on-site along the eastern boundaries of the STM site and off-site trails just west of the site's western boundary. These trails provide access to open space areas located north of the STM site. An access easement located along the eastern edge of the 25-acre Camp George West parcel provides access between the security building and the future site of Camp George West Park.

F.7 Disposition

NREL has no plans to dispose of any property or facilities in the foreseeable future.

Appendix G: National Wind Technology Center Site and Facilities

The National Wind Technology Center site is adjacent to DOE's Rocky Flats Environmental Technology Site about twenty miles north of the South Table Mountain site. The topography is flat and accessible. Most developed land at the NWTC is used for outdoor field tests of wind turbines, for which direct access to wind from Eldorado Canyon is needed. The site is ideally suited for a wind research facility because it is subject to intermittent, extremely high-velocity winds, and the site's wind resource is well characterized. It is not well suited for wind power production, however, because the wind patterns are not consistent. In addition to R&D in wind energy, the site supports NREL's R&D in hybrid power technologies and distributed energy resources. The NWTC site was transferred from the Rocky Flats Plant to NREL in 1993, and 25 acres were added in 2002. No radiological operations were conducted on this site, and there are no radiological contamination issues.

The future development of the NWTC is likely to be affected by several internal and external factors. The site has no municipal water supply for staff use or fire protection, and depends on water trucked in to storage tanks from a local supplier. Future development must take into consideration the potential limitations of the existing water supply. Also, the site is buffeted by gale-force (greater than 100 mph) winds at certain times of year, which can cause damage to vehicle windshields and make the site unsuitable for certain kinds of outdoor tests. Suitable windbreak solutions are not yet in place. Other site issues include deterioration of the paved and unpaved roads, which are on the deferred maintenance backlog, and the lack of outdoor areas for staff breaks. Lastly, since most of the acreage is used for wind turbine research, new buildings have to be sited where they will not affect the wind regime in the turbine test areas, nor be damaged by any failure of research turbines.

Externally, private mining companies have operations adjacent to the south and west site boundaries. While DOE owns the surface mineral rights, any future interest from the private owners of subsurface mineral rights may affect site development. The future of the Rocky Flats Environmental Technology Site (RFETS) to the east will also affect the NWTC. Converting the RFETS to a wildlife refuge, as currently planned, may bring visitors into a positive relationship with more public interest in NREL's research, or may bring controversy over the affect of NREL operations. NREL will continue to monitor the various stakeholders who are involved in the future directions of the RFETS.

Figure G.1 National Wind Technology Center

G.1 Location, History, and Usage

The 305-acre NWTC is located approximately 16 miles northwest of Denver and 20 miles north of NREL's South Table Mountain site. This is a relatively isolated area adjacent to DOE's RFETS in unimproved, unincorporated Jefferson County. The site is south of Highway 128 and northeast of aggregate mining and processing facilities on the east side of Highway 93 between Golden and Boulder, Colorado. The Boulder/Jefferson County line is the site's northern boundary line. A regional location map is presented in Figure G.1.1. A local setting map is presented in Figure G.1.2. A site map is presented in Figure G.1.3.

Since the mid-1970's, DOE has conducted wind research and development activities at the NWTC, formerly the Wind Energy Test Center, which is located within the legal boundaries of the buffer zone of the RFETS. Although the entire RFETS, including the buffer zone, is currently designated under CERCLA, the buffer zone was managed as a "no activity zone" during the production years of The Rocky Flats Nuclear Weapons Plant. No radiological operations were conducted on this site and there are no radiological contamination issues per groundwater sampling and air monitoring program data provided by RFETS. The site is hydrologically upslope and upwind of the RFETS. As part of the recent EA of the NWTC, the EPA sampled all areas of the NWTC and statistically found no radiological contamination above background levels. The EPA also formally redefined the CERCLA designated buffer zone of RFETS to exclude the 305-acre NWTC.

The mission of the NWTC is different than the mission at RFETS. Since 1993, DOE's Golden Field Office has managed the NWTC for wind, alternative, and renewable energy research, while the remainder of the RFETS continues to be managed by DOE's Rocky Flats Field Office as an environmental closure site. DOE/NREL will continue to manage the NWTC as an energy efficiency and renewable energy, research, development and testing site after RFETS is closed.

The Industrial User Facility (IUF) building was completed in 1994, providing 11,000 square feet of space that is used by the wind program and industry to assemble and test wind turbines and components. In 1994, NREL renovated Building 251 and installed a site-wide electrical grid. At that time, there were turbines on the site that continued to operate for specific research purposes. FY1997 brought the installation of the Advanced Research Turbine (ART) and the Hybrid Power Test Bed (HPTB). Several NWTC facilities and infrastructure upgrades were made in 1997, including an emergency power generator, water system enhancements, access road safety improvements, and the site's main electrical switchgear. In FY1999, the 2.5 MW dynamometer facilities and lab were completed. The Controls Advanced Wind Turbine (CART) was installed in FY2000.

A contiguous piece of land about 25 acres, located in the adjacent to the NWTC, was recently designated for inclusion within the NWTC by the National Defense Authorization Act for Fiscal Year 2002. This property was previously a legacy part of the NWTC in the mid 1970's. Two legacy test sites and unimproved roads are located on this land.

NWTC is primarily used for wind energy research, development and testing, and is the only facility of its type in the United States. The NWTC's unique facilities support wind turbine design, development, testing, and certification. Fundamental research is also conducted on turbine aerodynamic and mechanical behavior, as well as turbine interaction with atmospheric conditions.

In addition, the site supports NREL's research in the areas of hybrid power technologies and distributed energy resources. NWTC supports the development and validation of information, data, and testing standards associated with distributed generation equipment and its interconnections with the public utility grid. Hybrid and distributed energy systems that combine various traditional and renewable energy technologies also are tested, as are various distributed energy devices and systems.

Wind turbines and other energy generating facilities at the NWTC have and will continue to contribute power to the local electrical distribution system as a natural byproduct of the research and testing activities on-site. The amount of power produced varies depending upon research activity and hardware type. As larger machines in the multi-megawatt class are tested, these power contributions may be substantial. Currently, DOE has no power purchase agreement in place to receive credit for this energy production, but a power purchase agreement with the local utility company may be negotiated in the future.

The site, at the mouth of Eldorado Canyon, was selected because of intermittent, extreme high-wind characteristics that are favorable to research. These characteristics do not support the objective of full-time wind power generation because of the periods of calm winds between high wind events. The NWTC is not a wind farm or a dedicated renewable energy generation facility, and no short-term or long-term plans exist to convert the site to serve this purpose.

