# A Research Strategy for Ocean Carbon Dioxide Removal and Sequestration

## Committee

## Scott C. Doney

**Chair**

Scott Doney is the inaugural Joe D. and Helen J. Kington Professor in Environmental Change at the University of Virginia. He was a postdoctoral fellow at the National Center for Atmospheric Research from 1991-1993, and he served as a scientist at the National Center for Atmospheric Research from 1993-2002 and then the Woods Hole Oceanographic Institution from 2002-2017 before moving to the University of Virginia. Dr. Doney's expertise spans oceanography, climate and biogeochemistry, with particular emphasis on the application of numerical models and data analysis to global-scale questions. His research focuses on how the global carbon cycle and ocean ecology respond to natural and human-driven climate change and ocean acidification. His previous experience with the National Academies includes membership on a number of committees in association with the Space Studies Board, Board on Atmospheric Sciences and Climate, and Ocean Studies Board. He has also served as an external reviewer for several National Academies reports. Dr. Doney graduated with a BA in chemistry from the University of California, San Diego in 1986 and a PhD in chemical oceanography from the Massachusetts Institute of Technology/Woods Hole Oceanographic Institution Joint Program in Oceanography in 1991.

# Holly Buck

**Member**

Holly Buck is an assistant professor of Environment and Sustainability at the University at Buffalo. She is an interdisciplinary social scientist who works across rural sociology, human geography, and science and technology studies to understand the social and environmental dimensions of emerging technologies. Previously, Dr. Buck was a NatureNet Science Fellow at UCLA's Institute of the Environment and Sustainability, and an Emmett Climate Engineering Fellow at the UCLA School of Law, with research focusing on the governance of climate engineering (2017-2020). Her Ph.D. (Development Sociology, Cornell University, 2017) focused on public engagement with emerging environmental technologies, with chapters on carbon removal, solar geoengineering, and emerging "blue revolution" marine technologies. She was also an NSF IGERT Fellow in Food Systems and Poverty Reduction during her PhD, and she maintains an interest in interdisciplinary work on food systems. Dr. Buck is currently a contributing author to an IPCC chapter on cross-sectoral governance, which includes reviewing literature on food systems governance as well as carbon dioxide removal governance. Her recent and current research involves the social dimensions of technologies to remove carbon from the atmosphere. Lead-authored or sole-authored publications have focused on the linkages between adaptation and carbon removal (One Earth), social barriers to rapid scale-up of CDR (Climatic Change), the politics of negative emissions in rural communities (Global Sustainability), the challenges and opportunities of BECCS for communities (Current Sustainable/Renewable Energy Reports), and the implications of treating carbon removal as waste management (Interface Focus). Specific to marine carbon removal, Dr. Buck has authored a book chapter on an ocean fertilization event off the coast of Haida Gwaii, based on stakeholder interviews she conducted in Haida Gwaii and Vancouver in 2013. Her book After Geoengineering (2019) also discusses marine bioenergy with CCS, and draws on interviews with people working in the field. She also has experience with public engagement on solar climate intervention strategies, and presented some of this research to a NAS committee on solar climate intervention at a meeting at Stanford in 2019, as part of that committee's information gathering process. Dr. Buck's work relating to climate intervention more broadly has focused on themes like the governance of stopgap measures (Nature Sustainability), public engagement in research (Geoforum), and possible harms to ocean life (chapter in edited volume Blue Legalities: The Life and Laws of the Sea).

## Ken Buesseler

**Member**

Ken Buesseler is a marine radiochemist and member of the Ocean Twilight Zone Project at the Woods Hole Oceanographic Institution (WHOI). He is best known for work using natural and manmade isotopes in the ocean to study processes such as the movement of carbon and iron from the surface to deep ocean, as well as studies of the fate and transport of radioactive contaminants in the ocean. Dr. Buesseler participated in two ocean iron fertilization (OIF) experiments, leading one of three research vessels during the last major US OIF experiment off Antarctica. In 2009 he was elected Fellow of the American Geophysical Union; in 2013 selected as foreign member of the Dutch Academy of Sciences; and in 2018, elected as a Fellow of the American Association for the Advancement of Science. He is author on more than 175 research publications with 10 papers focused on OIF. In 2011 he was noted as the top cited ocean scientist by the Times Higher Education for the decade 2000-2010. Dr. Buesseler received his PhD from Massachusetts Institute of Technology and Woods Hole Oceanographic Institute in 1986.

