

Strategic Plan for the Natural Resource Ecology Laboratory, Colorado State University

Prepared by the NREL Strategic Planning Committee in Consultation with the Director of the NREL

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1.0 NREL Vision, Mission and Summary of Strategic Goals

Institutional Vision and Mission

The Natural Resource Ecology Laboratory is a globally recognized leader in developing practical solutions to complex environmental challenges and advancing our fundamental understanding of the natural world. Our research originates from the premise that a clear understanding of the complex interactions that characterize whole ecosystems is required to devise management strategies for the conservation and sustainable use of natural resources. Our approach to ecosystem science is grounded in systems analyses, and our working philosophy integrates the natural, physical and social sciences, through mentoring, education, and active engagement with stakeholders.

The NREL Intellectual Environment

The NREL strives to foster an open, collaborative and collegial intellectual environment that promotes and values critical thinking to advance the field of ecosystem science and resource management. NREL scientists value the diversity of ideas and approaches that various disciplines and individuals bring to address environmental challenges; understanding that it is through this intellectual diversity that environmental systems and challenges are best studied and addressed. Towards this goal, the NREL strives to foster a culture of intellectual curiosity and creativity that includes the following elements.

- ***Trans/Inter-Disciplinary Research*** – NREL scientists come from different disciplinary backgrounds, often with different epistemologies, to work collaboratively on fundamental and applied research questions.
- ***Systems-Thinking and Analysis*** - NREL scientists study across different levels of organization in the environment from the genome to the globe, and emphasize the use of systems analysis to uncover key drivers of environmental phenomenon.
- ***Multiple Research Approaches*** - NREL scientists use complementary research approaches linking experimentation with computer modeling to advance fundamental understanding and predictive capability of our science.
- ***Basis for Adaptive Management and Policy Development*** - NREL research leads to environmental assessments that form an expanded basis for adaptive management and policy development.

These innovative and forward thinking approaches have enabled NREL scientists to seek creative solutions through multiple means to address pressing environmental challenges facing society. As a “research first” institution within Colorado State University, the NREL advances basic and applied research frontiers, while simultaneously rethinking and redefining how research engagement interacts with traditional academic endeavors (e.g., education, advising, and outreach) within a land grant institution.

The current intellectual environment and operations are supported by grants and contracts from federal and state agencies, and private foundations. Over time, two trends have merged that may adversely affect our mission and vision. First, while the NREL has shown modest increases in funding with more funded grants and contracts, their average size has decreased. Second, the NREL scientific staff demographic does not reflect the diversity of the populations we serve and

is bimodal, with mostly early and late career scientists few mid-career scientists. We believe that confronting the conditions underlying these trends is the best way to meet the aims of the vision and mission the NREL and to move the lab forward.

Strategic Goals - What is needed for NREL to move forward?

Four overarching goals have been identified to further expand on the vision and mission of the Natural Resource Ecology Laboratory (NREL).

Goal 1 – Fortifying, Growing and Sustaining the NREL Intellectual Environment

- Objective 1.1 – Fortify and Grow the NREL Scientific Staff
- Objective 1.2 – Grow the Intellectual Environment by Enhancing Opportunities for Early Career and Visiting Scholars
- Objective 1.3 – Provide Professional Development Opportunities for Support Staff
- Objective 1.4 – Promote Diversity within the NREL Community
- Objective 1.5 - Expand Research Impact and Engagement with Stakeholders

Goal 2 – Promoting Awareness of NREL Research

- Objective 2.1 – Develop Visual Branding Language for NREL
- Objective 2.2 – Enhance NREL Web Presence
- Objective 2.3 – Expand Traditional and Innovative Outreach Pathways

Goal 3 – Enhancing Educational Opportunities, Analytical Laboratory and Computational Facilities

- Objective 3.1 – Increase Course Offerings, Certificate Programs and Professional Development Institutes
- Objective 3.2 – Enhance NREL EcoCore Facility
- Objective 3.3 – Enhance Computational Facility

Goal 4 – Becoming a Leader in the Era of Open Science

- Objective 4.1 – Create an Open Science Platform
- Objective 4.2 – Enhance Data Management Capabilities and Open Science Investigations

As the strategic plan is implemented, NREL committees and individuals that are charged with these goals will provide routine updates to the Director of the NREL, the NREL research community, and the External Advisory Committee. The updates will include an overview of the implementation and metrics gauging our success.

2.0 Goal 1 - Fortifying, Growing and Sustaining the NREL Intellectual Environment

NREL research is directed toward constituents who include scientific peers, industry, land managers, policy makers, students, and the broader society. Our scientists publish original research and syntheses, conduct workshops, deliver invited talks, and take leadership roles informing regional, national, and international policy development. Our scientists have contributed to Nobel Prize-winning work, provide congressional testimony, contribute to grand efforts such as endangered species conservation, and regularly provide information to resource managers. Students and young professionals are mentored within the laboratory, and approaches for training young decision makers are expanding.

