THE YALE PLANETARY SOLUTIONS PROJECT

Mission Statement: The Planetary Solutions Project will help solve global environmental problems caused by human activities, especially climate change and the loss of biological diversity. Planetary solutions developed at Yale will integrate the natural, health and social sciences, engineering, and humanities; be disseminated through education, outreach, and civic leadership; and be supported by incentives and policies to promote their implementation.

Introduction

Human activities are pushing Earth’s planetary-scale natural systems toward critical thresholds or tipping points. These are sudden or irreversible changes as physical and biological systems cross a point of no return, and they operate at a scale at which they can become detrimental to most species, including humans. Examples are the melting of giant ice sheets and sea-level rise; changes in ocean circulation and acidity; increased frequency and intensity of heat waves, tropical cyclones, floods, wildfires, and droughts; ecosystem failure, including food systems; the degradation of biological diversity; the emergence of new pathogens, and extinctions. Many of the areas that will be hardest hit by such abrupt changes are home to the world’s poorest communities. Planetary-scale solutions to these problems will require interdisciplinary analysis and forecasting of Earth system thresholds, and well-reasoned responses to mitigate losses and adapt to change. Developing global, integrated, and powerful new solutions to these problems has become a fundamental challenge for universities and other institutions around the world, and a key priority for Yale.

A crucial step in implementing planetary solutions is translating scientific, engineering, and economic knowledge into practical and effective policies. This entails climate, ecosystem, and public health monitoring and modeling studies, the exploration of economic tools such as carbon pricing, analyzing policies to promote rapid improvement in green technologies, and adaptation strategies for especially vulnerable regions and people. Moreover, the implementation of such policies requires better public understanding of environmental threats and hence increased outreach, education and scientific literacy.

The Yale Planetary Solutions Project will bring to bear the full weight of the University’s resources and expertise, spanning the sciences, engineering, humanities, education, communication, law and business. Already, we are well positioned for this mission, with faculty and students exploring these issues in relevant science, social science, engineering, and humanities departments across the university. To develop effective planetary solutions, we need to leverage these existing programs, and build more productive bridges among them. Likewise, to combat these existential threats to our planet and to future generations we must fully engage with a network of universities, research institutions, and governmental bodies around the globe.

An outline of our Planetary Solutions Project strategy follows under three broad headings: Mitigate, Adapt, and Engage. These are intended to capture the breadth of our response to environmental crises, and to orient our efforts, but are in no way meant to confine our activities. Indeed, we fully embrace the necessity to work across traditional disciplinary boundaries. Only in so doing, will we fully succeed.
1. **MITIGATE: Curtail harmful anthropogenic climatic and environmental changes**

   - Develop sustainable methods of carbon capture and storage

   In 2015, the United Nations Paris Agreement\(^1\) determined that global warming in excess of 1.5 degree Celsius (2.7 degrees Fahrenheit) above pre-industrial levels would have catastrophic consequences for much of the globe. To stay below this 1.5-degree limit, society will need to dramatically reduce greenhouse gas emissions. Replacement of fossil fuels with renewable energy is imperative, but is realistically decades away, and will not be enough to remain below the 1.5-degree limit. The requisite mitigation will need “negative emissions” approaches over the coming decades. Carbon capture and storage (CCS) methods are the primary means for generating negative CO\(_2\) emissions. Sustainable forest growth in tropical regions and urban environments represents one means of carbon capture and storage but is not sufficient alone. Other CCS methods must be explored and tested, and their effectiveness and consequences assessed before they can be implemented.

   There are many potential CCS strategies, including through mineral uptake, or “weathering”, in which silicate minerals are converted to carbonate minerals through natural chemical reactions. Such carbon storage is effectively inexhaustible and permanent. Biological capture and storage include carbon uptake through forest growth, algal crops, and soil remediation. Any portfolio of strategies for carbon dioxide removal and storage must be guided by scientific and economic projections that account for water resources, land use, environmental impact and food production.\(^2\)

   Yale faculty in several units provide significant cross-disciplinary expertise in areas of geological carbon cycling, subsurface fluid flow and storage, mineral weathering, photosynthesis, reforestation and afforestation, soil chemistry and microbiology, and the design of catalysts for the uptake of CO\(_2\) into organic molecules, to name a few. Scientific and economic research and strategies of carbon dioxide removal and storage are rapidly growing fields. Yale is poised to leverage its strengths in science, engineering, policy, and economics to become a major contributor to these vital mitigation solutions.

