NATIONAL SCIENCE FOUNDATION
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Dear Colleague Letter: Critical Aspects of Sustainability (CAS): Innovative Solutions to Climate Change

September 30, 2021

Dear Colleagues:

This Dear Colleague Letter (DCL) encourages the science and engineering communities to develop forward-thinking research that will demonstrably aid in the Nation's goal of reaching net-zero greenhouse gas (GHG) emissions and developing approaches for adapting to the change that is already occurring. CAS: Innovative Solutions to Climate Change is a call to action that encourages the submission of certain types of proposals to appropriate existing NSF core programs to lay the foundation for disciplinary and interdisciplinary research and to answer fundamental questions related to novel approaches and solutions to climate change. NSF's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs are also interested in supporting entrepreneurial efforts on these topic areas. As outlined in more detail below, research ideas focused on short- and long-term sustainable solutions are sought as are conference (workshop) proposals that identify specific gaps in existing research approaches. The project description should clearly articulate climate relevance and contribute to new approaches regarding innovative solutions that address climate change mitigation and adaptation.

A recent report published by the National Academies in 2021 highlights the need for transforming the world's energy system to one with net-zero carbon emissions by 2050 in response to climate change.[1] The report calls for expanding our innovation toolkit by investing in new technology and reducing the cost of existing technology in a socially just way. Other reports, listed below, provide guidance on research needs and recommended strategies for both climate mitigation and adaptation.[2-15]

POTENTIAL TOPICS

Investigators are encouraged to apply their expertise creatively to climate change solutions independently or where appropriate, collaboratively, including with industrial or international partners. Interdisciplinary approaches are strongly encouraged as are ideas consistent with

the NSF's Growing Convergence Research (GCR) solicitation as well as SBIR/STTR Programs. This list of potential topics is not comprehensive. Please contact a program director in the area most appropriate for your topic to discuss your idea by sending an email to cas@nsf.gov.

Reduce Greenhouse Gas (GHG) Emissions and Energy Use. Proposals that explore innovative solutions to reducing GHG emissions and concentrations are encouraged. Topics may include:

- Improved or new approaches that reduce energy use and energy waste relevant for manufacturing, recycling, and upcycling; strategies for reducing nitrous oxide and methane emissions; strategies for ecosystem restoration through reduction of GHG emissions; biological and biotechnological approaches to reduce or mitigate GHG emissions.
- Green chemistry, refrigerants, and manufacturing concepts; development and use of sustainable materials and systems; targeted development of novel diagnostics and necessary databases of underlying atomic and molecular data; molecular and cellular strategies for sustainability, such as growing the circular bioeconomy.
- Innovations in major energy-consuming technologies such as desalination, cement manufacturing, and metal production (e.g., refining and smelting); reduction in energy use and increased energy efficiency in manufacturing through changes in processing, use of data analytics, and near-final form fabrication.
- New smart technologies for homes, cities, communities, power grids, transportation, and agriculture, to reduce the climate and carbon footprint; efficient co-design of computer systems, particularly data centers, and their energy sources and cooling systems, to reduce GHG holistically; foundational approaches and infrastructure for sustainability in computing systems and thereby in the social and economic systems that build on these including reducing energy consumption in processors, networks, and data centers; mitigating e-waste issues in computing systems; developing methods for online engagements in lieu of travel; using intelligent computing techniques to mitigate GHG emissions related to logistics, community mobility, and others.

Energy Innovations Relevant to Climate Change Mitigation. Proposals focused on mitigating negative impacts of climate change are encouraged to address fundamental scientific questions aimed at providing solutions relevant to renewable energy and related topics. Proposed research or requests for conferences (workshops) on mitigation strategies should consider potential long-term environmental consequences. Topics may include:

- Photo- and electrochemistry for energy conversion and storage including bio-inspired systems, fuel-cells, hydrogen gas storage and production, thermophotovoltaics, and agrivoltaics; renewable energy production and storage including "beyond Li-ion battery" technologies; development of carbon free fuels; advanced materials, concepts, and

systems for thermoelectrics, radiative cooling/heating, thermal energy storage including bio-inspired systems, and waste heat recovery and long-distance transmission; utilization of artificial intelligence to effectively build in knowledge of underlying physical and chemical phenomena into systems modeling.
- Developing technologically advanced, economically competitive, environmentally benign methods, including biomining, for sustainable exploration, exploitation, and utilization of critical minerals and geomaterials relevant to clean energy systems; understanding geothermal processes and evolution and their responses to natural and human-made changes.
- Efficient and massive-scale integration of distributed energy resources (DERs - wind, solar, energy storage) in electric power transmission and distribution grids to reduce carbon emissions, including power electronic converter design and controls, new ways of distributed optimization and control of DERs, risk modeling and risk analytics, adaptive, secure, and self-optimizing energy markets and policymaking; collaboration between climate science, predictive modeling, and machine learning for better solar forecasting.
- Strategies for increasing resilience of infrastructure such as power grids to hazards and disasters such as hurricanes and wildfires, which may be exacerbated by climate change; integration of electric vehicles and hybrid electric vehicles into existing electricity grid services; new control architectures for operating power grids and transportation networks while respecting cross-coupling issues on stability, efficiency, power quality, price, cyber-security, resilience, etc.; social and behavioral sciences and public policy solutions for energy equity; fair, accountable, transparent, and ethical artificial intelligence for smart homes, smart buildings, smart grids, smart transportation, and smart agriculture.

Enhance GHG Sequestration. GHG sequestration proposals are encouraged that address approaches of removing GHGs through industrial or enhanced natural processes. Topics may include:

- Improved approaches to carbon capture, including, but not limited to advanced materials and biological systems; strategies for ecosystem restoration through carbon sequestration; biological and biotechnological approaches to enhance biological carbon sequestration.
- Strategies to reduce the sources or enhance the sinks of GHGs (carbon dioxide, methane, nitrous oxide) in terrestrial and aquatic systems, including carbon dioxide removal via soil carbon sequestration, deep carbon storage, and enhanced weathering or mineral carbonation.
- Controls over carbon dynamics in natural and managed ecosystems, including multi-omic approaches to inform use and conservation of adaptive traits that increase carbon uptake and retention in natural and managed biological systems.

- Understanding the process that govern GHG uptake in the ocean and impact on the ecosystem.

Accelerating Strategies for Climate Change Adaptation. Adaptation-related research that addresses potential strategies to enhance resilience of natural, societal, or engineered systems to changes in temperature, increased extreme weather, precipitation changes, socio-economic repercussions, etc. are encouraged. Topics may include:

- Systems biology approaches to understand and enhance the adaptation of managed and non-managed ecosystems to a rapidly changing climate; biocultural restoration to enhance system resiliency; feedback dynamics between biodiversity, climate, and sustainable natural systems; direct and indirect roles of biodiversity in climate change solutions (e.g., carbon sequestration).
- Plant community composition and GHG uptake, range expansion and habitat connectivity, restoration planning, trait and physiological adaptation to climate change, demographic responses, plant-soil feedback, and trait-mediated responses to disturbance; speciation and extinction dynamics related to changing climates, including adaptation rates and comparative species resiliency; assisted evolution, evolutionary rescue, and the study of evolutionary mechanisms relevant to rapid adaptation and plasticity of organisms.
- Climate impacts on the rates of geochemical and biogeochemical cycles, including nutrient cycling, that drive GHG emissions from and sequestration by terrestrial systems; climate impacts on the water cycle and water availability (surface water, groundwater, soil moisture, glaciers, snow, flooding, drought); interactions between the land surface and atmosphere that drive changes in water storage; integration of groundwater recharge, storage, and withdrawal into projections of water availability, improved forecasting, and projections of drought and flood risk; rates and magnitudes of sea level rise globally and locally as a function of cryosphere, ocean, and solid Earth interactions, including impacts on flooding, erosion, and saltwater intrusion.
- Adaptation related to infrastructure, hazards, coastal protection, and building design; social dynamics impacting and resulting from climate change adaptation strategies; climate impacts on the frequency and severity of extreme events and climate related "tipping points" in terrestrial systems; exploration of potential impacts of different possible approaches to solar radiation management.