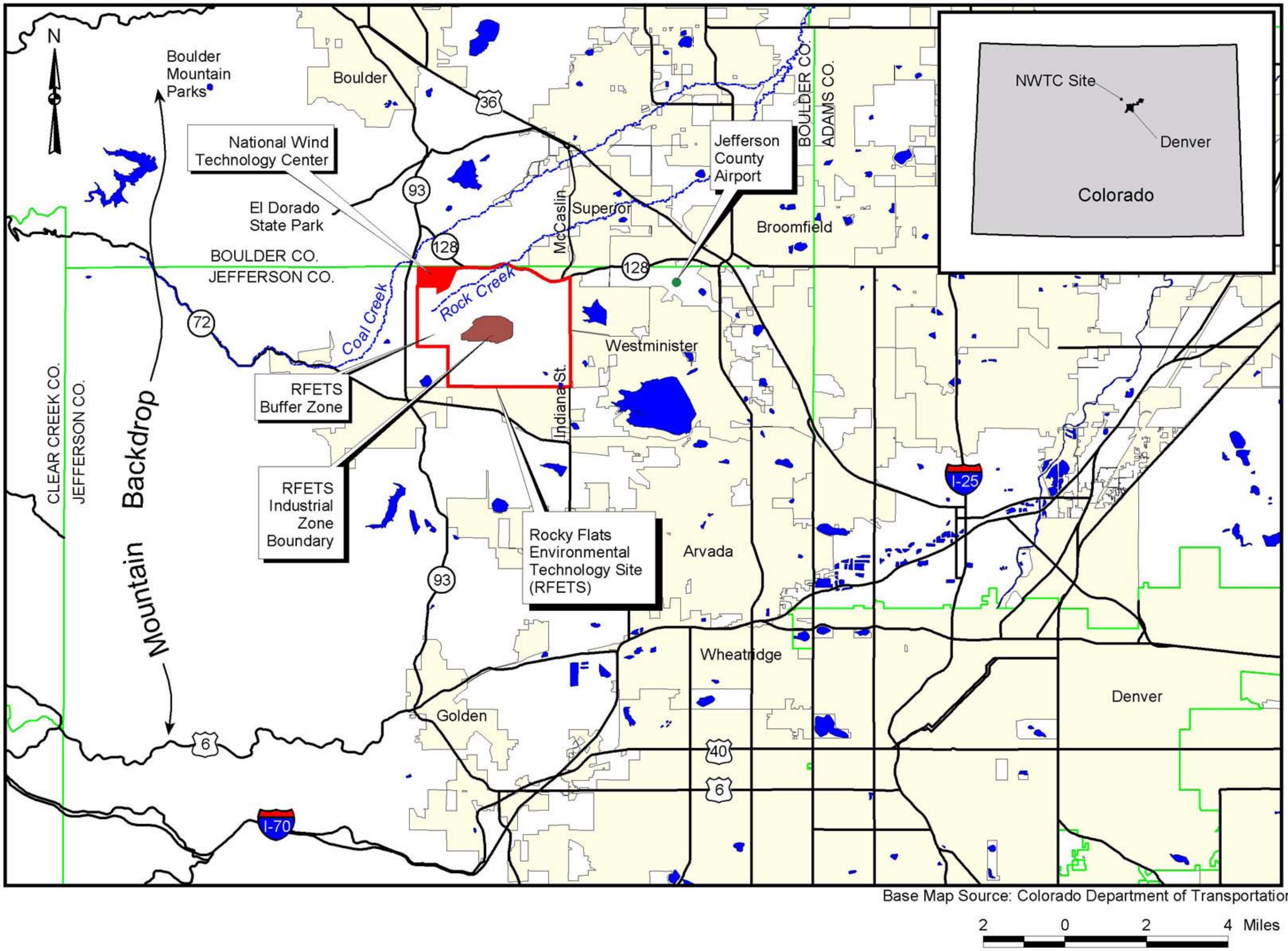


Figure G1.1 Regional Location Map

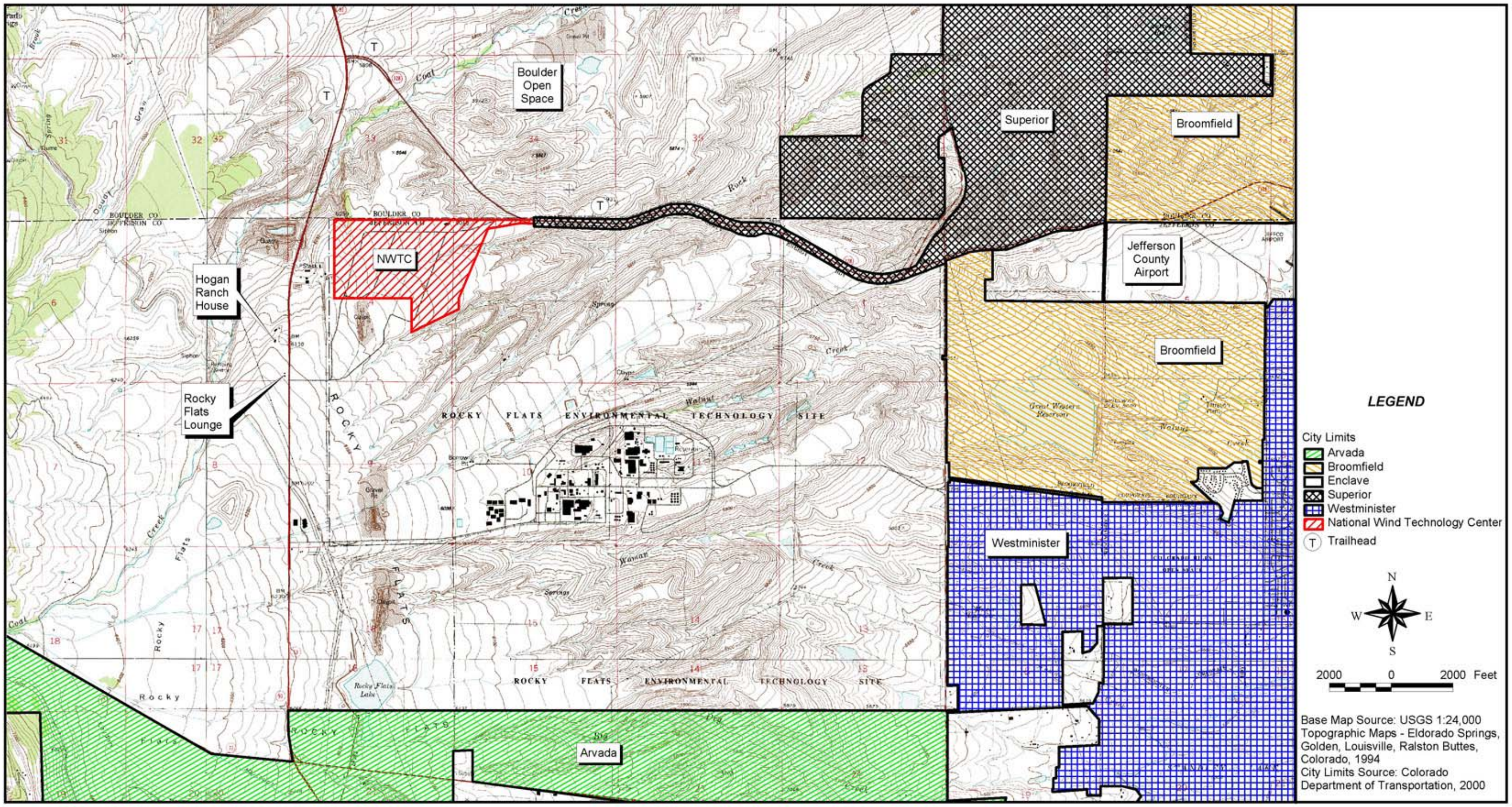


Figure G.1.2 Local Setting Map

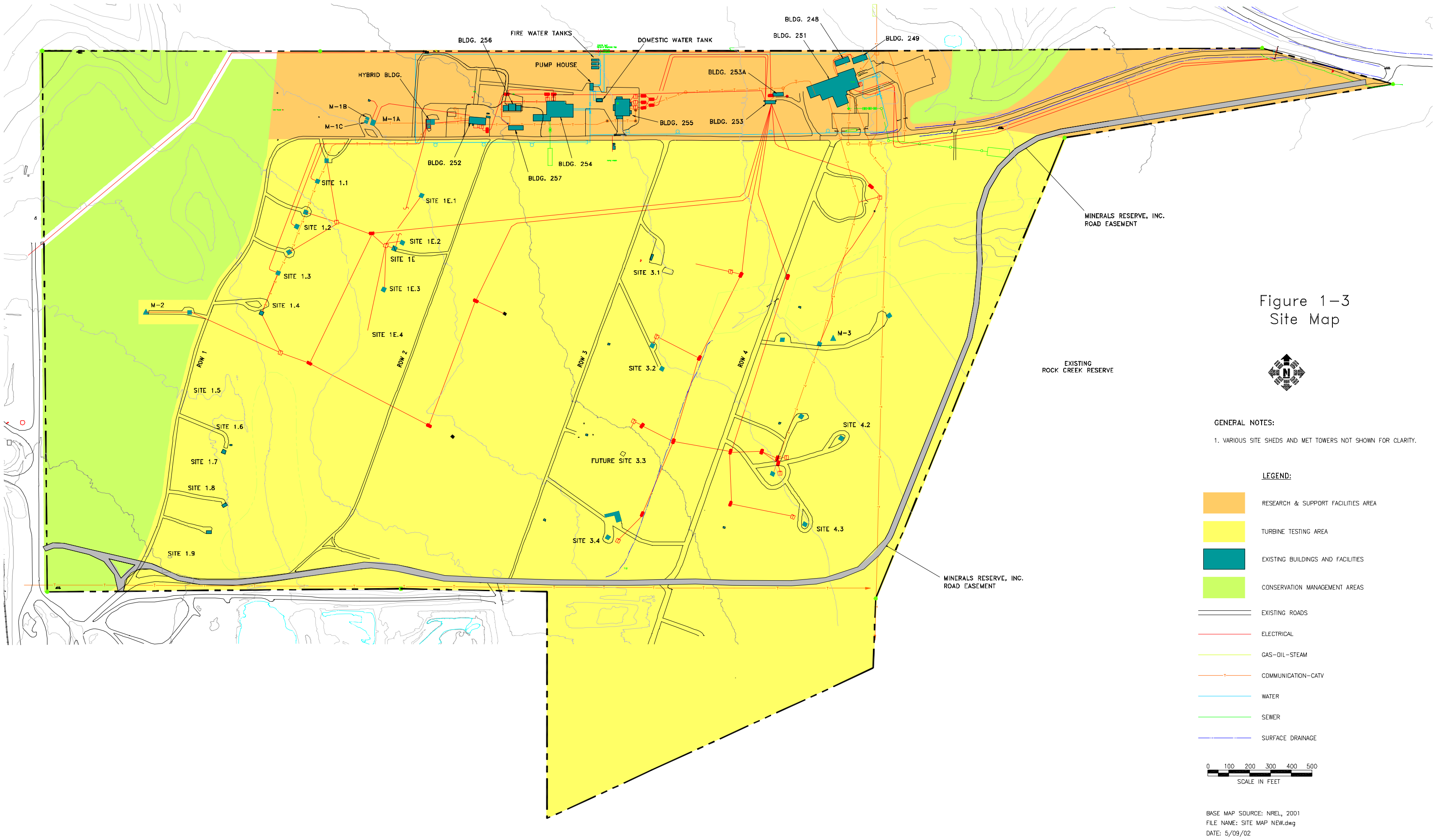


Figure G.1.3 National Wind Technology Center Site Map

Land Use Plan

Figure G.1.5 National Wind Technology Center Land Use Plan

G.2 Surrounding Community

Land uses on properties contiguous to the site include dedicated Boulder County and City of Boulder open space to the north and west of Highway 93, dedicated buffer lands of the RFETS and the recently designated National Wildlife Refuge to the east and south, and industrial uses on private land directly adjacent (AMS Drilling and Blasting) to the west as well as LaFarge aggregate mining and concrete batch-plant to the southwest.

The project vicinity beyond these contiguous areas is characterized by open space to the north and west, expanding residential and commercial development to the east involving the communities of Superior, Arvada, Broomfield, Westminster, and unincorporated areas of Jefferson County, and the industrial facilities on the RFETS to the south.

DOE owns the surface mineral rights of the site; however, the subsurface mineral rights are under private ownership. A local aggregate mining company, lessee of the subsurface mineral rights on the site, and DOE/GO have an agreement that no mining activities will be initiated within the boundaries of the NWTC through at least 2015.The aggregate mining facilities west and southwest of the site are comprised of surface excavations, material conveyors, rail lines and processing facilities. Two companies, TXI and LaFarge operate on separate, but contiguous sites located between Highway 93 and the project site's western boundary. Mineral Reserve, Inc.'s aggregate mining operation is located south of the site.

Jefferson County Airport is located due east of the site near the U.S. Highway 36/Highway 287 interchange. Airport runways are aligned in a northeast/southwest configuration. Aircraft takeoff and landing patterns do not pass directly over the NWTC.

G.3 Land Management

Topography
The NWTC is basically flat and accessible. Most of the land has been reserved for wind turbine testing. Direct access to the wind from Eldorado Canyon is necessary for wind turbine testing; therefore, nothing can be situated on the NWTC that would interfere with the wind flow reaching the research turbines. Buildings have been developed primarily along the northern boundary to avoid interfering with the wind fetch, and to avoid building in areas that may be made unsafe by major failures in research turbine operation.

Although the land is basically flat and accessible, the absence of water and sewer service presents a challenge for large-scale development.

Climate and Ecology