## M. Debora Iglesias-Rodriguez

**Member**

M. Debora Iglesias-Rodriguez is professor of biological oceanography and vice-chair of the Department of Ecology, Evolution, and Marine Biology at the University of California, Santa Barbara. Debora has worked for twenty years on diversity and function in marine phytoplankton combining molecular approaches, carbon physiology and biogeochemistry in the lab and in the field. She has broad interest in mechanisms controlling diversity and function in marine biota and the effect of ocean acidification (OA) on marine plankton. She has contributed to several white papers on OA, was a speaker at the 2011 IPCC workshop on OA, and one of her papers (Science 320: 336-340) was identified by Thomson Reuters as “fast breaking paper” and at the top 0.01 most cited papers in Geoscience in 2008. Dr. Iglesias-Rodriguez has a B.Sc. in Biology & Biochemistry (University of Santiago de Compostela, Spain) and a PhD (1996) on carbon utilization in phytoplankton (Swansea University, U.K.).

## Kathryn Moran

**Member**

Kathryn Moran joined the University of Victoria in September 2011 as a Professor in the Faculty of Sciences and as Director of NEPTUNE Canada. In 2012, she was promoted to the position of President & CEO, Ocean Networks Canada. Since then, she has led and grown the organization following the vision of enhancing life on Earth by providing knowledge and leadership that deliver solutions to science, society, and industry. Dr. Moran's interests include topics related to the Arctic, ocean drilling, ocean observing, and climate change including ocean carbon sequestration methods and offshore renewable energy. She previously served on three National Academies committees: the Committee on Emerging Research Questions in the Arctic; the Gulf Research Program Advisory Board; and the Standing Committee on Understanding Gulf Ocean Systems. Dr. Moran holds degrees in marine science and engineering from the University of Pittsburgh, the University of Rhode Island and Dalhousie University.

## Andreas Oschlies

**Member**

Andreas Oschlies is Professor of Marine Biogeochemical Modelling at GEOMAR and the University of Kiel, Germany. His research interests include the global carbon, nitrogen and oxygen cycles, their sensitivities to environmental change, and the development and quality assessment of numerical models appropriate to investigate these. He was head of the Collaborative Research Centre "Climate-Biogeochemistry Interactions in the Tropical Ocean" (SFB754) running from 2008 to 2019, is funding member of the Global Ocean Oxygen Network (GO2NE), member of the GESAMP Working Group 41 on Marine Geoengineering, and currently leads the Priority Program "Climate Engineering: Risks, Challenges, Opportunities?" (SPP1689) funded by the German Research Foundation. He has contributed to a number of assessment reports, such as "Large-Scale Intentional Interventions into the Climate System? Assessing the Climate Engineering Debate" for the German Ministry of Education and Research (2011), "The European Transdisciplinary Assessment of Climate Engineering (EuTRACE)" for the European Commission (2015), the GESAMP "High level review of a wide range of proposed marine geoengineering techniques" (2019), and the IPCC Special Report on the Oceans and the Cryosphere (2019). Dr. Oschilies studied Theoretical Physics at Heidelberg and Cambridge (P.Phil., 1990) and received his PhD in Oceanography from the University of Kiel (1994).

## Phil Renforth

**Member**

Phil Renforth is an Associate Professor for the School of Engineering & Physical Sciences, Institute of Mechanical, Process & Energy Engineering at Heriot-Watt University, Riccarton, UK. He is an engineer and geochemist interested in understanding how reacting carbon dioxide with rocks and minerals may be able to help prevent climate change. His research expertise and interests include enhanced weathering, negative emission technologies and alkaline waste and is also interested in understanding geochemical carbon sequestration in the ocean by increasing ocean alkalinity. Dr. Renforth serves on the Scientific Committee for the international conference on negative CO2 emissions, the Geological Society's Engineering Geology Committee, Scientific Council for the UK Carbon Capture and Storage Research Centre, and on several editorial boards. He presented to the National Academies Committee on Developing a Research Agenda for Carbon Dioxide Removal and Reliable Sequestration. Dr. Renforth earned his PhD in geo-environmental engineering from the University of Newcastle-upon-Tyne (2011).