Research Addressing Synergistic Topics. Proposals addressing cross-cutting topics could focus on technology and workforce development with an emphasis on behavioral and social aspects related to climate mitigation and adaptation. Topics may include:

- Measurement and sensing innovations, scalable, low-cost and internet of things (IoT) powered sensor network technology to measure emissions and other relevant parameters; on-device learning approaches for energy-efficient, distributed sensing,

processing, and actuation.
- Artificial Intelligence and other data analytics, computational and statistical modeling and simulation approaches that directly address climate change solutions; use of quantum computing for solving problems on renewable integration and climate science; use of current quantum computing devices and future digital quantum computers for addressing major computational challenges facing renewable energy, such as large-scale simulations on climate modeling and weather forecasting, distributed generation, and scheduling and dispatch of renewable resources.
- Understanding the role of human behavior in achieving mitigation strategies; integrated socio-environmental dimensions of climate change solutions; attention to questions of environmental justice; vulnerability and weakened resilience due to the often overlapping and cascading effects of poverty and climate change that need to be addressed together; international aspects of any of the topics highlighted in this DCL, particularly involving developing countries.
- Energy and climate education, capacity building, and broadening participation.

Ultimately, the Grand Challenge of reaching net-zero emissions and limiting, mitigating, and adapting to climate change will require effort from multiple disciplines and convergent approaches. Plans that include a basic science foundation and system approaches are required, and the formation of cross-disciplinary teams is encouraged. Training of an interdisciplinary and more diverse future scientific workforce will help address these challenges, and public engagement with adaptation and mitigation strategies will be crucial.

PROPOSAL SUBMISSION

This DCL encourages the submission of conference (workshop), GOALI, or standard research proposals to appropriate existing NSF core programs to lay the foundation for disciplinary and interdisciplinary research on innovative solutions to climate change. NSF's SBIR and STTR Programs also seek proposals in this area as a way of kickstarting small businesses with deep technical solutions to climate change. Conference (workshop) proposals are required to be interdisciplinary and bring research communities together to develop novel solutions to mitigating or adapting to climate change. The budget of a conference (workshop) proposal is generally limited to $50,000, but under exceptional circumstances may be supported up to $100,000. The Division of Chemistry (CHE) and the Division of Earth Sciences (EAR) are also interested in supporting high-risk, high-reward EArly-concept Grants for Exploratory Research (EAGER) and Research Advanced by Interdisciplinary Science and Engineering (RAISE) proposals. For EAGERs and RAISEs, proposers are required to send email inquiries indicating relevance to CHE or EAR to cas@nsf.gov. Proposals submitted in response to this DCL are encouraged to involve participants who are members of underrepresented groups and institutions. Proposals submitted to the GCR program should be research proposals consistent with the GCR

solicitation.

Prospective principal investigators must send an email inquiry to cas@nsf.gov prior to submission to ascertain whether the proposal is suitable for CAS: Innovative Solutions to Climate Change DCL and for the specific program or programs in one of the participating divisions or offices. In the email inquiry, the PI should provide an indication of the target program(s) for the proposed topic in the participating divisions. Please note that the PI-indicated target program may not be the only program that will consider the submitted inquiry. Research concept outlines or brief summaries (no longer than 2 pages) are required for conference (workshop) and EAGER and RAISE proposals, and are encouraged for standard research proposals. These should be submitted by email to cas@nsf.gov. If the topic is found suitable, PIs will be directed to submit the proposal to the proper, existing disciplinary research program in one of the participating divisions. Guidance on the preparation and submission of standard research proposals is contained in Chapter II of the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG). Specific guidance on the other types of proposals that may be submitted in response to this DCL (i.e., Conference, GOALI, EAGER and RAISE) can be found in PAPPG Chapter II.E. The titles for all submissions should include the prefix "CAS-Climate:", after PAPPG or solicitation specific title requirements.

Participating Divisions (email inquiries to cas@nsf.gov directly, not to individual Program Directors)

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Sincerely,

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