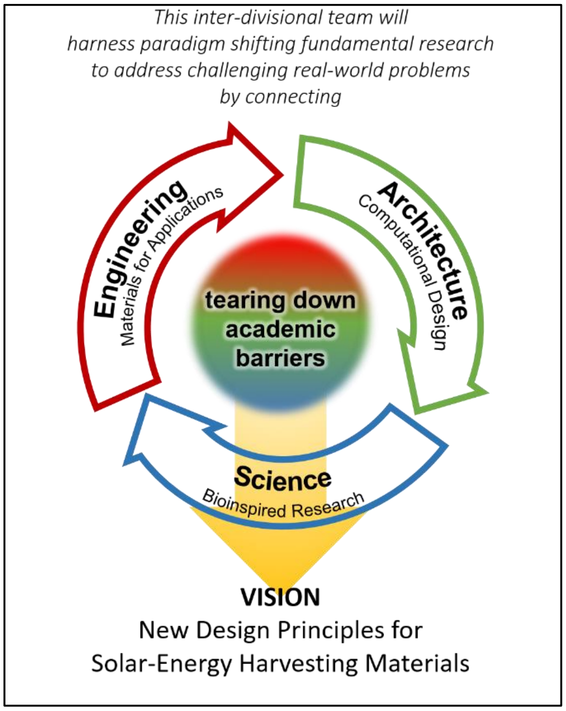

Figure 1: Schematic illustrating of proposed initiative.

A PARADIGM SHIFT INSPIRED BY NATURE:
New Design Principles for Solar-Energy Harvesting Architectures

Project Team:

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Chemistry | **Division of Science**, CCNY
(*low-dimensional quantum material systems at the nanoscale)*

Prof. Frank Melendez, Associate Professor (Co-PI)
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(computational design and biomaterials)

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(advanced materials for optical applications)

Project Concept Description:

Keywords. Renewable Energy, Global Warming, Climate Change, Bioinspired Materials for Solar Energy Harvesting, Photosynthetic Plants and Bacteria, Solar Cells, Photovoltaic Applications, Computational Design, Visual Programming in Architectural Design.

Objective and Approach. The overall contamination of our environment is contributing to effects of dramatic climate change while limited energy resources on Oil, Coal, Gas which provide ~80% of our energy needs (will last for not more than up to 50-150 years) or Uranium (will last for not more than approx. 90 years) is leading to global conflicts and international turmoil. Global warming as well as the limited energy resources present a major risk to both the US economy and national security. Over the last decades, funding for renewable and sustainable energy has been substantially increased, especially through main funding agencies such as the National Renewable Energy Laboratory (NREL), the National Science Foundation (NSF), the Department of Energy (DOE), the Department of Defense (DOD) *etc.* Even though their emphasis is on inter-disciplinary research teams, they rather focus on collaborative teams within science and/or engineering only. In contrast, the inter-divisional approach of our initiative (**Fig. 1**) allows a holistic approach to *encompass all length and time scales* for bioinspired energy architectures (**Fig. 2**) including socioeconomic and societal aspects with a focus on *bio-inspired materials design and architectures* that inhabit *stimuli-responsive materials properties* (**Fig. 3**). Our holistic approach holds the potential to unleash innovative breakthroughs as well as to achieve transformational advances in energy research and subsequently energy technologies. The future of sustainable energy technologies requires not only highly efficient but more importantly <u>*robust*</u> solar-energy harvesting materials, especially as rising global temperatures threaten the efficiency of existing photovoltaic installations. Unlike current solar energy conversion technologies, **natural photosynthetic organisms** and their solar energy harvesting architectures have clearly evolved beyond these challenges, capturing and transporting solar energy at remarkable efficiencies, even under extreme environmental stress.

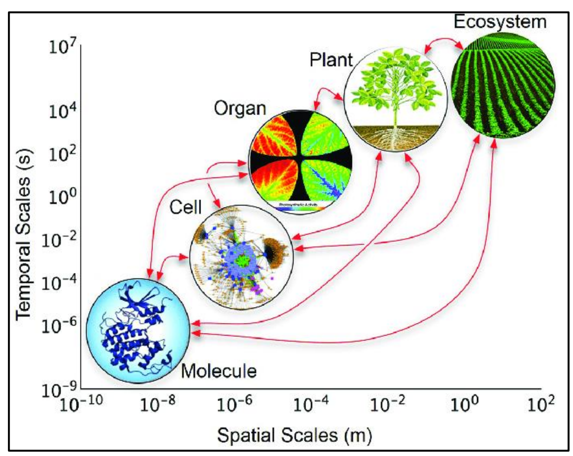

Figure 2: Layers of organization of biological models across temporal and spatial scales. *The y-axis represents real-time in which changes occur at each biological level; the x-axis represents the relative size or space which the biological level encompasses. The arrows indicate possible direct interactions among scales. (Image from Marshall-Colon et. al, Frontiers in Plant Science. 8. 786. 10.3389).*

Outcomes and Expected Products. Overall, this initiative aims to gather preliminary results and identify necessary infrastructure for proposing a NSF Materials Research Science and Engineering Center (MRSEC) for the FY 2023 competition. Specifically, the proposed CCNY | MRSEC Center for Bioinspired Energy Architectures will be led by CCNY in partnership with Columbia University, New York University, CCNY-ASRC, Princeton University, Harvard University and MIT, encompasses three Interdisciplinary Research Groups (IRGs) at the interface of Architecture and Science (IRG I), at the interface of Science and Engineering (IRG II), and at the interface of Engineering and Architecture (IRG III) as illustrated in **Fig. 1**.

