



**ECONOMIST  
IMPACT**

**Checking in on ocean-  
based climate solutions:  
Where we are and  
where we need to be**

COMMISSIONED BY

  
**Pacific  
Northwest**  
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# About the research and acknowledgements

*Checking in on ocean-based climate solutions: Where we are and where we need to be* is an article from Economist Impact's World Ocean Initiative, commissioned by Pacific Northwest National Laboratory (a US Department of Energy National Laboratory). Using desk research, a literature review and expert interviews, high-level thinking on ocean-based solutions for climate change is synthesised with an eye towards global impact, but a strong focus on US issues and perspectives. This is the first in a three-article series on ocean-centered climate change mitigation and adaptation.

We would like to thank the following experts for their time and insights:

- **Michael Conathan**, senior policy fellow, ocean and climate, Aspen Institute's Energy & Environment Program
- **Craig Dudenhoeffer**, chief innovation officer and co-founder of the Ocean Solutions Accelerator, Sustainable Ocean Alliance
- **Lee Kindberg**, head of environment and sustainability, North America, Maersk Line
- **Jason Scorse**, associate professor and chair; International Environmental Policy program, director, Center for the Blue Economy, Middlebury Institute of International Studies
- **Jyotika Virmani**, executive director, Schmidt Ocean Institute
- **Doreen Wong**, entrepreneurship lead, Sustainable Ocean Alliance

# Executive summary

The potential of the ocean for accelerating decarbonisation merits prioritisation in the global climate-change discourse. The ocean presents substantial climate mitigation and carbon storage options to help limit global warming, while simultaneously introducing opportunities for economic gain.

A wide variety of stakeholders, including businesses, academics, policymakers, multilateral groups and non-governmental organisations, are working to further develop and define ocean-based climate solutions. This report captures key narratives around such solutions through four sector-specific categories: clean energy; transport; food systems; and carbon dioxide removal and storage.

**Ocean-based, clean energy technologies hold the greatest emissions potential of all ocean-based climate solutions, and energy solutions are often interwoven into other solutions.**

Offshore wind has the highest potential for impact, with a theoretical capacity of 18 times today's global electricity demand. Alternate technologies for energy production, such as wave and tidal stream power, and those linked to other aspects of the decarbonisation supply chain, such as seawater mining and ocean-based biofuel production are still in earlier development phases. However, each holds long-term potential with increased research, design development and demonstration (RDD&D) support.

**The shipping sector has introduced ambitious carbon reduction goals, but technologies to achieve these targets are not yet mature.**

Current goals would see the international shipping sector reducing emissions—currently accounting for about 2.9% of total emissions—by at least 50% by 2050. In the long term, technologies such as low- or zero-carbon fuels, and wind-powered ships can reduce carbon emissions, but these solutions require further development and will necessitate large-scale infrastructure overhauls.

**Sustainable fisheries and aquaculture offer carbon-friendlier substitutes for terrestrial proteins.**

Switching to seafood proteins from land-based sources can help reduce greenhouse gas emissions substantially. In order to maximize these benefits, sustainable aquaculture operations will need to grow significantly as global fishing stocks are at capacity, and both aquaculture and wild-catch operations will need to be further decarbonised.

**The capacity of the ocean to absorb carbon could be enhanced through restoration, protection and engineering of marine and coastal habitats (known as blue carbon), as well as through more “technical” solutions.**

The ocean already absorbs approximately 25–30% of global CO<sub>2</sub> emissions, though this has contributed to ocean acidification. Protecting and restoring mangroves, salt marshes, seagrass and seaweed can maintain and support the

ocean's role in carbon sequestration. A variety of options that could have larger and more disruptive impacts on the ocean environment are also being developed, such as ocean alkalisation and electrochemical removal of carbon. Further testing and assessment of carbon dioxide removal solutions need to be accelerated, both to limit the potential harm, but also to understand how worthwhile investments will be as the world seeks methods of rapid decarbonisation.

