

A photograph of an offshore wind farm at sunset. The sun is low on the horizon, casting a warm, golden glow over the water and the sky. Several wind turbines are visible, their white towers and three-bladed rotors standing out against the colorful sky. The water is dark with some ripples. The overall mood is serene and hopeful, representing clean energy.

CROSSWINDS

THE FUTURE OF WIND

THE HIDDEN OCEAN COST OF CARBON

The study finds
that ocean-
related damages
are unevenly
distributed
across regions.
(Courtesy:
Shutterstock)

By adding in the potential damage to the Earth's ocean ecosystem, climate damage may be nearly twice as high as was once thought.

By EURO-MEDITERRANEAN CENTER ON CLIMATE CHANGE

An international study, featuring CMCC scientists, reveals that the true economic damage of climate change has been vastly underestimated — because the ocean has been left out of the equation. By integrating the latest ocean science into climate-economic models, researchers found that accounting for climate impacts on marine ecosystems and ocean-dependent infrastructure nearly doubles the social cost of carbon. The hidden ocean cost is estimated at \$48 per metric ton of CO₂, a figure that should be added to current policy calculations.

The social cost of carbon — the monetary value that climate economists associate with the damage caused by emitting each additional metric ton of CO₂ — has, to date, guided climate policy, carbon pricing, and cost-benefit analyses around the world. But there has been a major blind spot: the ocean.

IMPACTS ON MARINE ECOSYSTEMS

A new paper involving CMCC scientists Francesco Granello, Johannes Emmerling, and Massimo Tavoni shows that when the impacts of climate change on marine ecosystems and ocean-dependent economic activities are properly accounted for, the cost of carbon causing climate change rises dramatically.

Using the latest ocean science and economic modeling, the study introduces the concept of “ocean-based social cost of carbon,” or blue SCC, capturing climate damages to coral reefs, mangroves, fisheries, and global seaports.

The researchers estimate the blue social cost of carbon at \$48 per metric ton of CO₂, a figure that should be added to existing estimates of the social cost of carbon. This estimate is based on a standard “business as usual” scenario, in which no additional climate policies are implemented and climate change continues along its current trajectory. When compared with the values used in policy frameworks across countries, the results show that accounting for ocean impacts nearly doubles the social cost of carbon.

“The social cost of carbon puts a monetary value on the damage caused by emitting one additional (metric ton) of CO₂, making it a practical tool for cost-benefit analysis and for informing carbon pricing.”

Emmerling said. “Because CO₂ stays in the atmosphere for centuries, each (metric) ton has long-lasting impacts on societies worldwide. Existing estimates already account for effects such as mortality, health, biodiversity loss, and economic damages, but until now they have largely overlooked the ocean.

Our work focuses on quantifying that missing ocean component, which matters because the ocean covers most of the planet and, although its links to society are often indirect, they are highly relevant and have significant economic and welfare consequences.”

WHY THE OCEAN MATTERS

The ocean covers more than 70 percent of the Earth's surface and supports a wide range of economic and social benefits, from food supply and trade to coastal protection, health, and cultural value. Yet, its role has largely been absent from the climate-economy models that underpin carbon pricing and policy decisions.

The study brings together a rich literature of biophysical and economic studies into a single integrated framework, translating physical climate impacts into monetary welfare losses. This includes not only market impacts, such as reduced fisheries productivity or port disruptions, but also non-market values such as nutrition, health, biodiversity, and recreational values.

One of the most significant findings is that health impacts linked to fisheries account for nearly half of the ocean-related climate damages. In many countries, especially lower-income and island states, fish are a crucial source of protein and micronutrients. Climate-driven declines in fish stocks translate directly into higher mortality and poorer health outcomes — high-cost impacts that are rarely visible in traditional economic assessments.

Coral reefs emerge as another major driver of losses. Highly sensitive to temperature and ocean acidification, reefs provide ecosystem services worth hundreds of thousands — and in some cases millions — of dollars per hectare, from tourism and fisheries to coastal protection and biodiversity.

A STARK REMINDER OF THE IMPORTANCE OF CLIMATE POLICY

The study finds that ocean-related damages are unevenly distributed across regions. Countries with high dependence on marine ecosystems for food, tourism, and transport — including many lower-income countries and small island developing states — face disproportionately large welfare losses. In some economies, ocean damages account for 20 to 30 percent of total climate-related welfare losses, significantly amplifying existing inequalities.

By omitting ocean impacts, current estimates of the social cost of carbon — and therefore optimal carbon prices — are systematically too low. For comparison, carbon prices in major markets such as the EU currently hover around 70 to 80 euros per metric ton, well below the levels implied when ocean damages are included.

The findings suggest that fully accounting for ocean impacts could justify significantly higher carbon prices, strengthening the economic case for faster emissions reductions.

“What this study shows is that nature supports human well-being in fundamentally different ways, and a shifting climate threatens many of these contributions,” Granello



According to a study, the ocean has been a major blind spot in calculating the social cost of carbon. (Courtesy: Shutterstock)



One of the main takeaways from the study is that it really is important to take into account all different aspects of climate change. (Courtesy: Shutterstock)

said. “The ocean provides direct economic benefits like seafood and shipping, but it also sustains us through services that hardly appear in market transactions, such as coastal protection from mangroves, nutrients critical for human health, and the intrinsic value people place on knowing that marine ecosystems exist and that they will still be there for future generations. We need to recognize that all these contributions are highly valuable to human welfare. Losing a coral reef or a mangrove forest isn’t just an environmental loss, it’s a loss to human wellbeing that can’t be easily compensated for with money or manufactured alternatives.”

“One of the main takeaways from this study is that it really is important to take into account all different aspects of climate change,” Emmerling said. “It has effects on many things, a lot of which are still unrepresented — at least in economic modeling, and it can have a huge impact on so-

cieties and the economy. These damages are also highly unequal: Poorer and more vulnerable regions, particularly small island states, depend heavily on ocean ecosystems for livelihoods, food, and income. Damaging the oceans therefore risks deepening existing inequalities and increasing poverty.”

“The paper shows the importance of marine ecosystems for societal well-being and for the evaluation of the true cost of climate change damage,” said Tavoni, CMCC’s principal scientist and director of CMCC’s European Institute on Economics and the Environment. “The standard accounting of the socio-economic costs of climate change has ignored nature. In this and previous work published in *Nature* with the same collaborators, we have deepened our understanding of the fragility of ecosystems, and their consequences for humanity.”

The study was funded through the Scripps Institutional Postdoctoral Fellowship. Additional study authors include Octavio Aburto-Oropeza from Scripps Oceanography; Luke Brander from Leibniz University; William W. Cheung from the University of British Columbia; Chris M. Free from UC Santa Barbara; and Jasper Verschuur from the University of Oxford. ✎

ABOUT CMCC

The Euro-Mediterranean Center on Climate Change (CMCC) is a leading research institution dedicated to climate science, providing cutting-edge insights and innovative solutions for climate adaptation and mitigation strategies. CMCC plays a pivotal role in global climate research, working closely with international partners to advance climate modeling, forecasting, and policy recommendations. Read the full paper at www.nature.com/articles/s41558-025-02533-5.