   - Discover transformative and scalable energy alternatives

   Future reductions in carbon emissions will also require expansion of renewable energy sources to replace world-wide reliance on fossil fuels. Renewable power sources, such as wind and solar, can provide carbon-neutral sources of energy and have the potential to provide all of our society’s energy needs, but not twenty-four hours a day, seven days a week, as required for baseload electricity. Despite tremendous growth in the installation of photovoltaic solar panels and wind turbines and reductions in their costs, renewable energy sources currently provide only about 10 percent of our total energy usage. Impediments to expanded use of renewable energy sources include incentive obstacles such as continued fossil fuel subsidies and a lack of policies to promote renewable energy sources. Policy and implementation research for existing renewable energy technologies is critical for their adoption.

   Another major technological impediment to increased usage of solar and wind energy centers on our current lack of viable methods for storage. To power the planet completely with renewable energy, we

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1. [https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement](https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement)

need to develop innovative and cost-effective technologies to capture, convert and store energy. Many of these technologies can also be utilized for, or coupled to, carbon capture and storage strategies.

Nature stores solar energy in chemical bonds during photosynthesis, and this is the source of fossil fuels. By mimicking natural photosynthesis using artificial processes with higher efficiency, it would be possible to store solar energy in the form of high-energy molecules, solar fuels such as hydrocarbons like those in gasoline, enabling use of our existing infrastructure for transport and delivery of fossil fuels. To do this requires the development and application of catalysts for water splitting and carbon dioxide conversion. Scientists and engineers across multiple disciplines at Yale are working to discover scalable alternatives for renewable energy generation and storage that could transform our energy future. These efforts will require interdisciplinary research that brings together teams from multiple disciplines and instrumentation cores to facilitate cutting-edge research.

Even with available technologies, implementation of large-scale renewable energies requires economic and cultural innovation for adoption and deployment. We need to “leapfrog” over fossil fuels in increasing access to energy in the developing world. In collaboration with international colleagues, faculty at Yale are working to understand and overcome impediments to adapting renewable energies in the most highly populated, energy-starved areas of the world.

We also need to anticipate and manage other challenges associated with the transition to renewable energy technologies. These challenges include potential adverse health and environmental effects of mining rare earth metals and silicon for solar panels and lithium for batteries; land use challenges stemming from the need for large amounts of land for vast solar arrays; effects of off-shore wind farms on marine life; disposal/recycling of tens of millions of solar panels at the end of their useful life; the balance between de-centralized versus centralized energy systems; and equitable pricing and distribution of newly generated energy. Yale is well-positioned to form interdisciplinary teams to address these challenges.

• **Stem the destruction of vulnerable and diverse ecosystems**

The rate of global change, and the consequent decline of biological diversity, is faster than at any time in human history. The direct drivers are changes in land and sea use (e.g., expansion of agriculture and fisheries), direct exploitation of organisms (e.g., harvesting, logging, fishing), climate change, pollution, and invasive species. These changes have already severely damaged some of Earth’s most productive and genetically diverse ecosystems, such as tropical forests and coral reefs, and could trigger the extinction of nearly a million species within just a few decades. They also put the world’s food security at risk by undermining agricultural resilience to pests and climate change.

Stemming the effects of these dangerous global changes requires, first, the development of new and better ways of determining how the drivers of change, such land use change and global warming, impact species and ecosystems and their vital services, such as potable water. Progress requires that we expand our understanding to a much fuller range of organisms, including the insects, algae, fungi, and microbes that underpin the functioning of terrestrial and aquatic ecosystems. Second, we need more effective policies to conserve and sustainably manage biodiversity and ecosystems, including the expansion and sustainable management of protected areas within biodiversity hotspots.

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With the right investments, Yale can greatly magnify its impact in these areas. We are poised to capitalize on unprecedented technological advances in genomics, high-throughput phenotyping, remote sensing, and big data analytics. Collaborations between ecologists and engineers will yield a new generation of sensor technologies to monitor changes in biodiversity and ecosystem functions. Cooperation between scientists and faculty in the social sciences, law, business, architecture, and public health, will yield new approaches to mitigate the loss of our natural biological resources.