**Unlocking the decarbonisation and concurrent economic potential of the ocean will require sufficient investment and support to overcome tremendous logistical and technical challenges.** Given that the ocean comprises 70% of the planet and holds enormous opportunities for addressing climate change, these challenges should be seen as opportunities for productive

action rather than as barriers. According to one estimate, each dollar invested in the sustainable ocean economy will yield at least five dollars in return, and the OECD forecasts that ocean-based solutions could create US\$3trn in additional revenue and cost savings in 2030. Tens or hundreds of billions of dollars of investment will be required to tap into the potential of the ocean for climate change mitigation and economic growth. Ongoing blue finance innovation must continue in order to enable these investments. Coordination is key. Further effort is needed to improve data collection and management, which facilitate the full lifecycle of ocean solutions. Global standards must be harmonized in order to set common measures and benchmarks. Improved stakeholder alignment would help clarify the policy agenda. RDD&D will be crucial for accelerating the development of solutions.

**Ocean-centered decarbonisation and climate change mitigation**

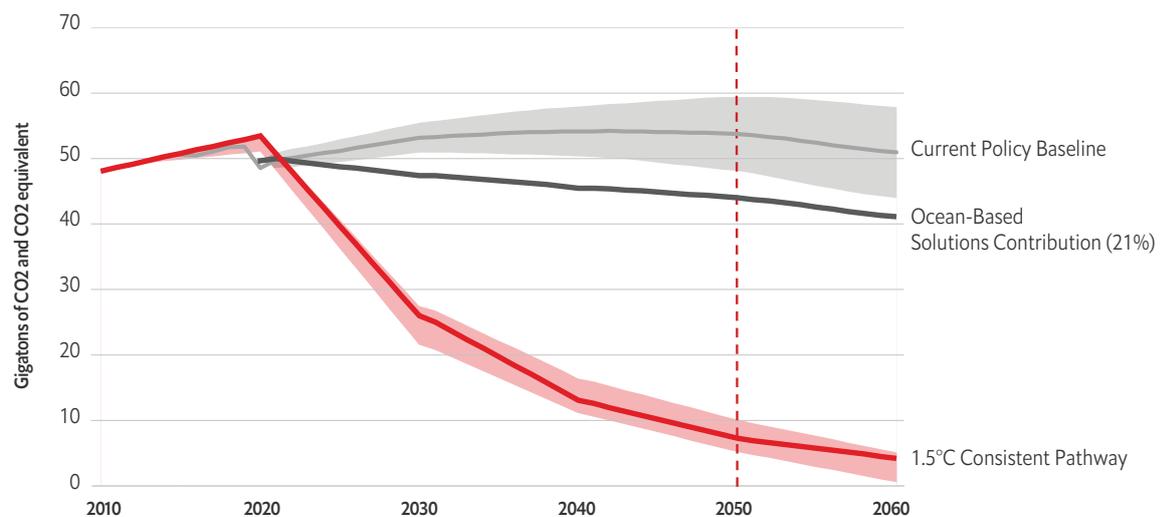
It has become widely accepted that global warming over 1.5°C presents massive climate-related risks to natural and human systems. 52 gigatons of CO<sub>2</sub> and CO<sub>2</sub> equivalent (CO<sub>2</sub>e) greenhouse gases (GHGs) were released into the atmosphere in 2020, and that number could rise up to 59 gigatons of CO<sub>2</sub> by 2050 if current policies continue.<sup>1</sup> This would leave an estimated annual gap of 52 gigatons of CO<sub>2</sub> and CO<sub>2</sub>e that must be closed globally by 2050 in order to meet the 1.5°C goal, or 41 gigatons even in the best case under current policies (see Figure 1).<sup>2</sup> To put this into context, one gigaton of emissions is equivalent to driving around the globe nearly 100 million times in an average car.<sup>3</sup> Reductions at this scale represent an enormous challenge: calls continue to increase for public, private and third-sector stakeholders around the world to take immediate, concerted action to mitigate GHG emissions and meet existing commitments through frameworks such as the Paris Agreement. There is no single solution that will

meet global emissions reductions targets; a range of options must be considered and pursued.

The ocean plays a critical role in the global climate system. Not only does the ocean take in an estimated 93% of the heat trapped by rising GHG levels, it also absorbs approximately 25-30% of anthropogenic CO<sub>2</sub> emissions while producing about half of the earth’s oxygen through the photosynthetic activity of marine plants and algae.<sup>4</sup> The risks to our ocean and coastlines from climate change are well publicised, including potentially catastrophic sea-level rise impacting many millions of people around the world,<sup>5</sup> continued acidification decimating marine life, and disruption of the ocean’s temperature gradient and typical flow patterns that could have enormous world-wide impacts on weather systems.<sup>6</sup>

The potential of the ocean for accelerating decarbonisation, however, merits increased priority in the global climate-change discourse. The High-Level Panel for a Sustainable Ocean

**Figure 1: The potential contribution of ocean-based solutions for decarbonisation**



Sources: Climate Action Tracker; High Level Panel for a Sustainable Ocean Economy

Economy (HLP), a multilateral group comprising representatives from 14 oceanic countries, estimates that by 2050 ocean-based climate mitigation and carbon storage options could make up 21% of the emissions reductions needed to limit global warming to 1.5°C.<sup>7</sup> Put differently, this equates to more than all current global emissions from coal-fired power plants worldwide.

