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Transformation

Ocean Tech: The Transformers

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Key takeaways

- The ocean covers 75% of the Earth's surface, contains 97% of its water, supports 80% of global trade volumes, and represents 99% of the living space on the planet by volume. It also generates over half of the world's oxygen. Yet, despite how critical the ocean is to both our existence and our transforming world, the opportunities it offers are too often overlooked.
- Bank of America Institute's three-part 'Ocean Tech' series explores ocean technologies through three lenses: Transformers, Explorers, and Savers - all focused on entry points that interrelate with the ocean.
- The first installment discusses 'Transformers' and includes ideas and technologies that have the potential to help us adapt to the ocean and unlock its resources. Here we explore everything from subsea cables and underwater data centers, to marine pharmacology and ocean real estate.

2.5 trillion reasons to dive into the sea

The ocean covers 75% of the Earth's surface, contains 97% of its water, supports 80% of global trade volumes, and represents 99% of the living space on the planet by volume. It also generates over half of the world's oxygen, serving as the planet's primary lungs.[1]

Yet, despite how critical the ocean is to both our existence and our transforming world, the opportunities it offers are too often overlooked. And while we are just scratching the surface of what's possible, the ocean economy has been valued at an estimated $2.5 trillion/year in economic value.[2] At this level, if the ocean were a country, it'd be the world's eighth largest economy[3] and ocean-based industries would be worth at least 3.5% of global GDP.

To start our deep dive into what's possible, BofA Global Research identified three entry points, the first of which we'll discuss in this publication:

- **Transformers** help us adapt the ocean and unlock ocean resources (e.g., subsea cables, underwater data centers, marine pharmacology, scarcity solutions, tidal energy, ocean real estate)
- **Explorers** allow us to understand the ocean (e.g., submersibles, marine security, AI, ocean of things, sensors, sonar/LiDAR (light detecting and ranging))
- **Savers** help restore ocean health (e.g., aquaculture, carbon removal, ocean waste clean-up)

The Transformers

The ocean is critical to the generative AI revolution (see: AI: From evolution to revolution? for more). In fact, 99% of the world's data traffic goes through subsea cables, and underwater data centers could save both energy and water usage. We can also leverage insight and data from the ocean – namely marine biomimetics – to discover new drugs. Here, we explore the ideas and technologies that have the potential to help us adapt to the ocean and unlock its resources.

Subsea cables

Data may be stored in the cloud, but much of it is actually sent and received along the ocean floor via subsea cables only about as thick as a garden hose. The term 'undersea infrastructure' refers to a complex network of highways stretching thousands of miles across the seafloor, carrying almost all the internet activities for multinational corporations. This is the world of submarine

[1] National Oceanic and Atmospheric Administration (NOAA)
[2] World Wildlife Fund (WWF), Boston Consulting Group (BCG)
[3] World Bank, Organization for Economic Co-Operation and Development (OECD)

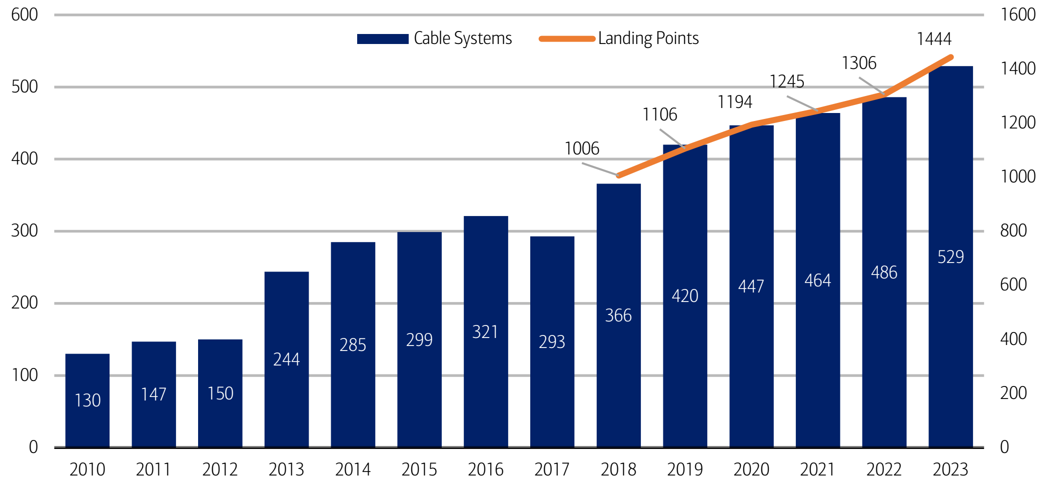
lines or subsea cables, which include power lines, canals, and optical data lines. It is estimated that there are over 500 active and planned lines worldwide, some of which can be quite short, while others extend up to 20,000 km.[4]