2. **ADAPT: Build resilient systems to accommodate global changes**

- **Facilitate evolutionary responses to environmental change**

With global warming and the ongoing decline in biodiversity and ecosystem services, humanity will need to adapt to rapidly changing circumstances. For example, the maintenance of our food supplies will demand the development of sustainable agriculture and fisheries practices. In turn, such efforts will require the conservation of genetic diversity in our cultivated species and their wild relatives. The evolutionary process itself may allow species to adapt to changing conditions, including climate change, much more rapidly than previously imagined, even in large and long-lived organisms. This emphasizes the critical need to maintain both healthy ecological and evolutionary systems to promote genetic diversity and adaptability to environmental change.

Increasingly, we appreciate that ecological and evolutionary processes are tightly coupled, and feed back upon one another. To ensure resilience in the face of global change and to devise necessary interventions, we need to better understand this coupling, and how it plays out over different spatial and temporal scales. New approaches include the use of CRISPR and “gene-drive” technologies to engineer more efficient crop plants, to stop the spread of invasive species and disease, and to rescue species on the verge of extinction. However, such approaches raise practical and ethical issues, including safety concerns, and their real-world implementation requires a clearer scientific understanding of their impacts as well as the development of relevant policies to ensure their fair and safe use. In addition to technological solutions to preserving biodiversity, setting aside land and sectors of our oceans as biological preserves presents significant policy and implementation challenges that deserve our attention.

Yale faculty are already at the forefront of research on coupled ecological and evolutionary dynamics, on very short and very long temporal and spatial scales. We are prepared to expand rapidly in this area and to promote the necessary collaborations among scientists, engineers, policy experts and ethicists. Strategic investments will position us to devise new and practical interventions to conserve biodiversity and improve environmental health.

- **Design adaptation strategies based on Earth-system, economic, and public health forecasting**

Human adaptation to global changes will require short to long term projections of climatic, ecological and societal responses. For example, we need to understand the consequences of increased atmospheric CO₂ and associated changes for temperatures and hydrological cycling, both regionally and globally. Projections of environmental changes -- including sea-level rise and ocean inundation, droughts, floods, and biodiversity loss, as well as extreme events such as fires, heat waves and
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hurricanes -- must be coupled with projections of large-scale human migration, infrastructure resilience, urbanization and adverse health impacts, in order to develop sound adaptation strategies.

This effort demands atmosphere, biosphere, and cryosphere research to improve climate and ecological models to better account for ice-variability, permafrost loss and methane release, shifts in biogeochemical cycles, the effect of clouds and aerosols, and changes to yearly and decadal climate patterns such as El Nino. It is further imperative to better understand biogeochemical effects on ocean acidification and the impact on marine ecosystems and fisheries. Earth system modeling can be coupled to economic modeling; these models can then be down-scaled to regional assessments for urban planning, and to assess the impact on vulnerable regions, including changes in fresh water availability, changes in air pollution, extreme events, sea level rise, migration of vector borne diseases, ecological collapse, threats to food production and infrastructure such as medical facilities, water-treatment and energy grids. Furthermore, public health modelers can develop early warning systems for vector-borne diseases to warn public health officials about the potential for outbreaks.

Yale faculty and students in multiple schools and departments provide expertise in the areas of atmospheric science and meteorology, oceanography, polar science and glaciology, hydrological and carbon cycles, ecosystem functioning, geochemical analysis of past climates, economic modeling, public health, game theory, policy and international law. With these resources, we are prepared to further expand our efforts into forecasting the impact of global change on Earth, biospheric, and human systems at the global and regional scales, and for vulnerable areas world-wide. Finally, we will need to scale the solutions suggested by modelling efforts. Yale has growing depth in implementation science and social science to design and test adaptation strategies tailored for specific populations for real-world effectiveness.

• Impact on Human Health

Food insecurity is just one example of a risk to human health. Ecosystem changes threaten the habitability of the places we live, the quality of water and air, and our ability to fight disease. The emerging field of planetary health, based on “the understanding that human health and human civilization depend on flourishing natural systems”\(^4\), clarifies the urgency of slowing and reversing rapid global changes. There are significant health co-benefits to mitigating production of greenhouse gases and pollutants, including millions of premature deaths averted from air pollution alone, as well as reduced cardiovascular disease from more plant-based diets and better urban design. These effects are felt first and hit hardest in marginalized communities, thereby exacerbating health inequalities. Health systems and societies must prepare for these impacts, including pandemic preparedness for additional zoonotic pathogens. As humans migrate with deforestation, desertification, and loss of coastal land, they can come into contact with new insect or other vectors of disease. In addition, disease vectors can spread due to perturbations of natural ecosystems.