On top of the climate benefits, these efforts could generate sizable economic gains. The ocean produced an estimated US\$2.5tn in global goods and services in 2015.<sup>8</sup> US Bureau of Economic Analysis figures suggest that in 2019 US\$397bn of America's GDP was already tied to ocean and coastal economic activity,<sup>9</sup> with 4.2% real GDP growth of the marine economy that year.<sup>10</sup> Many of the most promising ocean-based solutions for decarbonisation dovetail with sectors poised for growth. Global estimates predict that ocean-based industries could create US\$3trn of additional annual revenues or cost savings in 2030, with marine aquaculture, marine fish processing, offshore wind and port activities—all of which are burgeoning sectors for decarbonisation—included among those with the greatest potential to outperform the global economy.<sup>11</sup> The HLP estimates that each dollar invested in the sustainable ocean economy, also known as the “blue economy”, will yield at least five dollars of return.<sup>12</sup>

**“What we want to see is a myriad of solutions. Unfortunately, there isn't going to be a silver bullet. We will need thousands of solutions, and we're going to need increased collaboration.”**

Craig Dudenhoeffer, chief innovation officer and co-founder of the Ocean Solutions Accelerator, Sustainable Ocean Alliance

## Ocean-based solutions

There are a wide variety of stakeholders, each with their own overlapping objectives, working to develop ocean-based climate solutions. All of these actors have something to contribute. As Craig Dudenhoeffer, chief innovation officer at the Sustainable Ocean Alliance, suggests, “what we want to see is a myriad of solutions. Unfortunately, there isn't going to be a silver bullet. We will need thousands of solutions, and we're going to need increased collaboration.”

Academics, policymakers, multilateral groups and non-government organisations (NGOs), among others, are deliberating on which of these approaches—current, emerging and potential—matter for realising the environmental and economic potential of the ocean.

A number of groups have produced summary reports or policy agendas on these issues, such as the aforementioned HLP;<sup>13</sup> the Ocean Initiative;<sup>14</sup> the Middlebury Institute's Ocean Climate Action Initiative;<sup>15</sup> the OECD;<sup>16</sup> and the World Resources Institute, with NGO partners.<sup>17</sup> Many of these include taxonomies aimed at assessing solutions; clarifying them for decision-makers; and encouraging unified workstreams through the coordination of activities such as research and funding.<sup>18</sup> Solutions frequently do not fall neatly into a single bucket, as they are deeply enmeshed. This is particularly true of approaches to clean energy, which are necessarily interwoven throughout the other categories due to the central role of energy in carbon emissions and decarbonisation.<sup>19</sup> However, distilling these taxonomies, ocean-based solutions can be broadly classified into four categories: clean energy; transport; food systems; and carbon dioxide removal and storage (including so-called blue carbon). Each of these already offer both solutions with demonstrable return on investment (see Figure 2) and solutions that will require more development.



**Clean energy**

The ocean offers plentiful renewable energy, through offshore wind, marine energy—including tidal energy, wave energy, ocean thermal energy conversion and salinity gradient energy<sup>20</sup>—and floating solar.<sup>21</sup>

