iFAST: The International Forum on Advanced Environmental Sciences and Technology

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John Crittenden

GEORGIA INSTITUTE OF TECHNOLOGY

https://ce.gatech.edu/people/faculty/581/overview

J. Crittenden is the director of the Brook Byers Institute for Sustainable Systems and a professor in the School of Civil and Environmental Engineering at the Georgia Institute of Technology. Crittenden holds the Hightower Chair and is a Georgia Research Alliance Eminent Scholar in Environmental Technologies. Crittenden received his bachelor's degree in chemical engineering and master's and Ph.D. degrees in civil and environmental engineering from the University of Michigan. He was elected to the U.S. National Academy of Engineering in 2002, the Chinese Academy of Engineering in 2013 and the European Academy of Sciences in 2019. He is the 2015 Clarke Prize laureate, which is generally recognized as the American Nobel prize for water and received the 2020 Simon W. Freese Environmental Engineering Award, and Lecture for accomplishments in using fundamental scientific principles and current research findings to solve the most challenging water quality problems (American Society of Civil Engineers). He is the co-holder of five patents and the primary author of the bestselling textbook, *Water Treatment: Principles and Design* (2012, Wiley). He authored more than 415 articles that were published in refereed journals, more than 100 book chapters, reports and symposia, and has over 30,000 citations and a H index of 79. The articles present his research on sustainable urban infrastructure, membrane technologies, adsorption, and advanced oxidation including electrochemical advanced oxidation.

Gigatechnology: Developing Sustainable Urban Infrastructure to Solve Gigaton Problems

Gigaton problems are the most severe problems that challenge humanity, and they are measured at the "gigaton (billion tons)" scale. For example, the annual world energy consumption is around 12 billion tons of oil equivalent (Gton), 80% of that from nonrenewable fossil fuels. The combustion of these fossil fuels emits approximately 29 billion tons (Gton) of CO_2. In addition, the world uses more than 79 Gton of materials each year, only about 29% of which are renewable. Clearly, this is not sustainable in the long run. These gigaton problems call for solutions which can meet the gigaton scale, or gigaton solutions. The current practice of designing, building, and operating infrastructure is rooted in the Eisenhower era and is a barrier to the future. Its failure to recognize the interdependencies between infrastructure components results in a sub-optimal system that is viable only because of the availability of cheap fossil fuels and non-renewable resources and the externalization of costs, risks and harms. For infrastructure to support societies moving forward, a reimagining and restructuring needs to occur that: 1) uncovers the interconnections and interdependencies among civil infrastructure systems and their interactions with social, financial and natural systems; 2) works with industry, government and non-governmental organizations to create an interoperable systems platform that is necessary to design, simulate, test, monitor, build, control and protect massive, open and complex infrastructure systems; 3) develops, tests and implements the new laws, rules, standards and best practices for designing, building, financing, operating and decommissioning sustainable and resilient infrastructure across its total life cycle; 4) develops the pedagogy that teaches, trains and empowers the workforce, organizations and agencies that will transform infrastructure from isolated, simple and vulnerable components into a connected, complex and resilient system; and 5) recruits and retains a new generation work force that is as diverse as the communities in which they serve. This is not a call for incremental improvement. It is a proclamation of the dire need for bold infrastructure reform that can best be characterized as the creation of a new Science of Gigatechnology. Gigatechnologies are the largest engineered systems that humans create. They include regional electric power grids; networks of interstates and roads; municipal water systems; connected communications, sensors, and computing devices; and clusters of buildings that aggregate to form blocks, neighborhoods and cities. The science of Gigatechnology is more than just the designing, building and operating of these and other big systems, however. And they are more than just a digital overlay on top of physical systems conceived in a pre-cyber age. Gigatechnology is about the properties that emerge from big systems interacting with each other, and with social, economic, technological and natural systems. Smog, climate change, flooding, inequality and community identity are just a few examples of emergent properties. They cannot be seen or anticipated from the examination of just one element of the system, and those responsible for the overall function and fitness of the parts are rarely challenged to address infrastructures as a system of systems. It is paramount to understand that the new design is to create desirable emerging properties such as improving the quality or life, GDP, etc. Unlocking the mysteries of Gigatechnology is essential to the health and well-being of people, the planet and the worldwide economy.

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