March 2023

Towards a sustainable **blue economy**

> **Could the green transition play out in the ocean?**

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SUSTAINABLE OCEAN ALLIANCE

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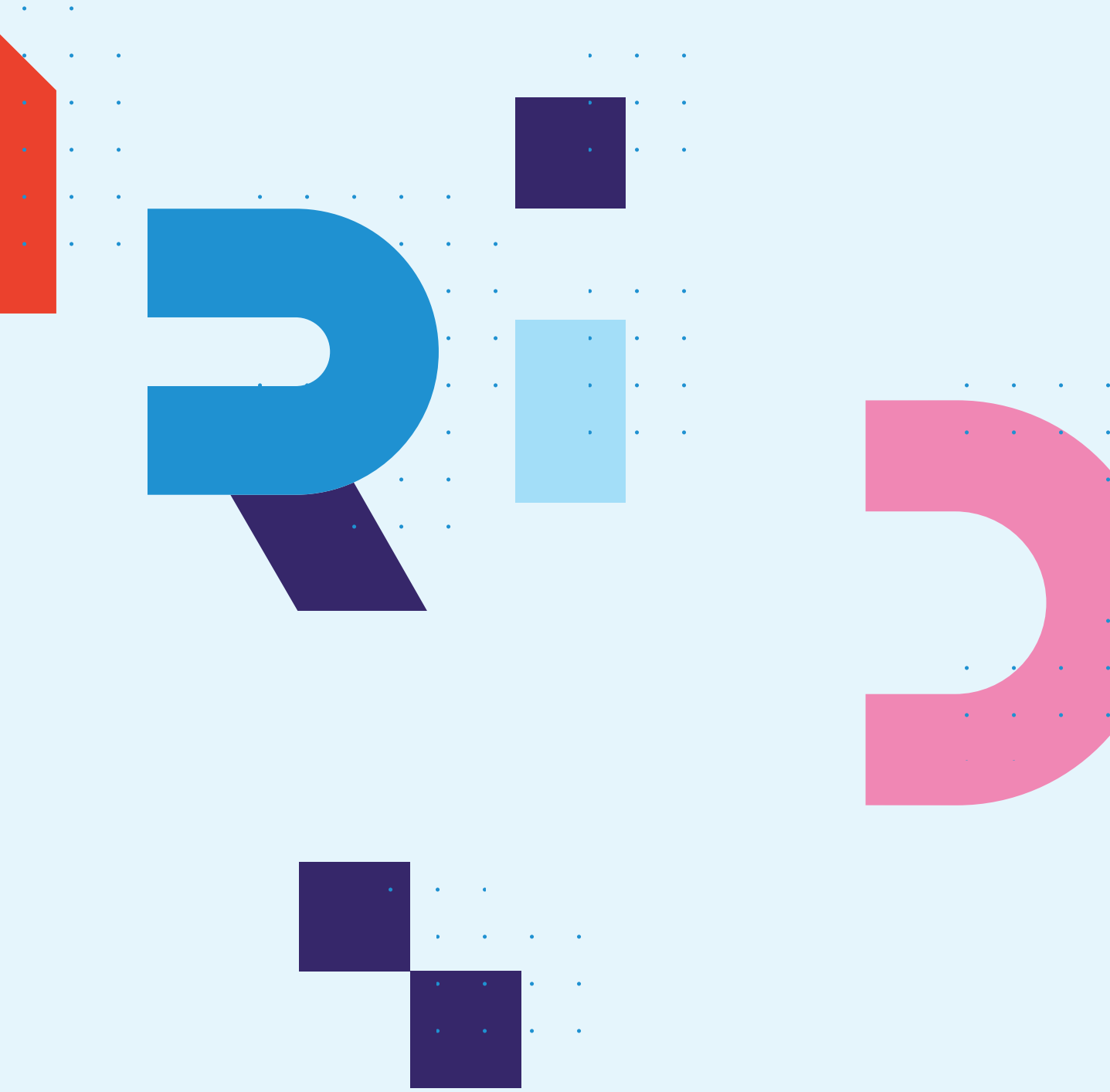