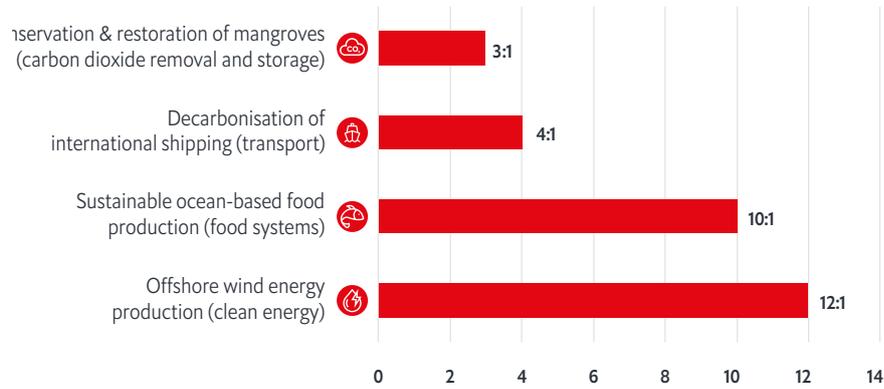
Energy production technologies hold the greatest emissions mitigation potential of all ocean-based climate solutions. Offshore wind is the most technologically mature. Although it only provided 0.3% of the global electricity supply in 2018,<sup>22</sup> it holds enormous total potential capacity—with a theoretical (if not practical) power-generating capacity of more than 18 times global electricity demand today. Dr Jason Scorse, director of the Middlebury Institute of International Studies Center for the Blue Economy, explains that, “by the numbers, the single most important ocean-based climate solution is offshore wind.” While there is a wide range in estimated impact,

under optimal deployment timelines, the HLP estimates that replacing coal energy with offshore wind energy could reduce emissions by up to 3.5 gigatons of CO<sub>2</sub> and CO<sub>2</sub>e annually before 2050.<sup>23</sup> Assessments of employment outcomes from offshore wind also vary widely, but sources generally agree it would serve as a large net creator of jobs.<sup>24</sup> The US, however, currently has only one operational offshore wind farm, although more are in development.<sup>25</sup> The total theoretical untapped potential of all marine energy sources is massive as well, equivalent to nearly two times current global energy usage even in the base case, and over four times in the best case.<sup>26</sup> Despite this potential, these technologies are far from mature, with only 65MW of wave and tidal stream power deployed globally as of 2020,<sup>27</sup> equivalent to roughly .006% of US utility-scale electrical generating capacity.<sup>28</sup>

Other technologies are being developed to use the ocean not just as a source of power, but also for the minerals and fuels needed to facilitate the green energy revolution. Deep-sea mining—particularly of the cobalt, nickel, manganese and other minerals needed for green-energy technologies such as batteries—is one of the most heavily debated



**Figure 2: Estimated benefit-cost ratios of select ocean solutions**



Source: High Level Panel for a Sustainable Ocean Economy

ocean-based solutions for decarbonisation.<sup>29</sup> Advocates for deep seabed mining claim that the benefits for the clean-energy transition, as well as reducing exploitative mining operations in locations such as the Democratic Republic of the Congo, outweigh potential costs. Detractors argue that the environmental and social harm will be too great, especially given the potential for biodiversity loss that could also impact fields such as biomedical research,<sup>30</sup> and suggest that at the very least more research is needed. Seawater mining technology, still in early development, offers a potential alternative that is likely to incur lower environmental costs.<sup>31</sup> Finally, there are ongoing efforts to develop the ocean as a source of sustainable fuels for both maritime and terrestrial use, including through algae-derived biofuel projects and seawater hydrogen extraction, but these remain at early technology readiness levels.<sup>32</sup>



**Transport**

The total GHG emissions of shipping is steadily increasing, accounting for about 2.9% of global

GHG emissions as of 2018.<sup>33</sup> Other forms of marine transport—such as cruise ships, with an estimated 0.2% of global emissions<sup>34</sup>—contribute less, but meaningfully, to this total. With system-wide changes to the way ships store and consume energy, as well as the infrastructure of global marine transport, totally eliminating net GHG emissions from this sector is achievable. The International Maritime Organization, the multilateral group responsible for coordinating shipping regulations, has set a goal of reducing CO2 emissions in international shipping by at least 50% by 2050.<sup>35</sup> This target remains far off and many solutions are still in the R&D stage or lack adoption at scale. However, solutions include batteries to store electricity; low- or zero-carbon fuels as replacements for fossil and bunker fuels (including renewable hydrogen, hydrogen-based fuels such as ammonia and methanol); wind-power for ships and nuclear power.<sup>36</sup> A range of multinational companies have committed to zero-carbon shipping fuels, adding additional incentive for the shipping industry to decarbonise.<sup>37</sup>

The infrastructure required to enable these solutions for longer-term success includes provision of ship, shore-side and on-shore power supply through renewable sources; development of the full supply chain needed to utilise alternative fuels (from production through

to bunkering and use); and optimising ports to support carbon friendly activities.<sup>38</sup> In the short run, lowering fuel consumption through efficiency gains—such as those from better technologies—or through slower transit times, and switching to comparably low-emissions fuels like liquefied natural gas could help set the industry on the course towards decarbonisation. Production of low and zero-carbon fuels at the scale and price-point required for successful maritime decarbonisation implementation will also rely in part on enormous upscaling of renewable energy generation.<sup>39</sup> Having this power come from ocean-based sources could be advantageous if there is proximity to port facilities and refuelling stations.