In 1858, when the first submarine cable was installed, a transatlantic transmission could take up to 18 hours. The first transatlantic telegraph cable connected London with North America and transmitted 143 words in about 10 hours. Today, there are approximately 900,000 miles of submarine cables carrying data at speeds exceeding 25 terabytes per second, meaning that that same 143-word transatlantic transmission would take less than one second.

These cables are essential for the global telecommunications network, carrying over 99% of data traffic or 95% of transcontinental internet traffic, delivering over three petabits of data (a petabit is equal to one quadrillion bits) including video calls, and enabling around $10 trillion in financial transactions per day. Even with the growth of satellites in telecom, cables can still carry far more data at a much lower cost. In fact, satellites account for less than 1% of all US international capacity.[5]

However, disruption of these cables could have significant impacts on communications between states or entire geographical areas.[6] In fact, according to the UN (United Nations), up to 200 subsea cable faults occur annually, with fishing and shipping activities, like dragging anchors, accounting for nearly two-thirds of the total.

Exhibit 1: 43 additional submarine cable systems were active or under construction in 2023 vs. 2022
Number of submarine cable systems active or under construction worldwide (2010-23)



Source: TeleGeography
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The oceanic data highways

The global market for subsea cables is projected to increase from $4.6 billion in 2022 to $21.3 billion in 2029.[7] Subsea cables are predominantly owned by various private investors – either large telecom carriers, content delivery providers or investor groups. Only about 1% of subsea cables are owned or part-owned by a government entity. Content providers now own or lease around half of all undersea bandwidth worldwide, and these tech companies are major investors in new cable, especially with the boom in AI. In 2022, they controlled about 66% of global submarine fiber optic capacity, compared to just 10% in 2012.[8]

Underwater data centers

The unfolding of the AI revolution and development and rollout of AI models entail greater demand for data centers. An underwater data center takes the IT (information technology) infrastructure (e.g., servers, storage media) and installs it inside a water-tight vessel and then submerges it underwater.

A dip to cool off?

Today, data centers consume 1-1.5% of global electricity produced, of which 40% is used for cooling.[9] Every one megawatt of power supplied to a data center requires approximately 285 tons of cooling, similar to the requirements for a 115,000 square foot commercial building. A 285-ton chiller costs roughly $225,000-250,000. With the greater adoption and rollout of generative

[4] Atlantic Forum
[5] TeleGeography, Visual Capitalist
[6] Atlantic Forum
[7] CRU Group
[8] Atlantic Forum
[9] International Energy Agency

AI, this water and energy use will increase, but with underwater data centers, the ocean offers a naturally cool environment without this additional cost.

In fact, underwater data centers would not consume *any* water for cooling or any other operational purpose. As such, they would not pose additional pressure on freshwater resources and their water usage effectiveness (WUE) would be zero. In comparison, a land-based data center can consume up to 4.8 litres of water per kWh. Additionally, since less energy is required for underwater data centers, less heat is emitted and doesn't warm the surroundings.

Making waves at the edge

Edge computing is a rapidly evolving segment that addresses the need to process data closer to where it is generated (the physical location where things and people connect with the digital world). Edge sensors measure activity in the physical world, which is fed into analytics applications and serve as the basis for decisions. Edge computing complements cloud computing by addressing latency, bandwidth, autonomy and privacy requirement (see: Next Gen Tech: Computing for more on this topic).

While data centers are typically hundreds of miles from end-users, edge computing brings these processes close to the devices where information is being generated or accessed. Demand for edge computing must be met from smaller data centers, often in urban areas closer to customers.