The elevation of the site is between 5990 and 6100 feet above sea level. The site is in the "foothills life zone," a transitional region between the grasslands of the plans life zone and the higher, tree-dominated montane life zone of the Rocky Mountains. With its location near the foothills, the weather conditions impact the facility designs and maintenance considerations due to the climate changes and snow loads. The site has extreme winds at certain times of year, which can cause damage to vehicle windshields and make the site unsuitable for certain activities, especially outdoor tests other than wind turbines.

The soils at the NWTC site are mostly cobbly sandy loam. Soil samples at the NWTC were analyzed and detectable quantities of VOCs, petroleum hydrocarbons, PCBs, and radionuclides did not exceed the State of Colorado Regulatory limits.

NWTC vegetation consists of mostly grasslands with small amounts of shrublands, woodlands, and wetlands. Some of the common wildlife found at the NWTC includes deer mice, ground squirrels, jackrabbits, coyote, mule deer, black bear, mountain lion, rattlesnakes, lizards, bullsnakes, and frogs. Endangered species have been identified and handling of these endangered species, if found, is done in accordance with NREL and DOE Best Management Practices.

Future Development

Additional building development will be limited to the extreme northern portion of the site because of the safety area and wind fetch required for the turbines. See land use plan (Figure G.1.5). To provide the largest area conducive to building construction, the east/west road could relocate to the south. Additional space to the east makes an ideal location for a visitors center. Expansion of existing buildings also provide additional administrative and research space. Expansion into the 25 acres recently acquired would provide additional test pads for research.

Any proposed improvements at the NWTC would have minor on-site and off-site land use impacts. Each improvement is subject to review under applicable programs, policies and procedures implemented by NREL at the NWTC intended to avoid and/or minimize impacts at the site. Sensitive areas of the NWTC are protected by various policies and practices and in most cases, the requirements pertaining to Conservation Management Areas. Designated corridors would be used for utility installation and restoration is required for surface disturbances.

Construction of five megawatt-class turbines, more towers and/or higher towers requires coordination to address FAA requirements associated with Jefferson County Airport height restrictions for navigation and communication equipment. NREL complies with FAA requirements. Preliminary consultation with FAA indicates that approval of the anticipated towers would not be precluded, but certain lighting and other requirements would apply. Light fixture requirements are likely to be similar to existing fixtures, but it is possible they may be needed in multiple locations for the taller towers.