**Food systems**

Rethinking and reworking our relationships with marine food sources can reduce carbon emissions. Sustainable fisheries, regenerative

aquaculture and increasing the share of ocean-based proteins in global diets are some of the key relevant solutions in this space. Of those solutions, shifting diets from terrestrial to seafood proteins (should fully plant-based options be off the table) has the largest capacity to reduce GHG emissions, mitigating 0.30-1.06 gigatons of CO2 per year by 2050 by decreasing demand for terrestrial land-based proteins.<sup>40</sup> There are additive economic benefits; NOAA estimates that fishing created 1.74 million jobs in the US and US\$244.1bn in sales in 2017.<sup>41</sup>

Globally, growth in fish consumption has outpaced that of other animal proteins.<sup>42</sup> Cultural barriers, however, currently limit this option in many high-income countries, where eating fish decreased per-person between 2007 and 2017. As Michael Conathan of the Aspen Institute notes, “Americans just don’t eat a lot of seafood, so in order to make it a significant contributor to food-based carbon drawdown, we have to change our culture, and that’s a longer-term play.” Furthermore, advocates suggest the sustainability of both wild-catch and aquaculture (cultivation of aquatic organisms) operations



will need to greatly increase, else we risk additional damage to habitats and biodiversity on top of the extensive damage that global overfishing has already wrought.<sup>43</sup> As nearly 95% of global marine fish stocks are already at capacity or overfished, according to the Food and Agricultural Organization of the United Nations,<sup>44</sup> long-term shifts towards sustainable aquaculture are merited. Nonetheless, there are significant opportunities for both aquaculture and wild-catch operations to decarbonize.

For aquaculture, the global supply of fish meal—used as feed in many of these operations—may be near biological limits. Large-scale sustainable alternatives must continue to be developed and adopted in order to reduce GHG emissions and support the sustainable expansion of global aquaculture operations.<sup>45</sup> Aquaculture operations have also traditionally been energy hungry, for hatchery operations but also for feed and chemical production. (Not to mention they have been a frequent vector of fish disease.)<sup>46</sup> Fish processing is energy intensive, too. Decarbonising the sector will require accounting for and reducing emissions throughout the supply chain for both aquaculture and wild-catch operations. When it comes to wild-catch fisheries, and tied to transport solutions, much of current emissions are produced by global fishing fleets. Shifting to clean propulsion systems could reduce current emissions by half. As with transport solutions more broadly though, R&D and adoption hurdles remain.<sup>47</sup>



### Carbon dioxide removal and storage

A range of solutions for taking advantage of our ocean and coastlines' ability to store carbon are being pursued. Some involve the protection, restoration and sometimes engineering of marine

and coastal ecosystems such as mangroves, salt marshes, seagrass and seaweed. These are often collectively referred to as blue carbon, and offer a number of climate-change mitigation benefits.<sup>48</sup> Some analysts predict that restoring coastal wetlands, for example, could offer 14% of the mitigation potential for holding global temperatures from going above 2°C those of the preindustrial period, given the high carbon stocks per hectare.<sup>49</sup> There's an enhanced urgency to conserve ecosystems because their degradation emits carbon back into the atmosphere. Supporters of blue carbon projects also point to jobs they say will be created for those who engage in such efforts, as well as the potential of blue carbon for offset markets (where emitters pay for sequestration).<sup>50</sup> These solutions have the added benefit of improving climate change adaptation (preparing for climate change and its impacts) through enhanced resiliency and biodiversity support.<sup>51</sup> Experts interviewed for this article, however, noted significant remaining uncertainties about the true gains for carbon drawdown and sequestration.<sup>52</sup>