Why does this matter? Well, more than half of the world's population lives within 120 miles of a coast. By putting data centers near coastal cities, data would have a short distance to travel, leading to faster and smoother web surfing, video streaming and game playing. As such, underwater data centers could be used as edge data centers and internet exchange points, becoming an important part of edge computing for cloud service providers.

Counting on every drop: Reliability is important

There are three factors that contribute to the reliability of underwater servers:[10]

- **Atmosphere**: Underwater data center containers provide an atmosphere of dry nitrogen (i.e., there is no oxygen), which is important as nitrogen is less corrosive than oxygen. As a result, underwater servers can last much longer than data centers on land.
- **Humidity**: Low humidity in an underwater environment creates less condensation, helps reduce the risk of corrosion, and therefore extends the life expectancy of servers.
- **Temperature fluctuations**: Consistent ocean temperatures reduce the risk of significant changes in ambient temperatures. Traditional data centers can have outages due to cooling system issues or failures.

Rock the boat

Underwater data centers do face unique vulnerabilities though, one of which is sound. Dense water carries acoustic signals faster than air and the isolated data center is difficult to monitor or service if components break. Sound injection attacks can make underwater servers unresponsive and cause outages and after just a few minutes, some hard drives could be permanently destroyed. Underwater infrastructure is typically more at risk than on land, and sabotage can be difficult to trace.

To address this, sound-proof panels can be considered but would likely raise the server's temperature too much, countering the advantages of cooling with the ocean environment. Additionally, the sound-proof panels could be overpowered by the volume increasing. Active noise cancellation – the technology behind noise-cancelling headphones – would be too cumbersome and expensive to add to every data center. Overall, sound threats would be a key issue to overcome, especially since climate change could make the ocean five times noisier by the end of the century.[11]

Marine-based pharmacology

Life has existed in the ocean for at least 3.7 billion years, over three times as long as on land, thus it harbours a unique biodiversity.[12] Most medicines from natural sources come from land-dwelling organisms, but as we discover new enzymes and remedies, researchers are looking more towards the ocean.

In fact, some studies have shown that marine invertebrates produce more antibiotics, anti-cancer, and anti-inflammatory substances than any group of terrestrial organisms. Around 15-20 marine-derived compounds have been approved for clinical use against cancer, pain, viral infection and heart disease.[13] Scientists have also discovered more than 10,000 new chemical compounds from sea sponges alone in the past 50 years and every year over 200 new chemicals are discovered from sea sponges.[14] Many of these new chemicals go into life-saving drugs to treat diseases, including HIV and Covid.

[10] Dgtl Infra
[11] Sheldon et al.; University of Florida News
[12] Pearce et al.; Strother et al.
[13] Pharmaceutical Journal
[14] Smithsonian Ocean

The ocean contains more than 200,000 described species of invertebrates and algae,[15] though this number is estimated to be a small percentage of the total number of species that have yet to be discovered and described. The unique adaptations of deep-sea life to extreme conditions – high pressure, low temperatures, no sunlight – are already contributing to scientific and medical innovations.[16]

Deep healing: Marine genetic resources

Products derived from marine genetic resources alone are valued at $50 billion, while a single enzyme isolated from a deep-sea hydrothermal vent used in ethanol production has an annual economic impact of $150 million.[17] Increasingly, digital sequence information (DSI) is all a company needs to create and mass-produce a product. For example, kahalalide F—a compound that was isolated from a sea slug and that is being tested against cancers and psoriasis—is created synthetically from DSI.

In turn, developing products from DSI has huge advantages: it requires no harvesting of ocean animals, plants or microorganisms, and its commercial potential is virtually limitless because a gene sequence can be resold. DSI is now the most valuable source for commercialization of marine genetic resources.

Under the sea: eDNA

Did you know that less than 1% of all animals have had their genomes sequenced? Environmental DNA (eDNA) is the genetic material shed by organisms in the water column and by collecting samples of mucus, faeces, or tissue particles, scientists can process eDNA to make new discoveries about marine life. It is an emerging technology that will help answer many questions about the water column and seafloor.