Storm Water Management

Potential impacts to surface water resulting from future construction would not be significant because NREL's existing programs, policies and practices would avoid or minimize impacts to storm water during construction and operations at the NWTC.

Storm water volume may increase due to future development because of a small increase in impervious surface areas. If the volume of storm water does increase, the additional amount should be small, and it is not expected to cause flooding, contribute significantly to erosion of storm water channels, or require substantial infrastructure modifications.

Groundwater Management

Site development would incrementally reduce on-site groundwater recharge by creating an additional amount of impervious surface on the site. This loss would represent a small percentage of the total NWTC site acreage and would not have meaningful consequences on recharge or groundwater availability.

Temporarily impacted lands, due to land clearing and disturbance from construction activities, have an increased susceptibility to noxious weed invasion. NREL actively manages weeds on-site through NREL's aggressive Weed Control Program.

G.4 Buildings and Test Sites

There are currently several research buildings and numerous smaller trailers, support and testing facilities located on the NWTC site located in the facility development area on the northern portion of the site between the site boundary and the primary access road (West 119th Avenue).

Table G.4.1 Summary of DOE-Owned Research Facilities on the National Wind Technology Center Site	
Building 251, about 22,000 gsf and built in 1982, provides facilities for administrative offices and some high-bay testing capabilities. Researchers also use the latest software to analyze next-generation turbine designs and the data collected from tests and experiments for research and development (R&D) and certification. The high bay at building 251 is used for static and dynamic load testing of small wind turbine blades, small wind turbine generator dynamometer testing, and wind turbine blade component testing. The high bay also houses an environmental chamber that exposes turbine components to extreme ambient temperatures like those found in Arctic environments or hot humid climates.	
The **Industrial User Facility**, about 11,000 gsf and built in 1996, includes office space for industry researchers working with wind program technical staff, experimental laboratories, computer facilities, a high bay and several test bays. Two testing areas are equipped with stands for blade fatigue testing that shows structural weaknesses in blades. The system is used to perform certification testing for blade design standards. These tests identify problems before they get in the field and helps lower the cost of energy.	
The **Dynamometer Test Bed** (also called the Dynamometer Spin Test Facility), about 5,500 gsf and built in 1999, provides the facility and equipment to conduct lifetime endurance tests on a wide range of wind turbine drivetrains and gearboxes at various speeds, using low or high torque. The 2.5-MW dynamometer helps researchers improve the performance and reliability of wind turbines and ultimately	

Table G.4.1 Summary of DOE-Owned Research Facilities on the National Wind Technology Center Site	
reduce the cost of the electricity they generate. Wear on drivetrains is an important factor in turbine reliability, with many components that work together as a system. By testing full-scale wind turbines, engineers from NREL and industry study the impact of various wind conditions with the goal of improving hardware designs.	
Turbine Test Pads. In addition to the two advanced research turbines permanently installed on the site, the NWTC provides outdoor turbine test pads for manufacturers that need to test their prototype machines. Companies that have had turbines tested at the NWTC include the Atlantic Orient Corporation, Bergey, Northern Power Systems, and the Wind Turbine Company. There are currently 21 turbine test sites available. Of those 21 sites, between 12 and 15 generally contain operational turbines or other test equipment; five of the turbines are larger than 100 kW.	

G.5 Utilities

The following discussions address electricity, gas, telecommunications, water, sewage, police, fire and ambulance services and infrastructure. Figure G.1.3 (1-3 EA label) presents the locations of on-site utility lines (electrical, gas-oil-steam, telecommunication-CATV, water, sewer and surface drainage).

Electricity and Gas
Electrical power for the NWTC is delivered through Xcel Energy power lines along Highway 93 and on-site. Overhead lines enter the NWTC property from the west along a 20-foot wide easement. The 13.2 kV power lines transition from overhead to underground at the NWTC west property line. From that point, all electric lines on the NWTC property are buried underground. The 13.2 kV power lines feed the Switchgear building (Bldg. 253), which feeds a split bus with two main circuit breakers. One bus feeds the site buildings, and the other feeds the turbine 13.2 kV distribution system to the test sites.

The turbine distribution is connected in a parallel configuration with Xcel Energy, thus allowing the NWTC to feed up to 10 MVA into Xcel Energy's grid with power generated during wind turbine research activities. There is no agreement for the NWTC to sell power into the energy grid.

Power demand ranges from a low of approximately 521 kilowatts to 933 kilowatts. Monthly energy consumption ranges from approximately 141,000 to 413,000 kilowatt-hours. Annual consumption is approximately 3 million kilowatt-hours.

A new medium pressure 4" natural gas line was recently constructed at the NWTC. The gas line runs along the west and northern property boundaries. The gas provides service for Bldg. 251 and the DER research area. As funding becomes available, other facilities will be converted to gas heat.

Telecommunications
The NWTC is served with 15 phone lines coming directly from Qwest and two T1 high-speed lines coming from NREL's South Table Mountain Site. These connections are provided to the site via overhead power line structures that drop below ground at the site boundary.

Water
The domestic water system consists of an underground 15,000-gallon tank, a transfer pump, a 2,000-gallon day tank, chlorine injection system, pressurizing pumps and an underground pipeline system to Buildings 251 and 254. The system has two pressurizing pumps. One is designed to be a backup if the primary pump cannot keep the system pressurized. Currently, approximately one 3,600-gallon truck delivery is made every week to replenish domestic water supplies. No off-site domestic water lines serve the site or adjacent properties. The absence of a domestic water supply is a challenge for further extensive development of the site.

Low water use fixtures have been installed throughout the NWTC as part of a comprehensive effort to reduce NWTC water consumption. Solar hot water heating may be included in future improvements.

Sewage
The sewage system at the NWTC consists of two separate septic tanks and leach fields at Buildings 251 and 254. The septic tanks are pumped once a year. Future buildings requiring domestic water would also require additional septic tank and leach fields. The size of each septic tank and leach field is based on maximum staffing and soil conditions at each facility.

Emergency Response and Fire Protection

The on-site fire protection system consists of three 25,000-gallon insulated tanks, a 1000-gallon per minute pump, a small pressurizing jockey pump, an emergency diesel generator, underground distribution pipeline, and fire hydrants. The underground pipeline extends around all buildings in a loop and fire hydrants are spaced along the main NWTC road. Currently, only Buildings 251 and 254 have fire sprinkler protection. Buildings 251, 252, 253, 254, 255, 256, and the Hybrid Building have fire detection. The current design is to provide a two-hour supply of fire protection water for a building fire. It is not likely that multiple building fires would occur simultaneously. Therefore, the existing fire protection system is considered adequate. However, extensive development of the site in the future would require additional fire protection water.

To protect the site from wildfire, NREL applies its Fire Protection Program to the site. NREL and the Colorado State Forest Service conduct periodic wildfire assessments to assess the hazards from wildfires and to determine if appropriate controls have been established to control these hazards. The Colorado State Forest Service completed a wildfire hazard assessment of the NWTC in September of 2001 and that NREL's Wildfire Hazard Assessment is technically sound and up to date.

In the event of a fire on the project site or adjacent lands, the Cherryvale Fire Protection District is under contract to provide emergency service equipment and personnel.

Ambulance service is provided by the Cherryvale Fire Protection District. In the event of an on-site injury, illness, or other situation requiring an ambulance, District personnel and equipment would be dispatched to the site.

In the event of a crime or other requirement for assistance on the project site, on-site security personnel would respond. If off-site support were required, the Jefferson County Sheriff would be contacted.

