Sustainability: Environment, Energy, Climate and Communication

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A. Executive Summary. Human activities are driving unprecedented changes in Earth systems of climate, biosphere, hydrosphere, atmosphere and cryosphere, while depleting natural resources and creating social, economic and political impacts that demand long-term, multi-faceted solutions. The consequences of human-environment interactions and resource impact are felt locally in California's Central Valley and Sierra Nevada, and globally in resource-strained communities, cities, and countries. Sustainability unites research and education elements at UC Merced involving *coupled ecological and human systems* of the Earth, and the development of sustainable pathways and practices through *integration of basic research and technological solutions across disciplines.* This initiative aligns elements proposed in SAF Round 1 from the Environmental Systems (ES) Graduate Group, the Sierra Nevada Research Institute (SNRI), and the Life and Environmental Sciences (LES) bylaw unit. It also draws from prior ES, LES, and Environmental Engineering (ENVE) strategic plans to build on existing strengths, takes advantage of campus centers and institutes, and links to other proposed initiatives with elements related to sustainability, natural resources, and the environment. This strategic initiative outlines five specific areas of growth that build on core strengths at UC Merced: 1) sustainability science and engineering, 2) renewable energy, 3) climate and atmosphere, 4) environment and health, and 5) communication and sustainability. These areas both represent opportunities within the UC system, and are central to building a sustainable future. In the long term, we envision building an interdisciplinary, innovative academic school that would add visibility to the strategic focus of sustainability. A school would vertically integrate undergraduate, graduate, and research endeavors, overcome current academic fragmentation, and physically unify faculty, students, and staff through additional buildings and research facilities.

B. Definition of the Thematic Area.

UC Merced's 2009 Strategic Academic Vision identified **Environmental Sustainability** as a key interdisciplinary theme for organizing research initiatives and academic programs. *The goal of this theme is to establish research and educational programs of coupled ecological and human systems that support sustainable use of energy, water, soil, and ecosystem resources. Addressing threats to human and ecosystem health, loss of biodiversity, and food and water security associated with global change requires integration of basic research and technological solutions across disciplines.* The field of sustainability science and engineering examines both fundamental interactions between nature and society, and society's capacity to create and follow sustainable trajectories. Education and communication involving our matriculated students, government and business, and the public are critical components to program success in addition to research and technology development. Thus, our thematic focus on sustainability provides a context and focus for multiple groups and research areas across campus in natural sciences, engineering, management, social sciences, humanities and arts.

Does it fit in one of the nine (9) defined Themes? This initiative directly addresses three themes identified by the Strategic Academic Focusing working group: 5) Environmental Sustainability, 6) Energy and Energy Systems, and 9) Life Sciences. It is synergistic with themes 1) Disparities: Equity, Diversity, Social Inequality, 3) Human Health and 4) Innovation and Entrepreneurship, and 7) Information, Computational, and Data Sciences, and Engineering.

Are there other SAF Initiatives that, in your opinion, might contribute to this Theme? This initiative is complementary to the proposal from the School of Innovation, Management, and Economics (SIME), particularly in the overlapping areas of innovation, sustainability, technology, environmental

management, and resource economics. It links to the initiative in Cognition, Computation, and Human Data Science through the Center for Climate Communication, the Center for Human Adaptive Systems and Environments (CHASE), and other research on human-environment interactions and communication. The California Institute of Drone Engineering Research (CIDER) initiative supports efforts in this proposal related to sustainable agriculture, biodiversity, pathogen risk assessment, and environmental engineering. Initiatives related to public health and infectious diseases from the Health Sciences Research Institute (HSRI) and the Molecular Cell Biology (MCB) group link to our components in health and environment. The systems approach of integrated observation and modeling, and the emerging systems ecology theme in Quantitative and Systems Biology (QSB) link to our focus areas of sustainability science, and health and environment. Other links include the emphasis on environmental ethics in the Applied Philosophy strategic initiative, and elements of social, economic, and gender disparities related to environmental resources and sustainability that drive the SAFI2 proposal on Diversity, Inequalities, and Representation. Initiatives in General Education related to environment and society connect with our undergraduate degree programs and to student scientific literacy campus wide.