## Joe Roman

**Member**

Joe Roman is a Fellow in conservation biology and marine ecology at the Gund Institute for Environment, University of Vermont. His research focuses on the ecological functions and services provided by whales and other marine mammals. His team's work shows that great whales, the largest animals ever to have lived, play important ecological roles in the ocean—from enhancing primary productivity to providing habitat for more that 80 endemic species when their carcasses sink to the deep sea. Dr. Roman is dedicated to science policy, scientific diplomacy, teaching, and research. He received his AB from Harvard College in Visual and Environmental Studies (1985), his MS from the University of Florida in Wildlife Ecology and Conservation (1999), and his PhD in Organismic and Evolutionary Biology from Harvard University (2003).

## Gaurav N. Sant

**Member**

Gaurav N. Sant is a Professor and a Henry Samueli Fellow at the University of California, Los Angeles with appointments in the Departments of Civil and Environmental Engineering and Materials Science and Engineering, and a Member of the California Nanosystems Institute and the Director of the Institute for Carbon Management. Dr. Sant's research interests include interfacial solid-liquid, solid-vapor, and solid-liquid-vapor reactions including dissolution, precipitation, and electrochemical corrosion with applications to (i) cement, concrete, porous media, (ii) hard biological tissues, (iii) metals and alloys, (iv) natural and synthetic minerals, and (v) glasses. In his research, special focus is placed on decarbonizing construction, the development of carbon mitigation technologies and promoting manufacturing disruptions in entrenched heavy-industry sectors. In 2016, Dr. Sant was selected as one of UCLA's Optimists and participated on a National Academies study, "Gaseous Carbon Waste Streams Utilization: Status and Research Needs." Dr. Sant received his Ph.D. in Civil Engineering from Purdue University in 2009.

## David A. Siegel

**Member**

David A. Siegel is presently a Distinguished Professor in the Department of Geography and Chair of the Interdepartmental Graduate Program in Marine Science at the University of California, Santa Barbara. His research focuses on aquatic ecosystems and their functioning on local to global scales. He has worked extensively in marine bio-optics, satellite ocean color remote sensing and oceanographic observations and numerical modeling for a wide range of problems from assessing marine biodiversity, quantifying the ocean's biological carbon pump, measuring and modeling Giant Kelp spatial population dynamics, and understanding the efficacy of nearshore fisheries management scenarios. Dr. Siegel has served as a member of the National Academies Committee on Assessing Requirements for Sustained Ocean Color Research and Operations (2011), and most recently was a member on the Ecosystems Panel of the National Academies 2018 Committee on the Decadal Survey for Earth Science and Applications from Space. He is a fellow of both the American Geophysical Union and the American Association for the Advancement of Science. Dr. Siegel received a B.A. in Chemistry and a B.S. in Engineering Sciences from University of California, San Diego (1982) and M.S. and Ph.D. degrees in Geological Sciences from the University of Southern California (1986 & 1988).

## Romany Webb

**Member**

Romany Webb is an Associate Research Scholar at Columbia Law School and Senior Fellow at the Sabin Center for Climate Change Law. Her research focuses on climate change mitigation, exploring how legal and policy tools can be used to drive reductions in greenhouse gas emissions, and support efforts to remove greenhouse gas from the atmosphere. Much of Ms. Webb's work centers on legal issues associated with the use of oceans for carbon dioxide removal and storage. She is a member of the Pacific Institute for Climate Solutions' "Solid Carbon" research study, which is assessing the feasibility of removing carbon dioxide from the ambient air using direct air capture facilities located on offshore platforms, and injecting the captured carbon dioxide into sub-seabed basalt rock formations. Ms. Webb received an LL.M., with a certificate of specialization in environmental law, from the University of California, Berkeley in 2013. She also holds an LL.B., awarded with first class honors, from the University of New South Wales (Australia).

## Angelicque White

**Member**

Angelicque White is an Associate Professor in the School of Ocean and Earth Science and Technology at the University of Hawaii. Her primary research interests involve understanding how specific organisms acquire the elements necessary for growth and how different nutrient sources impact primary productivity and particle export. She is also working on the development of stochastic, optimization models which can allow for more realistic simulations of the taxonomic and biogeochemical diversity of the phytoplankton community in the upper water column of the North Pacific. Dr. White received her BS and MS in Biology (in 1998 and 2001 respectively) from the University of Alabama in Huntsville and her PhD in Biological Oceanography form Oregon State University (2006).