12th Workshop on Renewable Energy and Sustainability (WREN2024)

Energy for sustainability: Where are we coming from and where are we heading to?

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Abstract:

Solar light has provided the energy for sustaining life on Earth for about three billion years. Currently, our principal energy source, fossil fuels, contains solar energy stored millions a years ago by ancient plants and microorganisms via photosynthesis. While nowadays we still have enough coal and other fossil fuels to sustain our needs for a couple of millennia, the release of carbon dioxide presents a principle treat to the human civilization the way we know it. Through the Holocene epoch, since the beginning of the Agricultural Revolution, humanity evolved on our planet with carbon dioxide atmospheric concentration staying in the range of about 260 to 290 ppm, which has ensured the weather pattern essential for flourishing of the human civilization. The unprecedented and ever-increasing rates of release of carboned dioxide in the atmosphere since the industrial revolution, are a serious treat for this planetary balance. Solar light is the energy source that has the capabilities to meet the consumption needs of humankind and sustain our ways of living in environmentally benign manners. A range of fundamental challenges, such as energy storage and cost vs. efficiency, however, still prevent solar (photovoltaic and photothermal) from becoming a viable energy technology. This presentation will cover a brief historic overview of the development of solar techniques and technologies and go into the state of the art and some of the fundamental challenges. Biological inspiration, i.e., taking ideas from natural living systems and implementing them in advanced engineering, has been driving the progress of solar-energy research and development for decades. The pursuit for artificial photosynthesis is an outstanding example in this quest. In this respect, charge-recombination and lack of appropriate electron-deficient photosensitizers still prevent high conversion efficiencies at the photocathodes of photocatalytic cells, i.e., the sites for reducing CO2 and water to form solar fuels. The role of localized fields from molecular dipoles present paradigms for enhancing the efficiency of desired charge-transfer processes, while suppressing charge recombination. We use bioinspired electrets for understanding and implementing dipole effects on charge transfer. (Electrets are systems with ordered electric dipoles.) Also, using biological inspirations we have developed a range of electron-deficient metal-free photosensitizers which present excellent candidates for hybrid photocathodes. These examples illustrate the importance of bioinspiration for advancing energy science in the pursuit of sustainable-energy technologies.