C. Intellectual Components of the Initiative

Why is this area(s) important? The combination of global change and human population growth places unprecedented stresses on environmental, ecological, and agricultural systems, creating new threats to human health, ecosystem viability, and food, water, and energy security. Human societies and natural ecosystems globally depend on our ability to manage resource consumption and mitigate adverse impacts of human actions on people and the environment, which requires combining basic research, applied technologies, effective communication, and research translation to stakeholders and policymakers. UC Merced is uniquely poised to advance basic science and applied solutions in sustainability from its existing base of transdisciplinary faculty research, interdisciplinary graduate and undergraduate degree programs, and cross-unit research institutes and centers.

What are the current key areas/achievements in this field, and those going forward? For decades, scientists have documented human perturbation to the Earth's climate system and its subsequent impacts on chemical and biological cycles. Anthropogenic impacts on critical earth systems are global, but their consequences are felt regionally and locally in coupled human-environment systems that affect water supplies, agricultural yields, air quality, fisheries, and ecosystems. Faculty in ES, SNRI, ENVE and LES have a strong track record of research and extramural funding in collaborative projects and as individual investigators related to the impacts of global change on water, air, soil, ecosystems, and biodiversity. We have a core of faculty working in basic research in environmental genomics, biogeosciences, and ecosystem science, and in applied areas of environmental engineering, sustainability, and management. Many faculty have strong partnerships with government agencies and local stakeholders. The ES Graduate Group and SNRI are the intellectual center on our campus for research and graduate education in the areas of environmental and sustainable systems, and link to existing undergraduate programs in Environmental Engineering, Earth Systems Science, Environmental Science and Sustainability (minor), and Biological Sciences (Ecology and Evolutionary Biology emphasis).

D. UCM's Role in this Theme

The UCM Campus' unique position in this particular field and current strengths on campus. Faculty in the ES graduate group and affiliated with the SNRI share a common interest in the study of natural and human-impacted environmental systems and the services they provide – their functioning, health, and sustainability on a planet experiencing rapid climate and ecosystem change. The scope of research within the group falls within the cross-cutting areas of:

- 1. Water, soil, air and climate science and engineering
- 2. Ecology, ecosystems and biodiversity
- 3. Sustainable energy systems
- 4. Natural resource science, economics, policy and management.

These areas are central to the mission of the campus and address broader societal needs. Research of existing faculty is mostly within the first three areas; the last area is currently being developed jointly with management faculty in the SOE as part of the proposed graduate program in Management of Innovation, Sustainability and Technology (MIST). Each area above has significant potential for growth of high-impact research that integrates science, engineering, and social sciences.

This plan identifies areas of strategic growth for research and education where UC Merced can fill critical niches within the UC system, develop collaborations with colleagues from other campuses, and compete nationally. This strategic initiative outlines five specific areas of growth that build on core strengths at UC Merced: 1) sustainability science and engineering, 2) renewable energy, 3) climate and atmosphere, 4) environment and health, and 5) communication and sustainability. These areas are central to the goal of building the knowledge base, technologies, and management solutions required for the sustainable use of resources and ecosystems in California, nationally and globally.

1. Sustainability Science and Engineering. Long-term water and food security is threatened by climatic effects on agriculture – an issue of paramount interest to the Central Valley and the State. Regionally and statewide, agriculture, ranching, timber and nature tourism play important roles in our economy and society, but these activities directly impact the sustainable use of water, soil, land, and energy. A major strength of our current academic and research programs is the strong integration of science and engineering that supports close coupling of science-based engineering, technology, and management solutions. Two areas of strategic development are:

a. Food and Water Security. Irrigated agriculture in the western U.S. depends on seasonally accumulated snow runoff from mountain watersheds. Warming temperatures are resulting in a shift from snow to rain and earlier snowmelt, which affects the timing of water availability for downstream agriculture and stresses seasonal water-storage capabilities. Extended dry periods under a more variable and changing climate will further impact water resources and agriculture. The debate around water security in California involves advocates for both "hard" (e.g., new storage and conveyance infrastructure) and "soft" (e.g., institutional arrangements, demand management) solutions to water supply challenges. A role for UC Merced is to build the knowledge base for better information that can support both hard and soft approaches, and to conduct research and development that provides this information. UC Merced has a leadership role within UC for water research, particularly around the Sierra Nevada and similar areas in the west, that serves as a strong foundation for expansion in agroecosystems and water security. Expanding research in the Central Valley is an opportunity to leverage existing strengths in water research and build a complementary area of excellence. Areas of potential research include global change impacts on quantity, quality, and timing of water supply and hydropower resources; water-information systems for both supply and demand, and for both planning and operations; water resources management; and groundwater management.

b. Biodiversity and Ecosystem Science and Services. Global change and population growth strongly impacts ecosystem function and services, and consequently, the strategies for mitigation of adverse impacts and adaptation. Ecosystems are undergoing rapid change in response to the pressures of global change as well as local land use changes driven by population growth. UC Merced is poised to play a leadership role in the biodiversity and ecosystem science community, with core faculty in ecology, evolution, ecosystem science, microbiology, environmental genomics, and biogeochemical cycling. As one example, the Central Valley will undergo extensive, large-scale ecosystem restorations activities over the next few decades, with possible investments of several billion dollars and changes in water use. Potential ecosystem services and associated research is critical to the state's economy and quality of life, and has global relevance. Broad areas of potential research include: ecosystem productivity and carbon storage; wildlife habitat quality and maintenance of biodiversity; ecological disturbance (e.g., wildfire, insect outbreak, drought-related mortality) and post-disturbance changes; adaptive management and regional planning for sustainable ecosystem functioning and services.

2. Renewable energy. Renewable energy systems such as solar, wind, hydroelectric, and biomass will play a major role in sustaining the economy and in improving environmental quality in California, the nation, and the world. The state has identified critical needs for research, development, and demonstration, including energy-efficient technologies, renewable generation, clean fossil generation, transportation fuels and vehicles, and bioenergy. Major, immediate efforts to focus research and technology investments towards these alternatives are critical to address the state's mandate to reduce greenhouse gas emissions to 1990 levels by 2020, and goal to lower emissions to 80% below 1990 levels by 2050. Using the region as a laboratory, there are research opportunities in integrating renewable technologies with production agriculture, including biomass, wind and solar. Attractive areas for growth are life-cycle engineering, industrial ecology, and planning and design of energy-efficient infrastructure and buildings. A center or institute in renewable energy would support opportunities for expanding research and educational opportunities in engineering, particularly Civil Engineering, and enable new opportunities in the areas of policy and management. UC Merced has a base of research in this area; e.g., the UC Advanced Solar Technologies Institute (UC Solar), a multi-campus research institute led by UC Merced. Our foundation in renewable energy is excellent and we are well poised to expand this area.

3. Climate and Atmosphere. UC Merced plays a leadership role in multiple aspects of climate within the UC system and nationwide, and fills a critical niche in the UC system by connecting fundamental climate science with research on impacts, mitigation and adaptation. The Sierra Nevada and Central Valley offer outstanding opportunities as well as natural laboratories for research. Together, they offer the research infrastructure and settings to study many of the challenges facing the nation. We have a strong core group working on applied climate science, primarily related to water and fire. As the state, nation and world search for climate solutions, numerous opportunities for research in related areas are emerging.

The San Joaquin Valley has the distinction of having the worst air quality in the nation, which will likely worsen with global change through wildfires, dust, and anthropogenic pollution. Poor air quality affects the region's public health, economy and general quality of life. These problems make the Central Valley and Sierra Nevada region an excellent natural laboratory for air pollution and environmental health research. UC Merced has started building research capabilities in the area of air quality and its impacts, but the potential remains largely unrealized. Research in this area can have important, direct impacts on public policy and environmental justice, which is highly complementary to research in the new UCM Blum Center for Developing Economies. UC Merced has a pivotal role to play in developing the science of air pollution, human and ecosystem health effects, and engineering solutions.