Given the current state of federal and state funding it will be difficult to sustain the existing intellectual environment, much less to grow and fortify the NREL tradition of excellence in scientific research by relying entirely on these sources of support. Consequently, a key objective to fortify and grow the intellectual environment with a more sustainable framework for scientific discovery.

Objective 1.1 – Fortify and Grow the NREL Scientific Staff

The NREL scientific staff is the centerpiece of the intellectual environment of the laboratory. Through their intellectual creativity, NREL scientists develop research ideas that are valued and funded through research programs administered by a variety of funding agencies, including federal, state and non-governmental institutions. NREL scientists lead the funded investigations with research associates, graduate students, post-doctoral scientists, and other collaborators, and disseminate results at scientific meetings, in published articles, and at other venues.

The core scientific staff include research scientists (Research Scientists I, II, and III, and Senior Research Scientists), academic faculty, government scientists, and retirees. This unique combination of scientists from different career tracks and at different points in their careers, provides a unique intellectual environment for scientific exploration. However, historically research scientist positions have not been sustainable unless a faculty appointment or other position was available to provide base funding for salary.

To fortify and grow the quality of our intellectual environment at the NREL, an objective of this strategic plan is to provide more opportunities that create a stable funding base for all NREL scientists, leading to more attractive positions for retaining and recruiting the top talents in the field. A stable funding base also addresses a lack of equity among scientists because all Research Scientist II and above are actively involved with creative development of research ideas and proposals, committee work, and student advising. However, some NREL scientists are not compensated for these activities unless they are provided funding through a faculty appointment or government scientist position.

There is clearly a need for a funding base that will entail additional responsibilities beyond conducting research through grants and contracts, but ultimately give each scientist a

consistent and reliable source of funding that is available every year. Scientists supported by these funds will have the opportunity to engage more fully in the mission of the laboratory and university, and have a more viable long-term career option at NREL.

1) Develop a base funding model that provides 4.5 months beyond the funding obtained through grants and contracts for all NREL scientists with a rank of RS II and higher.

A sustainable funding model needs to be developed, identifying funding sources and a process for the allocation of funds. The responsibilities will vary from individual to individual depending on the source of funding but will result in at least 4.5 months of base funding per individual.

Action Items

- Establish and charge a committee tasked with providing the Director of NREL a funding model that identifies strategies of funding, and provides an evaluation process to equitably distribute the funds.
- Director of the NREL will meet with each scientist and discuss options for establishing a funding base for their position given the funding model developed by the committee and the Director.

2) Develop and secure funding sources to support the proposed funding model

Base funding support may be provided by an academic department, government agency or foundation, but may also be provided through an endowment, course instruction, and joint ventures with stakeholder groups. It is likely that some combination of these options will be needed to meet the goal of a stable funding base for all scientists, beyond faculty appointments and government scientist positions.

Action Items

- Develop an endowment through a capital campaign to support salaries and other initiatives.
- Explore the feasibility of using a portion of indirect cost return to fund salaries for NREL related activities.
- Seek faculty appointments for our scientists that are joint appointments at the NREL and the academic department.
- Develop courses that can provide salary support through traditional formats and online venues, and professional development programs.
- Establish joint ventures with stakeholders who pay a fee to use NREL research expertise for addressing environmental challenges, which in turn, provides a stable source of funding for scientists (discussed later in this section).

The capital campaign is a key part of this strategy and will need a committee to oversee this effort in coordination with the Director of the NREL and the CSU Foundation. The capital campaign will also likely involve hiring a new staff member with communication expertise, or contracting with an external entity to assist with marketing our campaign. Promotional material will be developed to support the campaign, such as a one-pager for the CSU Foundation and Administrators, printed material for interested donors, and an updated web site (see Goal 2). Moreover, NREL scientists will need to be prepared for visits with interested donors.

Objective 1.2 – Grow the Intellectual Environment by Enhancing Opportunities for Early Career and Visiting Scholars

A key to innovation and productivity is the consistent input of new dynamic scholars. Currently awards through grants and contracts allow the NREL to support a K-12 Teacher-in-Residence (TiR) program, post-doctoral fellows, and host visiting scholars. These efforts can be expanded through the NREL Early Careers and Visiting Scholars Program, allowing us to target specific disciplines, serve the broader research and education community, and actively recruit scientists who would complement existing expertise within the laboratory. To meet this objective, we will create funding mechanisms that will allow us to attract scientists to NREL.

1) Establish the NREL Early Careers Fellowship and NREL Visiting Scholars Program

We envision the Early Careers Fellowship to include salary and some base research funding for a two-year period. The fellowships are intended for post-doctoral researchers with expertise that complements the strengths of existing scientists at the NREL. Each fellow will be given a RS1 status and encouraged to collaborate with more than one NREL scientists. Fellows will prepare proposals under the mentorship of established NREL scientists. Funding for this fellowship could be obtained through existing fellowship programs (e.g., NSF Post-Doctoral Fellowship, USGS Mendenhall Program) or supported through the NREL budget.