In addition to "natural" solutions for carbon capture, a range of more outwardly interventionist "technical" options are being explored by scientists and entrepreneurs. However, in reality the line between the two remains fuzzy, as even approaches involving marine and coastal habitats could entail large and potentially disruptive interventions to ocean systems. These include options like storing carbon in liquid form on the seabed, increasing the alkalinity of the ocean through various proposed means in order to improve its carbon-storing capacity, as well as the electrochemical removal of carbon.<sup>53</sup> Such solutions also merit consideration of a range of international and domestic laws that dictate the use of marine and coastal environments.<sup>54</sup> Both "natural" and "technical" ocean carbon-dioxide removal solutions must be carefully analysed before implementation at scale, not only because there are large associated risks of additional harm,

but also because we still have a limited ability to measure, predict and model how worthwhile these investments will be.<sup>55</sup>

### **Unlocking the ocean's decarbonisation potential**

Accessing the decarbonisation and concurrent economic potential of the ocean will require sufficient investment and support to overcome tremendous logistical and technical challenges. Coordination is key, and ongoing effort is needed to improve data collection and management, harmonise global standards, improve stakeholder alignment, and support RDD&D (research, design, development and demonstration). First, improved data provide the foundation for ocean-based climate change solutions by facilitating implementation and assessing impacts. As NOAA points out in what has become an oft-repeated refrain, more than 80% of the ocean remains “unmapped, unexplored, and unobserved”.<sup>56</sup> Certain domains, such as ocean CO<sub>2</sub> measurements, already see highly standardised, coordinated and integrated data products, but this remains the exception rather than the rule.<sup>57</sup> Dr Jyotika Virmani, executive director of the Schmidt Ocean Institute—a non-profit focused on advancing oceanographic research and knowledge—extolls the potential of initiatives such as the Seabed 2030 project to map the ocean floor.<sup>58</sup> At the same time, Dr

Virmani calls for additional global data on our ocean, and greatly improved coordination and management of the vast amounts of new data currently being gathered.<sup>59</sup>

According to one estimate, we now gather as much ocean data in one year as in the previous century, but these data serve limited use without standardised management practices.<sup>60</sup> Groups such as the Ocean Data Platform have taken up the mantle of ocean data management and distribution,<sup>61</sup> but the work remains unfinished. Moreover, while calls for improved ocean data collection and management sometimes stop short of including socioeconomic data, “standardized methods of measuring and valuing ocean industries” are also critical for demonstrating the value of investing in our ocean to a broad array of stakeholders, as organisations such as the OECD and Ocean Conservancy stress.<sup>62</sup>

The coordination imperative extends beyond data: ongoing work is needed to continue to improve or establish international alignment on a number of ocean climate issues, ranging from the technical standards of ocean-based energy options, harmonised transport and emission standards, and investing metrics and frameworks. For example, in maritime transport, US public port standards currently do not match those of the International Association of Ports and Harbors Environmental Ship index programme for clean ships, causing confusion and a lack of meaningful

**“Potential balkanisation of standards is a real risk for causing complexity that detracts from getting things done.”**

Lee Kindberg, head of environment and sustainability, North America, Maersk Line

regulation.<sup>63</sup> Dr Lee Kindberg, the North American head of environment and sustainability for shipping company Maersk Line, reiterates the industry-wide need for a level playing field around the world, noting that “potential balkanisation of standards is a real risk for causing complexity that detracts from getting things done.”

On the investment side, standardisation and coordination would allow for increased inflows of funding to ocean solutions. The authors of the Blue New Deal recommend that the US join the International Platform on Sustainable Finance (an IMF and World Bank sponsored programme) and adopt the Sustainable Blue Economy Finance Principles—which establish standards to ensure that private money is channelled into activities that will support ocean sustainability and ocean-led decarbonisation.<sup>64</sup> Frameworks such as the UN Global Compact’s Sustainable Ocean Principles and the EU taxonomy for sustainable activities also offer guidance for organisations, including investors seeking sustainable practices within portfolio companies, on what constitutes sustainable activities in the ocean space.<sup>65</sup> To build an active dialogue on these issues and facilitate alignment, groups such as the Center for American Progress suggest that the US join with international partners to establish an ongoing ocean forum within the UN Framework Convention on Climate Change (UNFCCC).<sup>66</sup> In an open letter to UNFCCC’s Executive Secretary Patricia Espinosa ahead of the 26th UN Climate Change Conference of the Parties (or COP26)