4. Health and Environment. The economic impacts of pathogens on agriculture and the food industry, the threat of bioterrorism, natural disasters, and the increasing need to ensure clean and safe air and water are some of the compelling examples of how fundamental research in Health and Environment directly connects to social, economic, and political impacts both locally and globally. Microbial life and the biogeochemical processes they underpin are key drivers of, and rapid responders to, global environmental change and its impact on humans. Target areas that build on existing strengths are:

a. Environmental microbiology and microbial ecology. Microbial communities play important roles in nearly all of the issues outlined above and below, from sustaining productivity of managed and natural lands, to treatment and bioremediation of contaminated waters, to their emergence as infectious agents. An improved understanding of the various positive and negative feedback responses of microbial processes to global change is essential to fundamental understanding and mitigation of impacts on human health, agriculture, water quality, and ecosystem function. This challenge is complicated, however, by the vast diversity of microorganisms in the environment and the dynamic nature of microbial genomes and communities. Interdisciplinary and novel approaches to understanding and using microbially mediated processes that influence health and environment include fields such as microbial genomics, ecology and evolution of microbial communities, geomicrobiology, environmental symbiosis and pathogenesis that can be studied with field, laboratory, analytical, and simulation methods.

b. Ecology and evolution of infectious disease. Emerging infectious diseases that may be transmitted to humans from animals (i.e., zoonoses) and environmental reservoirs provide one of the most unpredictable and significant threats to human health (e.g., HIV, SARS, and Valley Fever). Climate change is expected to affect transmission of infectious diseases through altered range or abundance of animal reservoirs or insect vectors, and prolonged transmission cycles, resulting in increased incidence of diseases such as Hanta virus, Lyme disease, and West Nile virus. Parallel threats for crops evolved alongside key agricultural systems (e.g., wheat rust, diseases of bananas), and longstanding threats are acknowledged in the evolution of antibiotic resistance in part due to prophylactic use in agriculture. We aim to understand population dynamics and genetics of reservoir species, hosts, pathogens and their interactions, as well as to address cultural, social, behavioral, and economic dimensions of healthy ecosystems. The program builds on existing strengths in ES, LES, and in HSRI, the environment and health group, and the infectious disease and immunity group.

5. Communication and Sustainability. The way messages about natural resources and sustainability are framed and disseminated has direct but differential impacts on diverse stakeholders' perceptions and attitudes about issues related to protecting and managing resources, such as air, soil, water, and species. This in turn influences policies and programs related to energy, land use, conservation, wildfire management, water use, and air quality. Implementation of science and engineering solutions for resource sustainability requires that different segments of society understand and accept information, adopt new technologies, and change their practices. Communication and society aspects of sustainability offer multiple, unique opportunities for local research in the Sierra Nevada and Central Valley that apply globally, and UC Merced can lead in innovative research. Sustainable development in response to population pressure poses multiple challenges for science, engineering, and technology, and their intersection with political, social, and cultural values. Research in this area may encompass approaches to integrative adaptive management, or alternatively, consider diverse issues such as environmental justice and the intersection of environmental sustainability research with politics and policy. Growth in this area will build connections between cognitive sciences and management, and natural sciences and engineering, through the interface with the new Center for Climate Communication spawned in SNRI. Another potential partnership is with the UC Division of Agriculture and Natural Resources to communicate with local stakeholders about impacts of climate and ecological changes on agriculture and water resources.

Other research and learning opportunities exist through co-curricular activities (e.g., with the Office of Student Life) and mapping of human activities such as land use and resources through time (e.g., with SpARC and Library). For non-majors, complementary programs in General Education such as Writing in the Disciplines and Information Literacy with the Library are key to creating a public able to stay abreast of rapidly changing issues and equipped to make informed decisions about sustainable resource use.