Our Visiting Scholars Program will provide opportunities for our peers to spend sabbaticals or other short periods (3 mo. – 1 year) in residence at the NREL to actively collaborate with our scientists. The program will match funds to cover salary of visiting scholars and assist with locating housing. These positions are envisioned as temporary with visiting scientist returning to her or his home institute after the residency ends.

These activities provides a formal mechanism to recruit individuals to NREL, broaden our collaborations, and invigorate our scientific endeavors.

Action Items

- Establish and charge a committee with developing a post-doctoral and visiting scholars program in coordination with the Director of NREL.
- Develop a post-doctoral fellowship program model that includes criteria for advertising, vetting of applicants, and expectations of successful applicants, along with funding mechanisms.
- Develop a Visiting Scientist Program model that includes criteria for advertising, vetting of applicants, and expectations of successful applicants, in addition to funding mechanisms.
- Integrate post-doctoral and visiting scientists into NREL community, providing opportunities for them to engage through our weekly seminar series and other scientific discussion forums.

2) Expand the NREL K-12 Teacher in Residence Program

NREL through its partnerships with local school districts has established a Teachers-in-Residence (TiR) program wherein K-12 teachers take a year-long sabbatical at the laboratory.

Teachers obtain valuable professional development leading to career advancement, and improved content and pedagogical knowledge. Currently the program is funded through a combination of grants and district funds. We aim to create a statewide TiR program serving 1-3 teachers per year.

Action Items

- Formalize the current TIR model with school districts across the state, beginning with schools in the CSU Alliance Partnership and those that currently partner with NREL education initiatives.
- Identify sources of funding and support for Teachers-in-Residence.

Objective 1.3 – Promote the Professional Development of the Support Staff

The NREL support staff provides important services to lab operations. We are committed to promoting the professional development of the support staff.

1) Seek and support professional development (PD) opportunities for support staff

Routine training is important to maintaining peak performance of NREL operations and for the career fulfillment and advancement of our staff. Currently, NREL staff members are provided the opportunity to take classes, attend workshops, and attend national and international conferences. We aim to be more proactive in identifying, promoting, and supporting PD opportunities.

Action Items

- Identify and pursue funding sources to support staff PD.
- Identify and post PD opportunities on the NREL website and through e-mail alerts.

Objective 1.4 – Promote Diversity within the NREL Community

The NREL is committed to promoting diversity at each level of the workforce where people from a wide range of backgrounds can feel encouraged, supported and comfortable to thrive in their profession.

1) Assess and monitor diversity of the NREL

We will assess, monitor, and increase the diversity of the NREL workforce, while maintaining equal opportunity for all job applicants as required by CSU. Reporting on diversity by CSU focuses on groups as defined by race and/or ethnicity, gender, socio-economic status, family college history, geography, and citizenship status (state and country). These classifications provide a starting point for comparisons among demographics at the University, the State of Colorado, and STEM disciplines in general as reported by the National Science Foundation and other relevant populations that also track these categories.

Action Items

- Establish and charge a committee to develop diversity targets for each employee category (e.g. research scientists, research associates, administrative staff, graduate

students and hourly employees) in coordination with the Director of the NREL. The committee will have representatives from each layer of the NREL workforce.

- Conduct and complete a survey of current NREL demographics including temporary workers and undergraduate students that conduct research at the laboratory under the direction of research scientists or are engaged in other opportunities associated with the NREL such as the SUPER program.
- Identify other activities to enhance the diversity of the NREL (e.g., links to student groups and associations on the NREL website, and diversity of related articles in EcoPress), and make the NREL more accommodating to underrepresented groups.

2) Employ strategies to achieve the desired diversity of our workforce and students

NREL has been proactive in developing relationships with professional associations to identify and recruit potential students and scientists to its ranks. To facilitate recruitment of a diverse workforce, the NREL will strive to augment these existing relationships, and is further committed to making the lab receptive and responsive to the needs of a diverse workforce.

Action Items

- Maintain and build on relationships with student groups and associations of underrepresented groups locally and nationally.
- Work with CSU departments to actively recruit underrepresented students into existing mechanisms such as the SUPER program.
- Work with Office of Equal Opportunity to improve the hiring process at the NREL.
- Highlight diversity recruitment beyond CSU (e.g., through EcoPress).
- Routinely assess NREL facilities to appeal to a diverse workforce.

The diversity committee will work at implementing these initial strategies, and create an ongoing and active dialogue to ensure a diverse and comfortable work environment at the NREL. The committee will seek advice from within CSU and beyond to aid the development of these activities.