G.6 Transportation

Site Circulation and Access

The project site has one primary access and a perimeter circulation road that begins at an intersection with Highway 128 and forms a loop within the site (Figures G.1.1 and G.1.2). The site access road is paved from Highway 128 to the Hybrid Power Test Building. The remainder of the perimeter road and other site access routes shown in Figure G.1.3 have gravel surfaces.

Highway 93 is located west of the site. Highway 93 and 128 intersect northwest of the site.

The NWTC granted a road easement across the site to aggregate operators to the south and west (Figure G.1.2). There is no short-term or long-term plan or schedule in place for construction of a road using this easement.

Future Road Improvements

CDOT, the Regional Transit District (RTD), and local governments are addressing substantial road and transit improvement needs in the vicinity of the NWTC. The major improvements are those associated with U.S. 36 and the Northwest Parkway projects. Improvements to U.S. 36 are expected to involve 4 lanes in each direction and improved bus and commuter rail service in the corridor between Denver and Boulder.

The Northwest Quadrant Feasibility Study proposes the following long-term improvements in the project vicinity:

- Widen Highway 128 to four lanes, two in each direction;
- Widen Highway 93 to four lanes, two in each direction; and
- Construct an interchange at the Highway 128/93 intersection.

However, due to limited funding it is not expected that this construction would occur in the next 10 to 15 years. No major interim improvements are identified for either highway or for the Highway 128/93 intersection. Some widening of shoulders and bridges along Highway 93 has been done and may be done in the future to improve safety, especially for bicycles.

Additional on-site improvements would include paving of some of the gravel roads and road extension onto the 25-acre addition to provide road access for new test sites.

G.7 Disposition

NREL has no plans to dispose of any property or facilities in the foreseeable future.

Appendix H: Leased Facilities

Since its inception in 1977, NREL has depended on the Denver West Office Park, a little over a mile from its central South Table Mountain site, for administrative and research support space. At various times NREL has used part or all of several different buildings in the Office Park, depending on staffing fluctuations. In late 2004, NREL moved out of Building 27 and consolidated most of its operations in Buildings 15, 16, and 17 (see photo), with a small space in Building 7. DOE's Golden Field Office and Denver Regional Office are located in the same buildings as NREL. Current leases are summarized the table below.

Building 15, 17, and 7 include offices and support spaces for Laboratory administrative functions, as well as researchers and program management activities for Buildings research, Geothermal research, the Federal Energy Management Program, international deployment activities, state and local deployment activities, and energy analysis activities.

Building 16 is used for research support activities as well as laboratory research. Portions of the research staff supporting basic science, photovoltaics, transportation, industrial processes, resource assessment, geographic information systems, and computational science are also housed in Building 16. About 15% of the Building 16 space is available for or used in laboratory activities. Building 16 contains essentially all of NREL's flex space for labs and most of the flex space for offices for new or expanded (overflow) activities and very limited additional staff. Because of its location in an office park, limited ventilation capacity, limited floor loading capacity, and lack of a service elevator, Building 16 has significant challenges for research use. NREL has established a rigorous set of ESH&Q criteria that bound the type and amount of laboratory operations that can be sited in Building 16. NREL has developed a Building 16 Comprehensive Plan that outlines multiple phases for the remediation and conversion of laboratory space back into office areas as funds become available for this activity. This plan is updated annually to reflect the latest thinking as annual operating plans, research program plans, and budgets become known.

Joyce Street Facility and ReFUEL Facility

The Joyce Street Facility (JSF) and the ReFUEL Facility are leased commercial spaces that provide temporary additional space for NREL's activities. JSF currently provides 56,000 ft^2 warehouse and storage space and has in the past accommodated a small amount of space for limited research experiments. The ReFUEL Facility is used for vehicle engine/fuel research activities.

Washington, D.C., Office
NREL leases space in the Aerospace Building near DOE's Forrestal Building for NREL staff working closely with DOE and for those activities most effectively managed from this location. In addition, it is used by NREL Golden staff visiting DOE in Washington.

Table H.1 NREL Leased Facilities -- 9/30/2006

Building	Location	Sq.Ft.	Lease Dates	Annual Cost (Current)	Occupants
Bldg. 7	Denver West	4,467	04/01/01-11/08/08	$44,670	11
Bldg. 15	Denver West	29,100	04/01/01-11/08/08	$404,230	72
Bldg. 16	Denver West	85,906	07/01/94-11/08/08	$1,486,129	194
Bldg. 17	Denver West	87,774	07/01/94-11/08/08	$1,436,911	264
Refuel Facility	Denver, CO	4,576	07/05/02-07/04/07	$33,865	5
JSF	Arvada, CO	56,000	09/01/97-01/31/08	$228,664	0
L'Enfant Plaza	Washington, D.C.	7,178	10/01/03-09/30/07	$332,828	14
TOTALS		275,001		$3,967,297	546

Appendix I: Acronyms

ACI	Asset Condition Index
AFUF	Alternative Fuels User Facility
AUI	Asset Utilization Index
BCCL	Biomass Chemical Characterization Laboratory
BTF	Blade Test Facility
BPCL	Biobased Polymer and Composites Laboratory
CAIS	Condition Assessment Information System
CAS	Condition Assessment Survey
CFR	Code of Federal Regulations
CRADA	Cooperative Research and Development Agreement
CRD	Contractor Requirements Document
CRS	Certified Realty Specialist
CSO	Cognizant Secretarial Office
DAB	Design Advisory Board
DOE	Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EPA	Environmental Protection Agency
FAC	FIMS Advisory Committee
FCI	Facility Condition Index
FIMS	Facilities Information Management System
FIRST	Facility for Integrated Renewable Systems Testing
FTLB	Field Test Laboratory Building
GDV	General Development Vision
GPE	General Plant Equipment
GPP	General Plant Project
GSF	Gross Square Feet
IBRF	Integrated Biorefinery Research Facility Expansion
IGPP	Institutional General Plant Project
IFI	Integrated Facilities and Infrastructure
LEED	Leadership in Energy and Environmental Design
LPSO	Lead Program Secretarial Office
LTS	Long-term Stewardship
LWTTF	Large Wind Turbine Test Facility
NEPA	National Environmental Policy Act
NIR	Near Infra Red
NREL	National Renewable Energy Laboratory
OECM	Office of Engineering and Construction Management
OMB	Office of Management and Budget
PDU	Process Development Unit
PPBES	Planning, Programming, Budgeting, and Evaluation System
PSO	Program Secretarial Office
PY	Prior Year
RPV	Replacement Plant Value

RSF	Research Support Facility
SERF	Solar Energy Research Facility
S&TF	Science and Technology Facility
SRRL	Solar Radiation Research Laboratory
TCPDU	Thermo-Chemical Process Development Unit
TYSP	Ten-Year Site Plan
VE	Value Engineering
VFD	Variable Frequency Drive
WFO	Work For Others Agreement

Appendix J: Definitions of Terms

Alterations. Adjustments to interior arrangements or other physical characteristics of an existing facility so that it may be more effectively adapted to or used for its designated purpose. Alterations do not result in betterment to a facility. Examples of alterations are as follows.

a. Removal or installation of interior walls for purposes of rearranging the layout of an office building, and incidental heating and ventilation ducting system.
b. Modifications that do not significantly extend the capacity of the system.
c. Construction of a door or passage through an interior structural wall.
d. Installation of new lighting fixtures that do not significantly increase the lumens emitted but may result in energy or maintenance savings. (RPAM)

Annual Utilization Surveys. Annual utilization surveys are directed by Federal Property Management Regulations § 101-47.802 to determine how well the real property assets are being put to use. The survey content must address the standard specified in Federal Property Management Regulations § 101-47.801, Standards. (RPAM)