It also has many benefits that complement traditional sampling efforts. For example, it does not require interaction with living organisms, making it a non-invasive sampling technology. It can also offer a window into the lives of organisms that have not been captured on video footage or may ordinarily shy away from the lights of a remotely operated vehicle or another platform. eDNA can detect a wide diversity of marine life, from bacteria to vertebrates, greatly expanding the scope of an expedition.[18]

Turning back the tide with marine beauty

Over the past 20 years, studies have identified the benefits of marine-based ingredients for beauty products, as they have unique characteristics and benefits with no equivalent in terrestrial organisms. Some offer protection against UV exposure, along with improved skin condition, and anti-aging properties. For example, fish oil-derived omega-3 fatty acids can improve skin health while mycosporine-like amino acids (MAAs) can act as sunscreen. The UVA photodamage-neutralizing capacity of a cream containing 0.005% marine-derived MAAs is comparable to a cream containing 1% of a synthetic UVA and 4% of synthetic UVB filters.[19] Even marine collagen has anti-ageing properties and absorbs one and a half times better than other forms, including bovine or porcine collagen.[20]

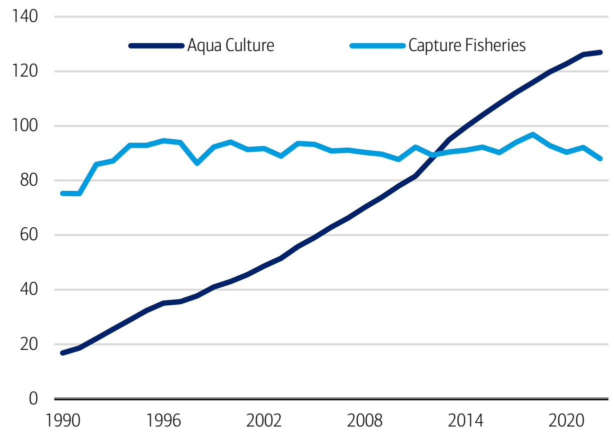
Feeding the world

Currently, the ocean represents around 2% of our overall calorie intake and 15% of protein intake.[21] But by 2050, there will be approximately 10 billion people on the planet and roughly half of the food they will eat will come from the ocean. Aquaculture (the counterpart to 'agriculture') has increased significantly over the past decade to surpass agriculture in production terms, largely driven by a combination of factors, including overfishing and declining fish stocks, biodiversity conservation, and the increasing global demand for seafood.

Fish farming is now the fastest-growing food sector in the world and is frequently cited as having the potential to address future global food security issues. With aquaculture, just 0.015% of the ocean's surface (the size of Lake Michigan) could produce more seafood than is currently caught by all wild fisheries today.[22] And that's saying a lot – fisheries are a major food source, providing more than 1.5 billion people with almost 20% of their average per capita intake of animal protein.[23]

[15] Winston, 1988
[16] Exaly
[17] DSM Observer
[18] National Oceanic and Atmospheric Administration (NOAA)
[19] Daniel et al.
[20] Khan et al.
[21] Food and Agriculture Organization (FAO)
[22] National Center for Biotechnology Information (NCBI)
[23] Food and Agriculture Organization (FAO)

Exhibit 2: Aquaculture surpassed wild catch in 2013
World aquaculture vs wild catch



Source: FAO. 2022. *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation.* Rome, FAO. https://doi.org/10.4060/cc0461en
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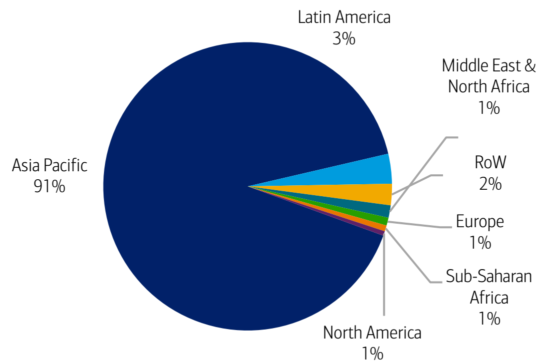
Exhibit 3: APAC represents 91% of global aquaculture production
Share of world aquaculture production



Source: FAO. 2022. *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation.* Rome, FAO. https://doi.org/10.4060/cc0461en
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H2O no!