Objective 1.5 - Expand Research Impact and Engagement with Stakeholders

While NREL research provides a basis for societal benefits, the results are not always conveyed to stakeholders who could use the findings to solve environmental challenges. Furthermore, the goal is to expand NREL research and outreach with stakeholders to increase the impact beyond a collection of individual efforts for broader applicability. Through this effort, NREL can establish new and strengthen existing partnerships with other departments and colleges across campus, such as partnerships with other colleagues in Natural Resources, SOGES, Liberal Arts and Natural Sciences; and other academic institutions, NGOs, foundations, community organizations, private enterprises, and government agencies. This effort is also expected to enhance interactions with boundary organizations that have a history of close engagement with NREL so they may be conduits linking NREL with stakeholders (e.g., DOI Northern Climate Change Science Center, USDA-ARS Central Plains Experimental Range).

1) Coordinate NREL research and outreach activities

NREL will strengthen existing activities and facilitate development of new activities to maximize societal engagement and impact. Through this effort, academic faculty, scientists and graduate students will be encouraged to explicitly recognize the needs of stakeholders, including communities, agencies, government representatives, private enterprise, NGOs and foundations, and others who may be interested in or affected by our work. NREL will also seek opportunities to develop new collaborative centers and syntheses, and promote involvement of graduate students and scientists in similar efforts organized by other organizations and institutions.

Action Items

- Develop a model for engagement with stakeholders that will establish guidelines for NREL scientists. The DOI Climate Change Science Center has a model framework for co-production of research with stakeholders that will be reviewed to inform the guidance for NREL scientists. This activity may also include seminars about best practices for engaging with stakeholder communities from invited speakers.
- Undertake a period of discovery, systematically interviewing potential stakeholders to learn how they address sustainability and where they struggle, where decisions are made, where money flows, to better understand societal needs, to guide our research initiatives, and to hone our questions and proposals.
- Enhance interactions with stakeholders by inviting proposals from NREL scientists who identify research teams addressing environmental challenges of interest to stakeholders. Successful proposals will be granted funding to support engagement with stakeholders, including meetings and travel. Some of the stakeholder groups may lend themselves to the Joint Venture framework discussed in the next section.
- Identify and seek funding for large collaborative center-type initiatives and influential synthetic analyses.
- Organize and host an international conference every few years to highlight critical research topics and produce synthesis papers.
- Promote students seeking fellowships and internships, and increase exchanges of students with other organizations.
- Promote NREL peer involvement in regional, national, and international syntheses, committees, panels and other efforts.
- This effort will need to be facilitated by existing staff and/or a new hire.

2) Develop and Implement Joint Ventures with Stakeholder Groups through NREL

Joint ventures are a way to more actively engage stakeholder groups throughout the research process, such as industry, government institutions and other entities, in which the stakeholders pay a fee to participate and cover the research expenses of the scientists. In turn, the research team conducts studies to address specific needs of the stakeholders and actively involve the stakeholders throughout the research. For NREL, these joint endeavors would likely involve stakeholder groups with specific environmental challenges that can be addressed by a NREL research team.

Joint ventures with stakeholder groups will broaden the impact of NREL research by working directly with stakeholders to address environmental problems of critical concern. These endeavors also provide opportunities to investigate ecosystem dynamics that are not always possible through traditional funding programs. In turn, joint ventures may uncover new research

directions that will form the basis for proposals to traditional funding programs, such as NSF, USDA, USGS, and DOE.

Action Items

- Initiate a review of existing joint ventures with stakeholder groups at CSU and other academic institutions, followed by a meeting with scientists to gauge interest.
- Invite proposals from NREL scientists who identify research teams for addressing significant scientific challenges that could lead to a Joint Venture (i.e., a subset of the proposals requested to engage stakeholder groups in the previous section).
- Facilitate development of joint ventures to establish contractual relationships with the participating stakeholders, and/or seek funding through existing extramural funding programs.
- This effort will need to be facilitated by existing staff and/or a new hire.

3) Develop Guidance and a Request for Proposals to Fund Development of Stakeholders Groups and joint ventures.

Enhancing interactions with stakeholder groups and developing joint ventures should foster an open, collaborative and collegial intellectual environment that promotes and values critical thinking to advance the field of ecosystem science and resource management. NREL could benefit from these interactions, but not at the expense of the intellectual environment that the laboratory has developed through its long tradition of conducting research. Clear guidance is needed that reflects these values.

Action Items

- Establish and charge a committee tasked with providing the Director of the NREL a set of guidance for interactions with stakeholders and entities participating in joint ventures.
- The committee will be charged with writing a request for proposals for funding development of new stakeholder groups and joint ventures.
- The committee will also review and rank proposals in consultation with the Director of the NREL.

3.0 Goal 2 – Promoting Awareness of NREL Research

As ecosystem science grows and changes so does how it is communicated and presented. A strong web presence is important for any institution in today's society, and the NREL web site will likely be the initial access point to the laboratory for prospective students and stakeholders, NGOs, donors, environmental activists, and other groups. A broad but growing presence on traditional and new media also promotes our research.

Objective 2.1 – Develop Visual Branding Language for NREL

Branding is important for any institution creating a design that is recognizable by peers, students, and society, depending on the notoriety of the institution. NREL is undertaking a new branding of the laboratory to enhance the recognition of our scientists and institution.

