

Earth: Extinguishing Anthropogenic Risks Through Harmonization

Tae Seok Moon

Department of Energy, Environmental and Chemical Engineering, Washington University in St. Louis, St. Louis, MO, USA

tsmoon7@gmail.com

Abstract

Human diseases can kill one person at a time, but the COVID-19 pandemic showed massacres could be possible. The climate crisis could be even worse, potentially leading to a bigger number of deaths of the human species and all living systems on Earth. I urge us to change our human-focused mindset to solve many problems, including the climate crisis, which humans caused to the entire ecosystems due to our arrogance: humans own this world. In this perspective article, I propose four recommendations to address climate issues through paradigm change and safe and sustainable technologies.

Keywords

Climate crisis; greenhouse gas; sustainable growth; environmental protection; engineering biology; Earth

Main

Since the Earth was built approximately 4.5 billion years ago, many organisms and viruses have been living in this gigantic house. Between 550,000 and 750,000 years ago[1], human ancestors started to rent it and live with other previously residing residents. Around 200 years ago, the Industrial Revolution made these messy residents start to destroy the old house. Unfortunately, the destruction speed is so high that we might be at the tipping point of irreversible demolition of the house[2]. For example, climate changes are clear and pose dire threats to the health and well-being of the Earth and its inhabitants. Notably, more extreme, frequent, and interconnected climate events are causing widespread vulnerabilities, damage, and loss to humans and nature, and these adverse impacts are compounding and often becoming irreversible.

One solution to the climate crisis or emergency would be to limit further development and plant a tremendous number of trees that can capture greenhouse gases (GHGs). However, it would not be a viable solution for developing countries where economic development is their priority. In addition, lands for food production are becoming limited, making traditional approaches such as planting trees to capture GHGs impractical. Although engineering approaches would be practical solutions to climate issues, they would contribute to climate risk mitigation, rather than absolute risk elimination that requires eradicating the hazard and risk at its source.

I envision that engineering biology will enable climate change mitigation and adaptation by lowering GHGs, removing pollutants, promoting biodiversity and ecosystem conservation, and providing sustainable bioproducts in the food and agriculture sectors, transportation and energy sectors, and manufacturing sectors[3, 4]. Notably, engineering biology is not the only solution for sustainable growth and environmental protection, but one of the approaches to address the climate crisis[4]. Using engineering biology, researchers can develop technologies that capture GHGs to mitigate global warming[5], upcycle plastic waste to reduce plastic pollution in an economically

viable way[6], enable bacterial nitrogen fixation to help increase crop yields without using chemical nitrogen fertilizers[7], and replace petroleum-based chemicals and materials with bioproducts[3]. To this end, multiple factors should be considered, and I propose the following four recommendations.

First, climate change is a global problem that should be solved by international collaboration. To this end, we should understand climate inequality[8]. For example, just 10% of the world population is responsible for almost 50% of global GHG emissions, while the top 1% of global GHG emitters are responsible for 15% of the emissions. While the traditional GHG emitters see it as a climate crisis or emergency, the developing countries may see it as an unfortunate byproduct of urgent economic development. However, economic growth and planet conservation might not necessarily be incompatible if we adopt and implement the concept of sustainable growth and clean technology such as renewable energy generation and green chemistry. The key change to make is our human-focused mindset; we should first admit that humans caused global issues such as climate change and should realize that our planet belongs not only to us but also to other living residents, including bacteria, insects, plants, and animals. Additionally, we should note the complexity and challenges of climate issues in terms of political, economic, and societal dynamics between different nations and generations. Nevertheless, I cautiously hope that it will be possible to enable harmonization between humans and other living systems as well as among nations with different political, economic, and societal interests to mitigate the climate problems.