The ocean contains 97% of the world's water but we could run out of freshwater by 2040 if we don't alter our course.[24] Two-thirds of the world's population could face water shortages by 2025.[25] And half the world's population endures extremely high-water stress at least one month of the year – a stat that is expected to reach 60% by 2050.[26] We dove into this topic in Global water scarcity: H2O no!

Enter desalination – a process that removes mineral salts from saline water, helping to turn seawater into potable or drinkable water. While an attractive solution, desalination currently only provides 1% of the world's drinking water,[27] and there are three challenges to address before this percentage can increase: 1) switching to renewables to reduce energy costs, 2) using more productive membranes, and 3) an eco-friendly solution to dispose of brine (a byproduct that has a high salt concentration).

Deep sea materials

Transitioning to clean energy alternatives will be metals-intensive, requiring up to six times current mining production through 2050, but with limited land-based mining capacities available to provide it. The deep sea could offer an abundant alternative source of the metals important for future technologies including electric vehicles and renewable energy infrastructure.

Several ocean sites have been identified that have polymetallic nodules lying on top of the seabed. They formed over millions of years by precipitating metals from seawater and sediment, and high concentrations contain cobalt, nickel, copper and manganese in a single ore. Just one of these sites has enough of these nodules to provide battery metals for ~280 million electric vehicles, more than the entire US car fleet.

However, despite the potential abundance of minerals that could be used in clean energy technologies, a combination of 1) increased recycling rates (reducing need for newly mined materials), and 2) alternative chemistries (e.g., lithium iron phosphate, sodium ion – neither of which require cobalt nickel or manganese), could alter the urgency or necessity for deep sea mining.

With more than 20 exploration sites already identified, further studies on the environmental impact of harvesting these is ongoing with regulations governing their exploitation due in 2025. Meanwhile, several companies are developing prototype robotic autonomous collection vehicles to analyze and collect the nodules from the seabed.

Powering the future?

Oceans are the world's largest untapped source of energy and could theoretically cater to two times the current global demand for electricity.[28] Ocean energy refers to all forms of renewable energy derived from the sea. Offshore wind is the first commercial example, but tides, waves and currents could be next, owing to their potential abundance and efficiency. Wave energy flow is 3-5x denser than wind. Although still at the research and development stage, over 300 prototypes of promising

[24] Aarhus University
[25] World Wildlife Fund (WWF)
[26] World Resources Institute (WRI)
[27] International Water Association
[28] International Renewable Energy Agency (IRENA), Ember

ocean technologies are under development including wave converters, tidal turbines, salinity gradient (power from differences in salt concentrations) and ocean thermal power (from differences in warm surface and colder deep seawater).

While the cumulative installed capacity of these new ocean technologies is relatively low (0.5 Gigawatts (GW) in 2023, vs. >3,000 GW total renewable energy capacity), installed capacity could reach 300-350GW by 2050, providing >10% of power demand in several regions, including Europe. Furthermore, submarine cables will become a key to connect all of this ocean energy, and interconnecting electricity grids internationally to balance intermittent renewable energy supply and demand. Submarine energy cable length already doubled from 2020-2023 but could rise a further five-fold by 2050 as electricity demand and ocean energy resources requiring connection to the grid increase.

Several regional and national government initiatives are now increasing scope of renewable energy investments to ocean energy, such as the US Inflation Reduction Act and the European Union's Horizon Europe and Innovation Fund, which has funded 18 wave/tidal pre-commercial pilot projects, for example. For more on energy innovations, see Next Gen Tech: Energy.

Ocean real estate

According to the UN, 1.6 billion people – that's one in five – don't have access to adequate housing and basic services, and by 2030, that number could almost double. One reason is that the number of homes has not kept up with the growth in household size, especially in urban areas that are getting more crowded. Beyond land, what if we can turn to the sea?

Since 2000, developers have added more than 2,500 square km (an area the size of Luxembourg)[29] to coastlines via land reclamation, or the process of creating new land from oceans, seas, riverbeds or lake beds. But what if we could eventually live underwater?

The ocean represents 99% of the living space on the planet by volume. So far, undersea habitats have been small scale and designed for temporary stays. Creating a permanent undersea colony would require significant advancements in materials science, construction techniques and life support systems.

[29] Sengupta et al.

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Disclosures