Action Items

- Develop visual branding language with design professionals in CSU's Creative Services.
- Incorporate branding into the NREL web site and other laboratory information materials.
- Incorporate branding into a scientific presentation template.
- Incorporate branding into symposium and seminar notices.

Objective 2.2 – Enhance NREL Web Presence

Enhancing the communication of NREL science on the Internet will attract a broader community of scientists and non-scientists. This can be accomplished through developing a new web site, social media, and other innovative outreach pathways.

The web site will feature information about the laboratory and investigators, and reflect our analytical, computational, and open science endeavors that will broaden the impact of our research. These capabilities should be relatively easy to access through searchable directories of up-to-date listings of overarching research questions, investigators, projects, datasets, and supporting information.

Action Items

- Create a new web site platform with CSU's Web Development Services.
- Integrate EcoPress materials into the NREL web site, featuring a new story on a weekly to bi-weekly basis. Use EcoPress analytics to evaluate interest from the public in various themes and programs at the lab that are featured in EcoPress articles. These analytics could be used to market the lab, encourage development of short courses on topics with greater interest, and enhance engagement with stakeholders.
- NREL web site will feature investigator pages that are easily updated and include links to external scholar pages, such as ResearchGate and Google Scholar.
- NREL web site will feature open science databases and resources for the research community.

- EcoCore will be featured on the web site for scientists, consultants, and others interested in using the laboratory services.
- Web site and social media should serve as a resource for the capital campaign to develop an endowment for the laboratory.
- Provide a portal for engagement with stakeholders and research conducted through strategic partnerships.
- Dissemination of information about short courses, summer school institutes, and other educational programs.
- Include short videos that range from researchers discussing findings to promotional information about NREL programs and opportunities for engagement (e.g., EcoCore, Educational Opportunities, and Stakeholder Groups).
- This effort will need to be facilitated by a communication specialist.

The web site will feature the environmental challenges that NREL scientists are actively studying, along with an integrated searchable directory and spatial map product of current and past research projects. Enhancing our web presence will support other objectives, and is expected to become a powerful tool for expanding the reach and impact of NREL research.

Objective 2.3 – Expand Traditional and Innovative Outreach Pathways

Outreach can be accomplished through a variety of ways. NREL will explore traditional and new approaches for outreach as part of this strategic plan with the goal of enhancing our impact and reach to society.

Action Items

- Use social media (Facebook, Twitter, etc.) to highlight NREL achievements and connect with peers, students, and the broader society.
- Create an online ecosystem research textbook, with modules incorporating our research perspectives.
- Increase our linkages with extension specialists.
- Work with Media and Community Relations to produce a monthly ecosystem science show that features NREL research, field sites, laboratory insights, and implications of research.
- A regular seminar and webinar series in the day or evening, for a broad audience, that discusses the relevance of ecosystem science to society. Record these sessions and make them available on Google Plus and YouTube.

4.0 Goal 3 – Enhancing Educational Opportunities, Analytical Laboratory and Computational Facilities

Educational opportunities further the mission of the university, and also provide opportunities to broaden the impact of NREL research, and provide base funding for research scientists. To increase impacts on training, education, quality of research and other objectives of the NREL, we will develop our education program with and beyond the partnership with ESS to include online and short course instruction.

NREL has an analytical laboratory and computational facility with excellent support staff. Extending our analytical capabilities through EcoCore will leverage the nimble nature of existing facilities, respond to a more diverse set of researchers, and generate revenue from clients to support the facility. Enhancing the computational facility will provide greater opportunity to conduct large scale spatial and temporal analyses that address critical scientific question through model-based assessments, diagnosing past phenomena and predicting future outcomes.

Objective 3.1 – Increase Course Offerings, Certificate Programs and Professional Development Institutes

The NREL is well poised to develop online and traditional short courses, such as instructional workshops on the DayCent model or Bayesian methods, in addition to summer professional development institutes. Some courses may be a mixture of traditional and online instruction, and/or field and laboratory experiences, such as summer professional development institutes. The NREL Summer Soils Institute is an example combining different instructional formats that could be replicated for other subject matter. Moreover, courses could be packaged so that certificates are awarded after a set of courses are completed, and possibly lead to the development of new degree programs as they mature. The investment in course development and instruction will be essential to meet the goal of fortifying research positions and providing viable long-term career opportunities for scientists.

Action Items

- Establish and charge a committee with developing a framework for enhancing education opportunities in coordination with the Director of the NREL.
- Develop an instructional and delivery model that optimizes the NREL approach to research and educational activities.
- Solicit proposals from NREL scientists to develop traditional and online short courses, in addition to professional development institutes. Courses may be proposed as packages to award certificates.
- Successful short courses may be further developed and offered for credit through CSU as course material matures.
- Encourage NREL scientists to submit proposals to extramural programs that fund educational program development, in particular certificate and degree programs.