Second, more technological infrastructure should be formed, including engineering biology research centers, incubators for climate technology start-up companies, and scale-up facilities for bioproduction[9]. Additionally, technology developers, especially researchers in academia, will benefit from experts in techno-economic analysis (TEA) and life-cycle analysis (LCA). Government labs that support TEA and LCA will be another useful infrastructure. Furthermore, we should consider absolute sustainability assessments when evaluating biobased solutions to climate problems[10-15]. To enable these activities, governments should increase funding for fundamental and applied research as well as commercialization efforts of climate-related technologies. Given the interdisciplinary and global nature of projects and activities focusing on climate issues, center-scale funding and international funding support will be important. Additionally, mid-size grants (e.g., 3M USD) that emphasize technological disruption or innovation will facilitate diverse high-risk and high-return projects to be initiated. Notably, a recent report shows the reduced proportion of disruptive technologies in the past decades[16]. The climate emergency may need innovative and even disruptive technologies, and funding agencies such as the U.S. ARPA-C and German SPRIND will have an important role in nurturing environments that encourage diverse and innovative ideas.

Third, we must shift our paradigm from individual bioproduction based on a single feedstock using a single microbe to consortium engineering in order to solve ecosystem-scale problems such as climate crisis and waste issues[3]. In other words, the entire planet can be considered a huge bioreactor[3], where photosynthetic or C1 organisms capture greenhouse gases[5, 17], nitrogen-fixing bacteria store the limiting nitrogen source for diverse other organisms[7, 18], and plastic-eating microbes convert plastic wastes into value-added chemicals and materials[6, 19, 20]. Notably, we should quantify the impact of consortium engineering on solving the climate issues. To achieve this ambitious goal, I suggest the following technological

development: 1) developing microbiota engineering tools that have species- or strain-level specificity and spatiotemporal accuracy by improving machine-learning-based computational and experimental tools[21, 22]; 2) using such strain-level knock-out and knock-in tools to determine the function and role of individual community members and the microbial consortium dynamics[21, 23]; 3) constructing or optimizing ecosystems that help solve global problems, including the climate crisis, food shortage, waste issue, and sustainable bioproduction[24, 25]; 4) ensuring biocontainment through the use of technologies such as auxotrophy and kill switches[26, 27]. Obviously, developing such technologies requires multidisciplinary and international collaborative efforts of many experts, including systems and synthetic biologists, soil, water, and atmospheric scientists, environmental engineers, and systems engineers, with funding support. Notably, researchers should also consider the limitations and risks of engineering biology-based solutions, such as biocontainment issues of genetically engineered cells[26, 28] and antibiotic resistance spread potentially caused by antibiotic resistance genes released into the environment from biological research laboratories[3, 29, 30], avoid the hype of technological solutions[31, 32], and think about dual use research of concerns[9, 30, 33].

Fourth, we must focus on workforce development and education to generate the well-educated public and future leaders who are passionate about solving climate issues and ensuring sustainability together. Although generating future educators is critical for continued workforce training, we should also encourage and nurture future entrepreneurs. For example, Nucleate is a student-run organization that helps entrepreneurs form companies. Industry, academy, and government leaders should pay attention to and support such activities to nurture future industry leaders. Importantly, to allow for diverse solutions to the complex climate issues, educators must consider diversity, equity, and inclusion when our next generations are educated[9]. Notably, climate issues can be addressed the most effectively by collaborative efforts by governments, industries, academia, NGOs, and the public.

Despite the serious and urgent climate issues, I am cautiously optimistic because of the younger generation's awareness of climate problems and passion for solving them as well as the current international efforts to solve climate issues through policy implementation, education, and technology development. Using engineering biology that is often scalable and easily accessible, our future leaders are working hard to address challenges in climate-related research, technology development, commercialization efforts, and policymaking. Obviously, despite the complexity of climate issues as discussed above, they can be addressed by harmonic collaborative efforts by all generations and all stakeholders. This article provides the global research labs, industry, and governments with visions and potential solutions to climate problems. Sustainable growth along with solving climate issues is possible with global collaborations that implement the suggested visions.

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Conflicts of interest

The author declares no competing interests.

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