Authorization Basis. Safety documentation supporting the decision to allow a process or facility to operate. Included are corporate operational and environmental requirements as found in regulations and specific permits and, for specific activities, work packages or job safety analysis [per DOE G 450.4-1B, Integrated Safety Management System Guide, dated 3-1-01]. (RPAM)

Betterments. Capitalized improvements to facilities that result in better quality work, increased capacity, and/or extended useful life as required to accommodate regulatory and other changes to requirements. Determining when and to what extent expenditure should be treated as betterment requires judgment. The proper basis for determining whether betterment is effected is when the effect of the replacement is related to each unit when a minor item is replaced in each of a number of similar units, rather than to the cumulative costs. Listed below are the various terms that are commonly used to describe various categories of betterments.

e. Construction is the erection, installation, or assembly of a new plant facility; the addition, expansion, improvement, or replacement of an existing facility; or the relocation of a facility. Construction includes equipment installed in and made part of the facility and related site preparation; excavation, filling and landscaping, or other land improvements; and design of the facility. Examples of improvements to an existing facility include the following types of work.
    i. Replacing standard walls with fireproof walls.
    ii. Installing a fire sprinkler system in a space that was previously not protected with a sprinkler system.
    iii. Replacing utility system components with a significantly larger capacity components (e.g., replacing a 200-ton chiller with a 300-ton chiller) and converting the functional purpose of a room (e.g., converting an office into a computer room).
f. Conversion is a major structural revision of a facility that changes the functional purpose for which the facility was originally designed or used.
g. Major Renovation and Replacement is a complete reconstruction of a facility that has deteriorated or has been damaged beyond the point where its individual parts can be economically repaired. If the item replaced is a retirement unit, its original costs (including installation cost) are removed from the plant and capital equipment accounts, and the cost of the newly installed item (including installation cost) is added to the plant and capital equipment accounts. (RPAM)

Capital Equipment. All types of equipment (structure-integrated, standalone, facility-specific, not-related-to-construction) for which DOE will retain title, costs $50,000 or more including the costs for installing the equipment, has an expected service life of at least two years, and will not be used up or destroyed or reduced to scrap during an experiment. (EERE, NREL)

Capital Equipment Not Related To Construction. Capital Equipment Not Related to Construction is Capital Equipment for which DOE will retain title, costs $50,000 or more including the costs for installing the equipment, has an expected service life of at least two years, and is not required to complete a general plant project or construction line item. Items of Capital Equipment Not Related to Construction required for experimental projects shall be budgeted from operating expenses if expectations are that the equipment will be destroyed during the experiment, or will have no further value other than scrap upon completion of the experiment.

- *Differentiating Between Capital Equipment and Construction Projects*. In most cases, Capital Equipment can be installed with little or no significant installation costs or construction activities required. However, in some cases the equipment requires significant construction activities to function, such as the provision of foundations, utilities, and structural modifications and additions to a building. As a rule, construction funds should be used when these construction activities constitute more than 20 percent of the equipment cost.
- *Differentiating Between Capital Equipment Related to Construction and Capital Equipment Not Related to Construction*. All projects, facilities, and Capital Equipment necessary to complete and *operate* a project are Project Specific General Plant Project and Capital Equipment; therefore, they are Capital Equipment Related to Construction. Other Capital Equipment acquisitions meeting the criteria in paragraph 2.5 are Capital Equipment Not Related to Construction. (EERE)

Computational Science. Computational science (in contrast to general information technology which refers to administrative computer-related activities)is a rapidly growing multidisciplinary scientific field with connections to the physical and biological sciences, engineering, applied mathematics, numerical analysis, and computer science. Computational science focuses on the integration of knowledge and methodologies from all of these disciplines, and as such is a subject that is distinct from each of them. It focuses on developing and applying problem-solving methodologies and robust tools for the solution of scientific and engineering problems. Computational scientists are scientists in their own right. However, they often work with the discipline-specific scientists and engineers to apply computational science tools to real world problems.

Construction. Construction is the erection, installation, or assembly of a new plant facility; the addition, expansion, improvement, or replacement of an existing facility (e.g., demolish existing facility and construct new one), or the relocation of a facility. Construction includes equipment installed in and made part of the facility and related site preparation; excavation, filling and landscaping, or other land improvements; and the design of the facility. Examples of improvements of an existing facility include replacing standard walls with fireproof walls or installing a fire sprinkler system, or replacing utility system components with components of significantly larger capacity (such as replacing a 200-ton chiller with a 300-ton chiller). (EERE)

Construction Line Item. Separate project activities that programs submit for funding in amounts greater than or equal to $5 million, and that the Congress specifically reviews and approves. (EERE)

Corporate Review Budget. Internal DOE budget prepared for the DOE Controller's Office. (NREL)

Corrective Maintenance. The repair or restoration of failed or malfunctioning equipment, systems, or facilities to their intended functions or design conditions. It does not result in a significant extension of the expected useful life. (RPAM)

Critical Decision Points. CD-0 through CD-4 are decision points in the process of developing and approving a construction line item project as delineated in DOE Order 413.3. See Table Z (section 5) and Figure X (section 5). While the development of a general plant project is qualitatively the same as a construction line item project, the critical decision points are not formally used with general plant projects. (NREL)

Current Real Property Assets. The site's total area in square feet for all operating and excess facilities less (a) those excess that have been funded for disposal, including demolition, sale, and out-lease, in the enacted budget and (b) those facilities that have been deactivated and decontaminated but not fully decommissioned and are being placed into long-term stewardship. For land it is the acreage of the DOE site. (RPAM)

Deferred Maintenance. Maintenance or any kind of reinvestment that was not performed when it should have been or was scheduled to be and which, therefore, is put off or delayed for a future period. (RPAM)

Deferred Replacement. Purchase of a new, sometimes upgraded or expanded capital equipment item to replace an existing asset after the end of the useful life of the asset. (See “Regular Replacement” and “New Capability”). (NREL)

Deferred Replacement Backlog. As of any given date, the total value of the active capital equipment that is older than its useful life. (NREL)

Disposal. Permanent or temporary transfer of DOE control and custody of real property assets to a third party who thereby acquires rights to control, use, or relinquish the property. (RPAM)

Equipment Condition Index. The ratio of the value of equipment that is beyond its useful life (also referred to as the Deferred Replacement Backlog) to the value of the rest of the equipment in the same category. The qualitative descriptors of good, excellent, etc are the same as the Facility Condition Index. (NREL)

Estimated Value Today. The acquisition cost escalated using Denver Consumer Price Index to 2004 (also referred to as Escalated Acquisition Cost). For equipment, this is the best equivalent available to the Replacement Plant Value used for facilities and infrastructure. (NREL)

Excess Real Property. Land, improvements to land, or both, including interest therein, which is not required for the Department's needs or the discharge of its responsibilities. For the purposes of reporting deferred maintenance, excess real property is an asset that is on the path for disposition. (RPAM)

Facility. Land, buildings, and other structures, their functional systems and equipment, and other fixed systems and equipment installed therein, including site development features outside the plant, such as landscaping, roads, walks, parking areas, outside lighting and communication systems, central utility plants, utilities supply and distribution systems, and other physical plant features. These include any of the DOE-owned, -leased, or -controlled facilities, and they may or may not be furnished to a contractor under a contract with DOE. (RPAM)