How will investment in this area make our program distinctive/competitive when compared to programs within UC and other research universities? Currently at UC Merced, the ES graduate group and SNRI occupy a unique position bridging science and engineering, and incorporating relevant elements of social and cognitive sciences. Our undergraduate degree programs in Earth Systems Science, Biological Sciences, and Environmental Engineering are delivered by faculty from different schools and academic units (see table). At established universities, inter- or multi-disciplinary programs in environmental research are often amalgams of traditional disciplinary departments. Strategic development of the sustainability theme would vertically integrate research among faculty, professional staff and post-doctoral scholars, graduate student training, undergraduate degree programs, and public engagement, education, and outreach, as well as horizontally linking research and academic programs across schools and institutes. The lack of barriers enables us to leverage a relatively small group of faculty to innovate in new ways, discover connections between disparate fields, shorten paths from basic research to application, respond rapidly to new funding opportunities, establish unique academic program and training opportunities, and communicate and translate research beyond the university.

A landmark, bold move for UC Merced could take this theme a step further to establish an integrative school (e.g., *School of the Anthropocene, School of Sustainability)* that leverages the

interdisciplinary goals of UC Merced and innovates within the UC System, nationally, and internationally to meet our interlocking mission of research, teaching, and service. This proposed transdisciplinary, innovative school would add visibility to the strategic focus of sustainability, and overcome current academic fragmentation and poorly defined resource streams (three schools, multiple academic units). Our current structure create barriers for leveraging resources such as graduate student funding, staff support, appropriate research and office space, and faculty efforts in teaching, graduate student mentoring, and program administration. Physical unification of faculty, students, and staff in a thematic building cluster on campus would support and highlight research, education, and non-academic partnerships around sustainability. Both physical integration and administrative unification through this new School would create a hub for research and solutions to environmental problems and sustainable resource use in the Central Valley and beyond.

E. What bylaw units/grad groups might participate, and how would they participate?

Academic Units	Graduate Programs	Undergraduate Degrees	Institutes & Centers
Life & Environmental Sciences (LES)	Environmental Systems (ES)	Environmental Engineering (ENVE); Mechanical Engineering (ME)	Sierra Nevada Research Institute (SNRI), Vernal Pools & Grassland Reserve
Engineering (Environmental, Mechanical, Materials)		Earth Systems Science (ESS); Environmental Science and Sustainability (ESSu minor)	Center for Information Technology Research in the Interest of Society (CITRIS); UC Solar
Cognitive and Information Sciences (CIS)	Cognitive and Information Sciences (CIS)	Cognitive Science (COGS)	Center for Climate Communication
Molecular Cell Biology (MCB)	Quantitative and Systems Biology (QSB)	Biological Sciences / Ecology/Evolutionary Biology (BIO/EEB)	Health Sciences Research Institute (HSRI)
Management (future)	Management (future)	Management (MGMT)	Spatial Analysis and Research Center (SpARC)

Faculty in ES and SNRI hold appointments mostly in the Schools of Natural Sciences (SNS) and Engineering (SOE), primarily in the LES academic unit in SNS and in the Environmental Engineering group in SOE, with affiliates from the groups indicated above. Faculty associated with this initiative teach in a range of undergraduate programs, primarily Environmental Engineering, Mechanical Engineering, Earth Systems Science, Biological Sciences, Environmental Science and Sustainability (minor). Faculty and students would participate in this initiative through the ES Graduate Group, the undergraduate degrees and graduate programs indicated above, SNRI, and related institutes and centers.

F. General description of special programmatic needs (specialized space requirements, special library collections, etc.). Faculty in ES/SNRI/LES/ENVE and other disciplines represented in this strategic initiative have diverse space needs, including a mixture of high-performance analytical laboratory space (i.e., one pass air, fume hoods, access to services, emergency backup power), shared instrumentation labs, space for processing environmental samples (water, soil, air, biota), instrument development and electronic labs, and computational and visualization studies. A current critical need is for an environmental research facility consisting of a greenhouse complex, growth chambers, and related indoor and outdoor experimental areas. Environmental research mixes experiments and observations in natural systems, semi-controlled outdoor settings, and controlled laboratories, and research is currently limited by the lack of a high-performance environmental research facility. Further, ample and accessible storage space for field equipment and supplies is desperately needed. Such a facility would allow space and conditions necessary for excellence in basic and applied research in sustainability, which requires a tight linkage between experiments in the laboratory and observations in the field.