Objective 3.2 – Enhance NREL EcoCore Facility

Some aspects of our analytical and research space need to be enhanced to meet the high standards needed for our research. Specifically, there is a demonstrated need for additional

facilities to conduct intermediate scale experiments, and to organize and access our refrigerated and storage spaces. In addition, there are opportunities to better use existing EcoCore infrastructure.

Action Items

- Improve communication with external EcoCore users regarding NREL informatics and intellectual assets that can be leveraged when making use of EcoCore.
- Create innovative experimental facilities, including mesocosms for polar research, aquatic ecology, and soil ecology.
- Organize and optimize preparation, storage and analytical space.
- Improve the facility for research and teaching by creating separate spaces to meet these objectives.

Ultimately the primary purpose of EcoCore is to serve the NREL community and stimulate the intellectual environment. Meeting this goal is expected to improve the facility for existing research projects, and also encourage more NREL investigators, graduate students and visiting scholars to use the EcoCore facility. A secondary purpose of EcoCore is to provide analytical services for clients with the goal of increasing revenues to better support the maintenance of the facility and salary of its staff.

Objective 3.3 – Enhance NREL Computational Facility

The NREL has been a leader in development of informatics and computational facilities to support ecological research and decision support for ecosystem managers and policy makers. Our computational facilities and analytical capacity has been enhanced through high performance computing and data management systems integrating data servers, network computing resources, and high band width connectivity with external institutions across the nation.

These facilities have enabled continued improvement in analytical and visualization capabilities to support data-model fusion efforts that incorporate complex and often large data sets into regional, national, and global assessments of ecosystem dynamics. These effort have led NREL to provide community leadership in model development and evaluation (e.g., Bayesian model testing, Markov Chain Monte Carlo (MCMC), data assimilation techniques), decision-support tools, and other computationally-intensive applications. However, the state of the art in the computational environment is constantly evolving with newer and better technologies that facilitate development of more complex analytical frameworks for conducting research. Enhancing computational and analytics facilities, therefore, is an ongoing challenge but important for meeting the needs of the intellectual environment at the laboratory.

Action Items

- Conduct an annual review of the NREL computational facility to identify needs and technological advances support the analytics and visualization needs of research efforts at NREL.

- IT staff will review latest technological advances and possibilities for incorporating newer technology into the facility as needed to support NREL projects related to data and information access, reproducibility, and retrieval, in addition to data model fusion efforts, decision support tools and other computationally-intensive applications.
- Provide more opportunities for IT staff to actively participate in investigations and discover better ways to use technology in support of project objectives.
- Further develop the shared computational resources at NREL for enhanced information and data mining and exploration in support of advanced analytics of complex social-ecological system research needs.
- Establish and charge an IT committee tasked with providing advice and oversight on the computation facility in coordination with the Director of the NREL.

Maintaining a high level of computational capacity at the NREL is strategic given the long tradition of NREL science for conducting and advancing model-based assessments in the ecological research communities. Maintaining this level of excellence will be reap many benefits for the laboratory, including more funding opportunities through grants and contracts, better stakeholder engagement, and capability to develop an Open Science Platform (see Goal 5).

5.0 Goal 4 – Becoming a Leader in the Era of Open Science

Open science has become a new mantra of the research world and NREL is poised to take a leading role in these efforts. The key arguments for a call to “open science” include increased reproducibility of scientific results and model runs by maintaining provenance information, improved ability to verify/validate results, improved co-design of experiments with stakeholders, improved ability to co-produce knowledge with stakeholders, and the ability to improve visibility of the NREL within stakeholder communities. Moreover, NREL research requires significant data management capabilities and excellent cyber-infrastructure, and in turn, these capabilities will need to expand with growing needs for open data access and transparency, and computational performance.

Objective 4.1 – Create an Open Science Platform

Open Science Platforms will lead to faster and more innovative research, resulting in synthesis data-intensive scientific discoveries. By leading the field with an open science initiative at NREL, we will create as a model for enhanced transparency, advance our research efficiency, and develop a closer relationship with peers in our research community and the stakeholders who can benefit from our science. To advance this objective, NREL will need a platform for dissemination of data, models and other supporting material.

Actions Items

- Identify and secure a section of the web site to better communicate the NREL Open Science Platform.
- Organize and provide access to legacy data from landmark NREL research over the past four decades.
- Incorporate the NREL Open Science Platform into data management plans and ensure data generated through recent NREL investigations are made available on the platform.
- Augment the NREL web site with database driven searchable directories to support the Open Science Platform.
- Create and encourage use of a common conduit for all NREL publications to include open access data and models for each publication.
- Create an initiative through the NREL Open Science Platform to encourage open source development of ecosystem models.
- Establish and charge a committee tasked with overseeing the Open Science Initiative in coordination with the Director of the NREL.

Objective 4.2 – Enhance Data Management Capabilities and Open Science Investigations

NREL has compiled and managed numerous datasets over its 50 year history ranging from experimental and observational studies to model-based assessments. With its extensive legacy data and its ongoing synergistic activities, NREL is positioned to be a leader in the growing era of open science, but will need to ensure our cyber-infrastructure and technical capabilities are commensurate with this objective. In addition, NREL will need to be more than a data provider,

using open science datasets and other material to make new discoveries in the field of ecosystem science and natural resource management.