Facility Condition Index (FCI). The FCI is the ratio of the cost of deferred maintenance to the facility's replacement plant value. The cost of deferred maintenance deficiencies is determined by condition assessment inspections. Facilities Information Management System data is used to calculate FCI.DOE adopted the FCI in 1998 as its tool for measuring the condition of its facilities. [See GAO Report, NSIAD-99-100 Military Infrastructure: Real Property Management Needs Improvement, dated September 1999 (reference u) and National Association of College and University Business Officers Managing the Facilities Portfolio—A Practical Approach to Institutional Facility Renewal and Deferred Maintenance, 1991.] (RPAM)

Facility-Specific Capital Equipment. Standalone capital equipment that will be needed when a new facility is initially occupied in order to accomplish the mission of the facility. These items are typically research and/or information equipment. (EERE)

General Plant Projects. Any work performed that modifies, improves, or even just attaches to, an NREL facility or an NREL site. The work must benefit the entire lab or multiple programs/centers, cost greater than $25,000, and have a useful life of at least two years. The project must be an installation or assembly of a new facility, an installation that will be made a permanent part of an existing facility, or be related to utilities (water and sewage; heating, cooling, and power; communications or fire prevention systems). Each general plant project has a limit of $5 million, and each project mush result in a discrete, stand-alone entity, resulting in the delivery of a complete and usable facility, including the initial complement of equipment required for the facility to meet its intended purpose. Incremental general plant projects cannot be used to construct larger facilities. See the DOE Accounting Handbook, Chapter 10, "Plant and Capital Equipment." General plant projects can be used to adapt facilities for changes in research projects, to effect economics of operations, and to reduce or eliminate health, fire, and security problems. These projects provide for design and/or construction, additions, and improvements to land, buildings, and utility systems; and they may include the construction of small new buildings, replacements, or additions to roads, and general area improvements. (NREL, EERE, RPAM)

General Purpose Equipment. (Same as institutional equipment.) Equipment items that benefit the entire lab or multiple programs/centers, cost greater than $25,000, and have a useful life of at least two years. If this is a "systems" purchase where each component purchased is less than $25,000, the total system cost must be greater than $25,000 (e.g., a computer system). If this is a software purchase, it must be an operating system, defined as only the software necessary for the computer to operate as intended. Items such as paint, carpeting or similar items used in repair or maintenance would not be included as general purpose equipment. The equipment must not be intended for an experiment in which the equipment is expected to be used up, broken, or otherwise have no further use beyond the experiment (e.g., an experimental wind turbine blade). (NREL)

Information Technology Equipment. In general, all capital equipment at NREL can be broken into two main groups: information technology equipment, which typically has a strategic useful life of 3-5 years, and R&D equipment, which typically has a strategic useful life of 7-25 years. Information technology equipment includes computers, servers, electronic storage media, workstations, and other computer-related equipment. IT is discussed in three categories at NREL: 1) institutional information equipment or institutional IT (see below); 2) computational science equipment, which is used to perform scientific calculations in support of research; and 3) information technology equipment that researchers use other than computational science equipment, such as the computers researchers have on their desks. Computer-related equipment that is part of a large scientific instrument, as is now common, is considered R&D equipment. (NREL)

Integrated Facilities and Infrastructure (IFI) Crosscut Budget. A crosscut budget exhibit that has been developed to ensure sustained improvement in real property management. It constitutes, with the exception of new mission line-item projects, the resources required to implement a Ten-Year Site Plan. This crosscut budget identifies renovation, recapitalization, maintenance, and demolition projects for buildings and facilities by program and site. The IFI budget also includes reports on direct maintenance and an estimate of indirect maintenance and repair funding requirements. The IFI is developed in conjunction with the Department's budgeting process and submitted annually with the Presidential Budget to Congress. (RPAM)

Infrastructure. All real property, installed equipment, and related real property that is not solely supporting a single program mission at a multiprogram site or that is not programmatic real property at a single program site. (RPAM)

Institutional Equipment. (Same as general purpose equipment.) Capital equipment items that are used to support the general infrastructure of the institution. These typically include institutional information equipment, institutional scientific equipment, and institutional other equipment. (NREL)

Institutional Information Equipment. Computers, workstations, servers, electronic storage media, and similar capital equipment, that is necessary to manage administrative information such as that related to financial accounting, human resources, facilities management, email and telecommunications, etc. This does not include the computers, workstations, etc specifically used for computational science or high-performance computing in support of scientific investigation. (NREL)

Institutional Scientific Equipment. Spectrometers, microscopes, chromatographs, and other items of capital equipment that are used for conducting research that benefits multiple programmatic areas. This does not include the same types of instruments that are purchased and dedicated specifically to one program. (NREL)

Institutional Other Equipment. Miscellaneous items of capital equipment that support the activities of the institution that do not fit the information or scientific equipment categories. These typically include equipment items related to security, safety, facilities management, shops, etc. (NREL)

Land-Use Planning. A formal, integrated planning process that is used to identify an appropriate mix of land uses at each site and guidelines for development. [See DOE P 430.1, Land and Facility Use Planning, dated 7-9-96.] (RPAM)

Large General Plant Project. A general plant project that is estimated to cost between $1 million and $5 million.

Lead Program Secretarial Office (LPSO). A Program Secretarial Office (PSO) that is responsible for implementation of policy promulgated by Headquarters staff and support organizations for a field office. The LPSO owns the site, manages its own program projects, and acts as a host for tenant Cognizant Secretarial Offices/PSOs by providing facility and/or infrastructure support. The LPSO for NREL is the Office of Energy Efficiency and Renewable Energy. (RPAM)

Life Cycle. The life of an asset from planning through acquisition, maintenance, operation, remediation, disposition, long-term stewardship, and disposal. (RPAM)

Life-Cycle Cost. The sum total of the direct, indirect, recurring, nonrecurring, and other related costs incurred or estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposition of real property over its anticipated useful life span. (RPAM)

Long-Term Stewardship. The physical controls, institutions, information, and other mechanisms needed to ensure protection of people and the environment at sites where DOE has completed or plans to complete cleanup (e.g., landfill closures, remedial actions, removal actions, and facility stabilization). This concept includes land-use controls, monitoring, maintenance, and information management. (RPAM)

Maintenance. Day to day work that is required to sustain property in a condition suitable for it to be used for its designated purposes, including preventive, predictive, and corrective maintenance. Maintenance costs and work do not include the following.

a. Regularly scheduled janitorial work such as cleaning, and preserving facilities and equipment.
b. Work performed in relocating or installing partitions, office furniture, and other associated activities.
c. Work usually associated with the removal, moving, and placement of equipment.
d. Work aimed at expanding the capacity of an asset or otherwise upgrading it to serve needs different from or significantly greater than those originally intended.
e. Improvement work performed directly by in-house workers or in support of construction contractors accomplishing an improvement.
f. Work performed on special projects not directly in support of maintenance or construction.
g. Non-maintenance roads and grounds work such as grass cutting and street sweeping. (RPAM)

Mission Essential Real Property Assets. Those facilities and infrastructure assets that directly contribute to accomplishment of the program assigned missions or mitigation of environmental, safety, or health issues, which if not available, would adversely impact the mission. (RPAM)

On-time Replacement. Purchase of a new, sometimes upgraded or expanded capital equipment item to replace an existing asset on or before the end of the strategic useful life of the asset. (See “Deferred Replacement” and “New Capability”). (NREL)

Operating Facilities. Facilities that have a Facilities Information Management System status code of operating, operating standby, operating pending excess, operating under out-grant, or operating pending decontamination and demolition/disposition. (RPAM)

Optimum Period. That time in the life cycle of a real asset when maintenance actions should be accomplished to preserve and maximize the useful life of the asset. The determination is based on engineering/maintenance analysis and is independent of funding availability or other resource implications. (RPAM)