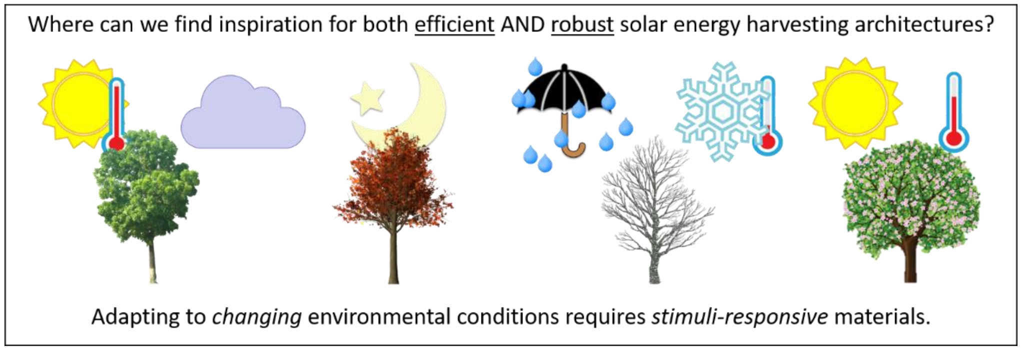

***Figure 3:** Robustness of photosynthetic organisms stem from its dynamic, stimuli-responsive properties.*

Merits and Impact: High academic barriers between diverse disciplines such as Architecture, Engineering, or Science preclude collaborative efforts. In fact, current cross-disciplinary research as funded by federal funding agencies such as NSF, DOE, DOD etc. is envisioning collaborations *within* these disciplines rather between them. Researchers from these disciplines address similar energy related issues but, however, at different length and time scales (**Fig. 2**), for example, architects on a human scale, engineers on a macroscopic/microscopic scale, and scientists even on a nanoscopic length scale. Combining these highly diverse approaches within *one* initiative and subsequently within the planned CCNY | MRSEC Center for Bioinspired Energy Architectures holds the exciting potential for a true paradigm shift in energy research and beyond.

	Month 1-2		Month 3-4		Month 5-6		Month 7-8		Month 9-10	
1a	■	■	■	■	■	■	■	■		
1b	■	■	■	■	■	■	■	■		
2		■	■	■	■	■	■	■	■	
3			■	■	■	■	■	■	■	■
4									■	■

Milestones and Timeline: 1a Identifying synergy effects between Engineering, Science, and Architecture on different length and time scales; 1b Synthesize and characterize the proposed material systems; Design and characterize the proposed optical devices; 2 Expanding the inter-divisional research team in order to identify potential partners for planned CCNY | MRSEC on campus and beyond. 3 Compiling and analyzing test data for planned CCNY MRSEC proposal; 4 Submission of annual technical report; Discuss Year-1 results and Year-2 development plan with AFRL program officer.

Budget: For Year 1, the total budged requested is $197,000. PI and Co-PIs. The senior personnel will be responsible for the design and execution of all experiments. They will be directly involved in all research components, including supervision of the students involved, dissemination of the discoveries through peer-reviewed manuscripts and presentations. Summer salary of 0.5 month is requested for Professors Eisele, Fan, and Melendez, so in total 1.5 months. Postdoctoral Associate (material science). We request 12 months of support ($60,000) for a Postdoctoral Associate with broad expertise in materials science and light-matter interactions. She/he will support the PI and Co-PIs in coordinating all research efforts within this inter-divisional research team, will synthesize the proposed material systems, design the proposed optical devices, and characterize them via super high-resolution nanoscopy techniques as they are available in *CCNY's Nanoscopy Cluster*, that is, our NSF funded Stochastical Optical Reconstruction Microscope (STORM)—setup located at the Grove School of Engineering's Nanoscopy Laboratory—as well as our NSF funded multi-functional Near-field Scanning Optical Microscope (NSOM) in conjunction with our NSF funded optical spectroscopy setup—both setups located at the Division of Science's Nano-imaging/spectroscopy Laboratory. Graduate Student (mechanical engineering). We request 12 months of support ($34,000) for a graduate student with broad expertise in mechanical engineering—including biomechanics, transport phenomena, and modelling of biological systems—to design, analyze, and manufacture the proposed devices. The student will overlap with the postdoctoral researcher in order to be trained in supramolecular chemistry, semiconductor nanomaterials synthesis, and related synthesis methods as well as in spectroscopy techniques. She/he will be working with scanning probe microscopy techniques and optical spectroscopy techniques. Master Student (architecture). We request 12 months of support ($25,000) for a master student with broad expertise in computational design, visual programming in architectural design, and urban architecture to execute proposed research and knowledge transfer in architectural design. The student will overlap with the postdoctoral researcher and the graduate student in order to train them in architectural design or sustainable architecture.