To minimize disruptions in clinical care, healthcare systems need to increase their resilience to the current and future impacts of climate change, including the increased frequency and severity of extreme weather events, and must develop the workforce needed to address pandemics. This will require collaboration among Yale physicians, nurses, physician associates, epidemiologists, environmental, climate and atmospheric scientists, engineers, management scientists, and healthcare administrators.

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Furthermore, adaptation for health requires a host of other measures such as new and improved infectious disease surveillance systems; regional climate assessments of temperature and hydrological cycling; urban forestry and high albedo urban pavement and roofs to help cool urban heat islands; public cooling centers where vulnerable populations can find refuge during heat waves; provision of water, rest, and shade for farmers, construction, and other outdoor workers during heat waves; and urban agriculture to address food insecurity. Clinical, nursing, public health, engineering, natural, and social scientists need to collaborate to develop approaches that maximize the effectiveness of such health adaptation measures.

- **Yale leads by example**

Yale has already begun to use its own campus as a platform for sustainability innovation, including through development, implementation and university network consultation on its carbon charge initiative\(^5\). The first university to level an internal carbon fee,\(^6\) Yale has now helped create a toolkit\(^7\) that provides guidance to other universities interested in instituting their own carbon charge projects. Another example where Yale has led is in its ‘pay as you throw’ pilot, which utilized a three treatment groups/two control groups study design.

The ability to use Yale energy, food, transport, design, landscape, and waste generation and consumption – with attendant greenhouse gas emissions, carbon footprint and biodiversity impacts – as evaluation testbeds can be creatively expanded. Incorporating behavioral economics elements (incentives, competitions, etc.) within and across university units also has enormous potential. Collaborations with Yale New Haven Health System and Yale Schools of Medicine, Nursing and Public Health are promoting green health initiatives.

Finally, Yale is not an island but is embedded in the Greater New Haven County and must be a civic partner in planning for a rapidly changing environment. Yale’s Earth system forecasting and regional models can assess the resilience of local communities to flood risk, sea-level rise, ground-water salination, shifts in rainfall and aridification, heat waves, spread of vector-borne diseases, and other related impacts of climate-change. The recent election of a F&ES graduate as the Mayor of New Haven and the 2019 Board of Alders declaration of a climate emergency\(^8\), provides the opportunity to collaboratively address vulnerable hotspots in New Haven County and Connecticut more broadly.

Making the university an active community partner can advance the science, policy and practice of carbon-neutrality, while also promoting a healthy environment for teaching, research and living at Yale.

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\(^5\) [https://carbon.yale.edu/](https://carbon.yale.edu/)
\(^7\) [https://secondnature.org/climate-action-guidance/carbon-pricing/](https://secondnature.org/climate-action-guidance/carbon-pricing/)
\(^8\) [https://www.newhavenindependent.org/index.php/archives/entry/climate_change/](https://www.newhavenindependent.org/index.php/archives/entry/climate_change/)
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3. **ENGAGE: Communicate, educate, and lead for change**

- **Convene the leaders of today and teach the leaders of tomorrow**

The implementation of solutions is dependent upon collective policies and actions by societies across the planet, those that embrace changes in behavior to reduce ecosystem degradation and biodiversity loss, engage in sustainable natural resource use, embrace technological advances, support vulnerable human populations, and avoid planetary damage. This effort requires leadership in education, outreach and scientific literacy, innovation of ideas and approaches, and partnerships with governments and communities. Great universities must provide this leadership, not only with their collective expertise, but in their will to serve society.

Yale, as a leading research and education institution, is uniquely positioned to communicate, educate, and lead for change toward planetary solutions, based upon strengths throughout the institution. Yale is an internationally renowned and trusted source of knowledge on biodiversity conservation, sustainability, innovative energy solutions, carbon cycling and climate science, business and the environment, climate change policy, human health, pandemics, and much more. Leadership for the upcoming century requires not only scientific, engineering, and analytical capabilities and knowledge, it requires understanding of value systems and ethics, diplomacy, and communication skills. Our University has produced leaders across all sectors, including climate change, biodiversity, global health, economics and policy.