Performance Measures. A quantitative or qualitative characterization of performance toward an objective. [See DOE G 430.1-4.] (RPAM)

Performance Objective. A statement of the desired output/outcome for an organization or activity. [See DOE G 430.1-4.] (RPAM)

Plant, Property & Equipment. Tangible assets that meet the capitalization criteria, that are not intended for sale in the ordinary course of operations, and have been acquired or constructed with the intention of being used, or being available for use by the entity. Plant, property, and equipment includes site infrastructure. (RPAM)

Predictive Maintenance. Those activities involving continuous or periodic monitoring and diagnosis to forecast component degradation so that "as needed" maintenance can be scheduled for facilities and infrastructure. (RPAM)

Preventive Maintenance. Those periodic and planned actions taken to maintain a piece of equipment within design operating conditions and extend its life and performed before equipment failure or to prevent equipment failure for facilities and infrastructure. (RPAM)

Prior Year (PY). The fiscal year immediately preceding the current year and two fiscal years preceding the budget year. For the field, Congressional Review, and the Office of Management and Budget, PY is the fiscal year in which the budget is being executed.
For the Congressional cycle, the PY is the most recently completed fiscal year. (RPAM)

Programmatic Real Property. Refers to reactors, accelerators, and similar devices used by programmatic personnel, acquired with line item funding, and listed in the Facilities Information Management System as "Other Structures and Facilities" under the 3200 series usage codes, such as 3209, 3221, 3251, and 3261. (RPAM)

Programmatic Capital Equipment (PCE). Equipment items not essential to the operation of a building that are purchased with program funds, cost more than $25,000, have a useful life of more than two years, and are not used up in an experiment. Programmatic capital equipment can include both capital equipment related to construction and capital equipment not related to construction. (NREL)

Program Secretarial Office (PSO). A senior outlay program office which has work performed at a site, but not as the host Lead Program Secretarial Office or Cognizant Secretarial Office at that site, and provides annual program direction and guidance to the site/field manager for the work to be performed at the site, and for budgeting to support program work and an appropriate share of their tenant costs to the landlord. The Office of Science is a PSO at NREL. (RPAM)

R&D Equipment. Capital equipment items that are purchased for research purposes. Also called scientific instrumentation. As examples, this includes large lab instruments such as spectrometers or microscopes, which typically have a strategic useful life of 7-10 years; centrifuges or vacuum pumps, which may have a strategic useful life of 10-15 years; and fermentors and cranes to move wind turbine blades, which may have a strategic useful life of 15-25 years. R&D equipment is considered in two categories according to the funding source and therefore the beneficiary: 1) institutional scientific instruments or equipment, which benefits the entire lab or multiple programs, and 2) program capital equipment, which benefits one or perhaps two programs. (NREL)

Real Property Assets. Any interest in land, together with the improvements, facilities, structures, and fixtures located thereon, including prefabricated movable structures and appurtenances thereto, under the control of DOE. All real property owned by or leased to the Government or acquired by the Government under the terms of the contract. It includes both government-furnished property and contractor-acquired property as defined in Federal Acquisition Regulation 45.101. DOE-owned, -used, and -controlled land, land improvements, structures, utilities, installed equipment, and components are included.
Real property and real estate means land and rights in land, ground improvements, utility distribution systems, and buildings and other structures. Real Property Assets are defined by the Federal Property Management Regulations § 101-47.103-12, Real Property. (RPAM)

Recapitalization. Major renovations or reconstruction activities, including facility replacements, needed to keep existing facilities modern and relevant in an environment of changing standards and missions. This includes the restoration and modernization of existing facilities but not the acquisition of new facilities or the demolition of old ones, unless the demolition is carried out as part of a renovation project or in conjunction with construction of replacement footprint elsewhere. (RPAM)

Reinvestment. Any and all investments made in existing facilities to maintain, sustain, or recapitalize both capital and operating RPAM and NREL). *See Section 6.0*

Repair. The restoration of failed or malfunctioning equipment, system, or facility to its intended function or design condition. Repair does not result in a significant extension of the expected useful life. (RPAM)

Replacement Equipment Value (REV). As applied to programmatic capital equipment or general purpose equipment, the cost to replace the existing equipment with equipment of comparable or upgraded functionality. Because of the lack of other cost estimating procedures, RPV for equipment is often estimated as the original acquisition cost escalated to the current date using an appropriate consumer price index. (RPAM and NREL)

Replacement Plant Value (RPV). As applied to a structure, the cost to replace the existing structure with a new structure of comparable size using current technology, codes, standards, and materials.

Site. A geographic area owned or leased by or for the account of the Federal Government for the performance of DOE program activities. The term includes any extant buildings, infrastructure, and other improvements. (RPAM)

Small General Plant Project. A general plant project that is estimated to cost about $1 million or less. (NREL)

Standalone Capital Equipment. Capital equipment items that are not part of the functioning of a building. Standalone capital equipment includes scientific instrumentation, process development equipment, computer equipment, etc. (See structure-integrated capital equipment.) (NREL)

Structure-Integrated Capital Equipment. Capital equipment items that are part of the functioning of a building, such as chillers, fans, toxic gas monitors, etc. (NREL)

Surveillance and Maintenance. Activities conducted throughout the facility life-cycle, including providing, in a cost effective manner, periodic inspections and maintenance of structures, systems and equipment necessary for the satisfactory containment of contamination, and for the protection of workers, the public, and the environment. RPAM)

Sustainment. Maintenance and repair activities necessary to keep the inventory of facilities in good working order. This includes regularly scheduled maintenance as well as anticipated major repairs or replacement of components that occur periodically over the expected service life of the facilities. (RPAM)

Sustainability. The simultaneous and balanced pursuit of economic viability, environmental health, and public responsibility over the long term through appropriate investment decisions and operating practices. (NREL)

Ten-Year Site Plan (TYSP). A planning document that identifies the site's annual and strategic program requirements and priorities, and links these to real property asset requirements. Real property asset requirements must be consistent with program missions, budgets, and planning estimates. Planning employs costing efficiencies, eliminates excess buildings, consolidates operations where practicable, and addresses mission-critical requirements through an appropriate mix of recapitalization, new construction, and disposal of excess facilities. (RPAM)

Total Estimated Costs (TEC). The Total Estimated Cost of a project is the specific cost of the project including cost of land and land rights; engineering, design, and inspection costs; direct and indirect construction costs; and the cost of initial equipment necessary to place the plant or installation in operation. (RPAM)

Total Project Costs (TPC). The Total Project cost is the Total Estimated Cost plus the following: All research and development, operating, plant and capital equipment costs, specifically associated with project construction up to the point of routine operations, which will include but not limited to: pre-title I activities, R&D necessary for fabrication, testing, and rework of prototype equipment; R&D required prior to start of construction; one-time costs related to testing, startup, operator training, and commissioning; initial inventories and spare parts; site suitability testing and evaluation; quality assurance related to site suitability and testing; regulation compliance; grant to state and local governments; payments equal to taxes; systems studies and selected systems engineering services; institutional activities related to facility siting and external interactions; decontamination and decommissioning costs; economic escalation; contingency (applicable to TPC). (RPAM)

Useful Life. *(Also Service Life)*The estimated length of time that an item of equipment is expected to be in service.

Value Engineering. An organized effort directed at analyzing the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life-cycle cost consistent with required performance, reliability, quality, and safety. For purposes of this Order, value analysis, value management, and value control are considered synonymous with value engineering. (RPAM)

Appendix K: References

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