Peter Thomson, the UN special envoy to the ocean reiterates this recommendation. He calls for closer integration of ocean issues in UNFCCC programmes for a “source to sea approach to management” that will “link governance, operations, practices and finance across marine, coastal, freshwater and terrestrial systems and stimulate cooperation between upstream and downstream actors.”<sup>67</sup>

For US advocates of ocean solutions, alignment, and common goal setting in particular, would also be advantageous. Experts cite diverging opinions among advocacy groups over any solutions perceived to hold potential for impacting natural systems, ranging from aquaculture operations to full-on “geoengineering”. Michael Conathan, senior policy fellow of ocean and climate at the Aspen Institute, warns that these disagreements risk “policy paralysis”, and issues a call to action. He implores the NGO community at large to, “figure out how to resolve and unify” in order to present common objectives because “politicians don’t know the issue well enough, and they want the environmental community to speak as a unified voice to instruct policy.” Continued effort is also needed to integrate coastal communities into the policy dialogue. This begins with properly assessing the impacts and tradeoffs for coastal communities, effectively communicating these impacts and tradeoffs, and ensuring there is broad buy-in, lest ocean-based solutions come to be viewed as doing more harm than good. Dr Scorse stresses this point, commenting that “in the next stage, there will be a focus on environmental and social justice. There is going to be a lot of attention on employment impacts, community development and equity.”

Proponents are clear that developing the blue economy and funding ocean-based climate solutions will require billions of dollars in investment—somewhere between the tens and hundreds of billions—and widespread policy support.<sup>68</sup> Recent studies indicate that of all the Sustainable Development Goals, ocean-based

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sustainability (SDG 14: Life Below Water) has received the least investment.<sup>69</sup> On the whole, the global financial system has not yet broadly recognised the ocean's capacity to provide value through climate-mitigating, sustainable development. This despite the growing body of evidence that investments into the blue economy can provide substantial return, and the increasing number of financial products and services focused on ocean sustainability (such as blue bonds, accelerator funds and ocean-related insurance).<sup>70</sup> As Dr Kindberg notes, "it's going to take a huge amount of capital. But the question is: what do we need to do as a society to make this happen?" Mr Dudenhoeffer echoes this refrain, remarking that "the oceans are disproportionately important in the climate conversation. Across the board, we need to see more innovation, which will happen if we are investing more in market-driven, scalable solutions."

One specific area where additional investment is needed is basic science and RDD&D to foster next-generation solutions and enable technology leaps, particularly in domains that require a significant amount of funding, testing and lead time, such as renewable energy and maritime decarbonisation efforts.<sup>71</sup> Many ocean solutions are still at low technology readiness levels. Cultivating seaweed for carbon dioxide removal and reduced ocean acidification requires further testing to understand ecosystem impacts and to lower operational costs.<sup>72</sup> There are currently no viable zero-carbon deep-sea vessel technologies to facilitate maritime decarbonization.<sup>73</sup> Even

in the more technologically advanced offshore wind space, improved capacity requires continued innovation in deep water and floating platform technologies.<sup>74</sup> In conjunction with the decarbonisation benefits to be gained from advancing these technologies, there will be vast economic opportunities for those who are able to bridge the "valley of death" from research and testing into sustainable market activity given the potential of ocean-based climate solutions.

Fostering innovation and helping firms reach market viability can be accelerated by strategic government investment and involvement. Mr Dudenhoeffer adds that "increasing collaboration, and creating communities where you have multiple players in the room allows for interdisciplinary cross pollination. That's where you see really cool innovations that have the potential to be large businesses and also realise the intended impact." An approach that has proved successful is through "blue tech" clusters that offer a platform to bring government, research, investment and industry groups together under one umbrella in support of integrated solutions.<sup>75</sup> Governments are scaling up investment in such clusters, including in the US.

While the hurdles that stand in the way of unlocking the ocean's potential for climate change mitigation pose formidable policy and investment challenges, "we have to remember that the ocean is 70% of the planet" Mr Conathan stresses. "It's a tremendous climate asset and there are huge opportunities that exist within it. It's not just a victim, and it has to be central to how we're moving forward on climate change issues."

**"The ocean is a tremendous climate asset and there are huge opportunities that exist within it. It's not just a victim, and it has to be central to how we're moving forward on climate change issues."**

Michael Conathan, senior policy fellow, ocean and climate, Aspen Institute's Energy & Environment Program

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