Actions Items

- Advance our cyber-infrastructure to support the Open Science Platform.
- Seek opportunities to advance investigations using open science datasets, models, and other information to make scientific discoveries.
- Ensure computational performance available to NREL scientists is adequate to support the investigations.

This effort will need to be facilitated by a full-time data manager. The full time data manager will coordinate activities with the Open Science Initiative Committee and Director of the NREL, ensuring success in advancing the core capabilities of the Open Science Platform. The data manager will develop data management plans and metadata documentation, deliver products to the CSU Libraries digital repository, and market the informatics capabilities of the laboratory.

Appendix I. NREL Overview

The Natural Resource Ecology Laboratory (NREL) is an innovative leader in the field of ecosystem science well-known for fostering a collaborative and enjoyable work environment for scientists who are passionate about discovery and application of knowledge. The NREL originated in 1968 with the Grassland Biome Project of the US International Biological Program (USIBP). George M. Van Dyne was the first director of the biome project and of the NREL. His vision of systems ecology was responsible for establishing NREL's ongoing tradition of leadership in the development of systems ecology and ecosystem analysis, and the establishment of interdisciplinary, integrative, holistic, and team-oriented research. As the USIBP came to an end in the mid-1970s, NREL scientists opted to keep the enterprise together through grants and contracts, which to date, has proven to be successful.

NREL is a multi-college research center within the Warner College of Natural Resources, and employs over 100 people per year in various job classes. Today, NREL Research Scientists, through their competitive grant funding, support and house a professional support staff of approximately 45 research associates, 8 full- and part-time administrative staff, 29 graduate students, and numerous undergraduate research assistants. Visiting scientists and students take an active part in the lab, even though they are funded through other sources. The Director of the NREL oversees the lab and also serves as the Head of ESS. The Director is advised by the NREL Executive Committee, consisting of approximately 10 members representing the diversity of NREL Research Scientists. The Director and the Executive Committee meet monthly to review and suggest changes to operations at NREL.

The scope of research at the NREL has evolved over the years, with the most recent and significant development occurring in 2011 with the formation of the Department of Ecosystem Science and Sustainability (ESS). NREL welcomed several researchers from fields of ecological and watershed sciences through the establishment of ESS. The systems approach to research is a common thread throughout most NREL studies, which occur across a diversity of study sites, scales, and topics.

The NREL consists of 34 core Research Scientists, 11 Postdoctoral Scientists (Postdoctoral Fellows or RSI), and 38 Affiliate Scientists. NREL Core and Affiliate Scientists contribute to multidisciplinary intellectual interactions; lead or participate nationally and internationally on complex, integrated research collaborations; and publish original results arising from an atmosphere of trust and collegiality. The collaborative research at the NREL spans a range of topics, such as biological anthropology; carbon cycle science; nitrogen cycling; climate change; communities, women and diversity; ecosystem modeling; fire ecology and management; greenhouse gas emissions and mitigation; invasion ecology; pest risk analysis; land use and management; physical hydrology; aquatic ecology; population and community ecology; soil biochemistry; soil ecology; environmental microbiology; species distribution modeling; and tree physiology.

NREL scientists have been acknowledged for their research achievements, including winner of the Tyler Prize and member of the American Academy of Arts and Sciences, recipient of the "Champion of the Environment" award from the government of Mongolia, winners of prestigious Ecological Society of America awards, contributors to the Intergovernmental Panel on Climate Change which was awarded the 2007 Nobel Peace Prize, and among the most Highly Cited Researchers listed by Thompson Reuters. NREL scientists include Presidents and Fellows of professional research societies, Fulbright Scholars, and National Science Foundation program officers. NREL graduate students and young scientists have received NSF and USDA Graduate

Fellowships, NSF Young Investigator, and Early Career Awards, in addition to recognition as University Distinguished Research and Teaching Scholars.

Over the past three years, NREL scientists produced a total of 330 peer-review journal publications, averaging between 65 and 85 per year. The scientists have also contributed numerous book chapters and several full book publications. NREL scientists have an exceptionally distinguished record of publications printed in some of the world's premier journals, such as *Science*, *Nature*, *Proceedings of the National Academies of Science*, *Bioscience*, *Ecology*, and *Ecology Letters*, covering their research in general science, the environment, and ecology. Several scientists have made significant contributions through book publications, including "Soil Biology and Biochemistry," by Eldor Paul, "Measuring Plant Diversity," by Tom Stohlgren, "Energetic Food Webs: A study of real and model ecosystems" by John Moore, "Rocky Mountain Futures" by Jill Baron, and "Sustaining Biodiversity and Ecosystem Services in Soils and Sediments," by Diana Wall. Our scientists have an exceptional record with respect to total publication numbers and citations, with several members and the unit as a whole ranking in the top 1% of scholars for disciplines within the environment and ecology. H-indices average 26 for NREL scientists, with a range from 5 to over 70.

