NATIONAL SCIENCE FOUNDATION
2415 EISENHOWER AVENUE
ALEXANDRIA, VIRGINIA 22314

NSF 22-060

Dear Colleague Letter: Design for Sustainability in Computing

March 15, 2022

Dear Colleagues:

Environmental impacts of computing technologies extend well beyond their energy consumption and require a holistic focus on broader sustainability. Negative impacts of greenhouse gas emissions, depletion of rare earth elements, and e-waste are exacerbated by the proliferation of computing throughout society and treatment of computing systems as disposable commodities with planned obsolescence. Furthermore, environmental concerns range from the better-known carbon footprint from energy consumption (e.g., cloud) to equally important concerns of embodied carbon[1], generation of methane, carcinogens, volatile organic compounds, and eutrophication, among others. Widespread use of compute intensive techniques (e.g., blockchain and artificial intelligence), handling and moving massive amounts of data, the rollout of next generation wireless/edge networks, and growth of smart devices amplifies the environmental concerns of this proliferation of computing. A new sustainable way of thinking about computing, across the full lifecycle -- including manufacturing, operation, and disposal -- is necessary to meet the needs of the present without compromising the wellbeing of future generations.

The current transition to a post Moore era is an opportunity to look well beyond *power efficiency* to make carbon and other sustainability metrics first order concerns in computing. This requires a paradigm shift towards *design for sustainability* that treats sustainability impacts as first order metrics and on equal standing with performance, reliability, usability, and operational energy efficiency. It is critical to consider sustainability across multiple dimensions (emissions, pollution, renewable versus limited resource usage, embodied costs, supply chain impacts, etc.) in every layer of the computing stack and across the computing spectrum from high performance computing to smart mobile devices. Design for Sustainability in Computing will require fundamentally new and disruptive research across all aspects of computing including modeling, design, reuse, programming, data management, fault tolerance, operation, and graceful degradation, of digital and computing-based technologies and their associated infrastructure.

The National Science Foundation's (NSF) Computer and Information Science and Engineering (CISE) directorate supports research and education projects that develop new knowledge in all aspects of computing, communications, and information science and engineering, as well as advanced cyberinfrastructure, through its Core programs. **The purpose of this Dear Colleague Letter (DCL) is to encourage the submission of novel and high impact proposals that advance sustainability in all aspects of computing to the CISE Core programs (NSF 21-616)**.

This DCL invites transformative, cross-disciplinary and potentially clean slate approaches to enable sustainability across all levels of the entire computing stack from hardware to networking to software applications. Proposals are encouraged to consider diverse notions of sustainability and propose suitable metrics for quantifying impact. Traditional energy efficiency and power savings methods alone are not in scope for this DCL. Computing techniques for sustainability in other fields are not in scope for this DCL. This DCL seeks ambitious and forward-thinking proposals on Design for Sustainability in Computing along multiple dimensions that go beyond energy efficiency. A non-exhaustive list of possible research topics includes:

- New models and metrics for sustainability that are broader than energy efficiency, as well as methods to discover and obtain pareto optimal points for tensions between addressing sustainability and other considerations like performance, correctness, security, privacy, usability, and human and economic cost.
- Techniques for responsible advancements of data organization, storage, precision, analysis, and movement, and judicious use of resource intensive techniques (e.g., machine learning, blockchain, and encryption) to meet sustainability metrics while advancing compute capabilities.
- Design for reusability principles across some or all levels of the entire computing stack to avoid obsolescence and enable longevity for devices (e.g., smartphones, IoT), including modular design for updating, common product-line sharing, repurposing, or retrofitting sub-components, and effective recycling of eventually decommissioned devices.
- Sustainability aware software/system abstractions, design methodologies, interfaces, and programming languages, hardware/software cross-layer optimization, and optimizing compilers for sustainability metrics that increase usability without loss of efficiency.
- Advances in computer architectures including reconfigurable architectures, accelerators, non-von Neumann processing approaches, approximate computing, intermittent computing, and fault tolerance for improved sustainability that reduces resource usage and increases effective system lifetimes.
- Advances in sustainability aware cloud technologies including service level agreements, scheduling, capacity planning and provisioning using advancements in disaggregated

computing in the edge/cloud, and effective integration with energy harvesting and renewable energy sources, reduction of secondary pollutants and novel cooling concepts.
- Advances in hardware that include green VLSI-CAD, replacements beyond hybrid CMOS+X, and use of cleaner legacy fabrication techniques targeting sustainable next generation processors for highest performance applications to mobile/edge/5G-and beyond.

This DCL neither constitutes a new competition nor a new program. Rather, interested proposers should prepare and submit proposals in accordance with the instructions in the CISE Core program solicitation (NSF 21-616) and the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG). Additionally, to call attention to responsiveness to this DCL, the Project Summary should include "SustainabilityDCL" in the keyword list. Proposals submitted to this DCL will count towards the proposal limits imposed in the CISE Core program solicitation.

Questions should be directed to: Nina Amla (OAD), Anindya Banerjee (CCF), Erik Brunvand (CNS), Linda Bushnell (CNS), Almadena Chtchelkanova (CCF), Dan Cosley (IIS), Alex Jones (CNS), Juan Li (OAC), Sylvia Spengler (IIS): at DSC-DCL@nsf.gov.

Sincerely,

Margaret Martonosi
Assistant Director
Directorate for Computer and Information Science and Engineering

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[1] Embodied carbon is the carbon dioxide (CO_2) emissions associated with materials and manufacturing processes.