Yale is an ideal convener for bringing together leadership from across the world related to planetary solutions. Our faculty lead through scholarship, as well as national and international service to government⁹, industry and nonprofit sectors. Global leaders come to Yale to network, collaborate, and benefit from our broad expertise in many areas of planetary solutions¹⁰. We seek to increase our impact as a convener of leaders, through conferences, workshops, policy forums, as well as support of visiting scholars and pioneers in relevant fields. Examples of these efforts include the Kerry initiative, the Yale Environmental Dialogue, School of Management green business collaborations, the Yale Institute for Biospheric Studies, and the Jackson Institute for Global Affairs.

- **Advance public understanding of global environmental threats and solutions**

A formidable barrier to addressing deleterious global changes, and to implementing political and technological solutions to them, is the lack of public understanding of complex environmental issues. It is imperative for educational institutions to examine and clear the obstacles to scientific understanding in the general population, focusing on environmental problems, but also extending to other issues of scientific literacy.

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⁹ Yale faculty members have received the Nobel prize for work in climate policy, have chaired key reports for the Intergovernmental Panel on Climate Change, have served as leaders in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, the US EPA, Treasury, the White House Council of Economic Advisors on environmental issues, and the International Earth Charter Council.

¹⁰ For example, Yale Environmental Dialogue, Yale Sustainability Leadership Forum, Yale Conference on Global Environmental Justice, the Yale alumni-driven Environmental Sustainability Summit, the Yale Center on Business and Environment’s (CBEY)’s annual Visiting Expert’s program, the Global Health Symposium, Yale School of Architecture’s “Environment, Reconsidered”, the Yale Graduate Conference on Religion and Ecology, and more.
Across Yale, faculty engage in communicating and engaging with citizens about environmental threats and solutions. For example, Yale’s Peabody Museum demonstrates the value of biological diversity to scientists and local to international citizens through exhibits, collections, and databases; its collaborations with artists provide compelling examples of the biodiversity crisis in the renowned Yale University Art Gallery. The Yale Program on Climate Change Communication studies public climate change knowledge, attitudes, policy support, and behavior around the world and engages diverse stakeholders and a national radio audience in climate science and solutions. A multitude of student- and faculty-led media engage in advancing public understanding from New Haven to international audiences, including the online magazine e360, the Yale Environmental Film Festival, numerous public lectures from the Yale Environmental Humanities Initiative, and more. Our medical, nursing, and public health faculty conduct outreach on global environmental health challenges and interventions all over the world.

While these individual initiatives are highly successful, each relies separately on year-to-year support from grants and donations. We aim to expand Yale’s strengths in public engagement and outreach by securing these critical programs, and by creating an array of new and impactful public education programs.

- Advocate for the vulnerable and promote environmental justice

Climate change and related environmental challenges will increase vulnerability for a number of populations in the world due to storms, epidemics, heat stress, fires, drought, desertification, sea-level rise, food availability, and related natural hazards. The World Bank estimates that by 2025, 140 million people will migrate from unlivable conditions within sub-Saharan Africa, South Asia, and Latin America, placing increased stress on resources in urban regions, and creating political unrest. Populations of concern within the U.S. include those who live in poverty in either urban or isolated rural areas vulnerable to extreme weather, pollution, and to social and economic hardships.

Yale has a history of support for vulnerable individuals through its work in nursing, medical, public health, and clinical law practice all over the world. We have rich scholarship in social justice and equity, and are building strength in fields related to environmental justice with new interdisciplinary hires and centers. We draw from the world class humanities, arts, the Divinity School and others to tell the human story of our place on this planet, and the imperative to ameliorate suffering. Yale students become deeply engaged in these programs through clinical practice, internships, capstone courses, and volunteer-ships through organizations such as the Urban Resources Initiative, Health Core, the Columbus House, Haven Free Clinic, the Refugee Health Program, and many others. Yale can expand our community relationships and civic engagement, from New Haven and Connecticut, to cities and rural areas world-wide.

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12 The “Local Global Health” initiative, Columbus House, Haven Free Clinic, Yale Refugee Health Program, the Environmental Justice Law Clinic, and much more.