In addition to journal publications, NREL communicates science to the global community through our website (<http://www.nrel.colostate.edu/>), presenting the NREL vision of interdisciplinary research, and our recently launched Internet-based publishing platform – EcoPress. EcoPress was originally funded by successive NREL development grants with a main purpose of highlighting NREL science and scientists through non-traditional communication outlets integrated with social media. Run by successive teams of graduate student editors, EcoPress creates a dynamic and engaging online presence for NREL, provides valuable opportunities for graduate student professional development and creative public engagement, and has the capacity to support additional science communication opportunities by engagement with NREL alumni and integration with more traditional NREL online content. This platform has become a diverse science communication outlet for NREL scientists. Authors include the breadth of the NREL community, from graduate students to research associates and primary investigators. Their contributions reflect the depth of NREL science from publication summaries, commentary, and opinions, to innovative presentations of scientific ideas.

Citizens and decision makers from Colorado and beyond learn about their environments from a wide variety of lectures and events in which NREL scientists participate. With two RAPID grants, NREL scientists work closely with Fort Collins, Larimer County, and State officials to understand and mitigate the combined effects of the devastating 2012-13 fires and floods. Science-manager partnerships between NREL scientists and the Department of Agriculture, USDA Forest Service, and Department of Interior are strong in the fields of carbon accounting, forest and range management and conservation, air quality policy, and adaptation to global change. NREL scientists are involved with National Climate Assessments and the IPCC, and support US government reporting of greenhouse gas emissions to the United Nations. NREL also hosts a NASA DEVELOP center in collaboration with the U.S. Geological Survey. This center fosters interdisciplinary research where undergraduate and graduate students receive training and hands-on experience working with scientists and natural resource managers utilizing NASA Earth Observatory technologies to address community concerns and public policy issues. NREL's global reach to the governments of Mongolia, Kenya, and Ethiopia influence how socio-environmental decisions are made at the highest levels. Moreover, NREL has helped shape global research collaborations, such as International Geosphere-Biosphere Programme, Diversitas, and International Human Dimension Programme, and will be fundamental to the new Future Earth.

NREL engagement extends to the public through invited seminars, testimony to state and national offices, and by developing close working relationships with professional societies (especially with the Ecological Society of America, American Geophysical Union, and others) and with various Non-Governmental Organizations, such as The Nature Conservancy, Environmental Defense Fund, and National Wildlife Federation. NREL scientists are frequently interviewed by the media, including appearances on the local public radio station, KUNC.

Education activities have a broad reach from training the next generation of scientists to improving environmental literacy. NREL scientists mentor outstanding graduate students, and during the past three years, 28 students have graduated from the Graduate Degree Program in Ecology, 10 from the Watershed Science program, and another four from other programs. NREL has launched students into successful careers in research, education, and public service.

The knowledge gained in our research is shared among many user-communities, which extend from K-12 education throughout northern Colorado, to State and Federal agencies, and to governmental and non-governmental organizations worldwide to improve environmental literacy. NREL scientists have developed a Summer Soils Institute to provide opportunities for teachers to learn how to study soils through lectures, field visits, and laboratory experience. Short courses have also been developed and offered on other topics associated with research at the NREL, such as application of the DayCent simulation model, species niche modeling, and greenhouse gas emission accounting.

NREL has blended its talents and working ethos even more fully into the central mission and goals of the University to support ESS. For example, ESS is offering a two-semester course for undergraduate students entitled “Research Skills for Ecosystem Science”, which was developed through a NREL project. The course enhances student research experience through instruction and active learning activities about scientific methods. The first semester consists of a series of classes on a range of topics, including forming hypotheses, experimental design, finding and reading literature, and analyzing data, which are led by two to four NREL scientists. During the second semester, students are paired with NREL scientists to complete a small research project and present their findings during a poster session that is open to the public. NREL scientists are also contributing to new online courses offered through ESS, “African Dryland Ecosystems and Societies” and “Critical Thinking in Ecosystem Science”.

NREL administrative staff provide grant management, laboratory, and IT support. The grant staff assists the scientists with completion of all proposal submissions. The team reviews the funding request and ensures that all proposals are in compliance with the funding opportunity. The grant staff also works with the scientists to implement each of their projects and ensures compliance with all regulations and guidelines set forth by the sponsor. This team is responsible for assisting scientists as they navigate CSU procedures while completing their research in a timely and efficient manner. EcoCore is the analytical laboratory facility (<http://ecocore.nrel.colostate.edu/>), with support staff that maintains the lab and equipment to ensure research can be completed in a timely manner. EcoCore is at the forefront of providing analytical procedures and equipment that are needed to address key scientific questions in ecosystem science. The Information Technology support staff facilitates NREL research through various desktop computing systems, and server design and maintenance for network computing. NREL research often uses large datasets that have specific IT requirements, and the IT team designs, builds, and maintains these systems in-house.