The sustainable blue economy: a new field of exploration

The climate emergency and its considerable consequences are forcing us to become ever more demanding, proactive, and aware when it comes to designing and developing new projects. At Leonard, the VINCI Group's foresight and innovation platform, we are committed to growing this awareness by exploring current and future transformations in order to help territories rise to present and future challenges. Since Leonard's creation in 2017, we have become accustomed to discussing the future of cities and infrastructure. Yet on a global scale, submerged lands represent a mere 30% of the earth's surface. In this booklet, we set out to discuss the remaining 70% of our planet. With this exploration of the sustainable blue economy, we wanted to incorporate seas and oceans, essential components of the green transition, in our reflections. The public sector, financial institutions, private companies, and innovators in general will all have a major role to play in this transformation; to do so, they will have to get to know each other and work together.

What exactly is meant by "blue economy"? Although the notion is gaining ground in the media, its definition remains unclear to many. Who are the stakeholders involved? What are their activities and future prospects? To delve into these questions, we joined forces with the Sustainable Ocean Alliance (SOA), a recognized expert on the subject. Together, we conducted an overview of the major challenges faced by the sustainable blue economy, from marine renewable energies and maritime infrastructures to coastline adaptation and the means to support and regenerate the ocean, a common good we all benefit from.

An invaluable asset for the green transition, the sustainable blue economy allows us to rethink our planet's equilibriums; at the same time, we now know that the next great discoveries and innovations will come from the ocean. For all these reasons, we invite you to discover this fascinating new field with us.

Julien Villalongue
Managing Director, Leonard

Finding innovation — and hope — in the blue economy...

The ocean is our biggest protection against climate change. As this report shows, the untapped potential of the blue economy is as vast as the ocean is deep. This gives me the most precious of commodities — hope.

I founded the Sustainable Ocean Alliance (SOA) to seek and scale solutions to the world's climate crisis. In less than a decade, we've built a community to restore the health of the ocean in our lifetime. Today, more than 7,000 young ocean leaders are driving grassroots initiatives across the world with the support of our collective mentorship, resources, and microgrants. And with the introduction of the world's first Ocean Solutions Accelerator, SOA has now had the honor of propelling 45 for-profit startups with scalable innovations to drive forward a sustainable Blue Economy.

We are honored to partner with VINCI Group's Leonard to raise awareness around the power of the Blue Economy. We knew this collaboration — and the resulting educational literature produced — would elevate innovative solutions for coastal communities impacted by the climate crisis and industries connected to the ocean.

Our alignment couldn't be more complimentary, as Leonard has gathered their own sizable community of actors to collectively build the sustainable cities of tomorrow. Many of the cities they prioritize lie in coastal regions threatened by warming oceans, acidification, and rising seas, among other timely threats driven by the climate crisis.

Tapping our combined networks, Leonard and SOA launched 2022's "Sustainable Blue Economy Event Cycle." Together, we convened leading figures across sectors to glean their expertise on topics ranging from investing in the future of the ocean, to harnessing the untapped power of marine renewable energies, to addressing the impacts of rising sea levels on coastal communities and transforming ports and sea freight transportation to meet environmental challenges.

Throughout this report, you'll find an overview of the insights shared across these discussions and be introduced to countless inspiring and disruptive startups and pilot programs solving the challenges of today to the benefit of our shared tomorrow.

I encourage each of you to consider how the resources outlined within the report might drive progress in your sector. From concerned citizens residing in coastal communities, to corporate leaders evolving business practices to reduce emissions, to government officials analyzing and implementing available technologies, to investors climate-proofing their portfolios, it will take all of us to spur the transition to the emerging, sustainable blue economy.

Join us in celebrating, amplifying, and implementing the groundbreaking work of these leaders and dreamers.

Daniela Fernandez
CEO, Sustainable Ocean Alliance (SOA)

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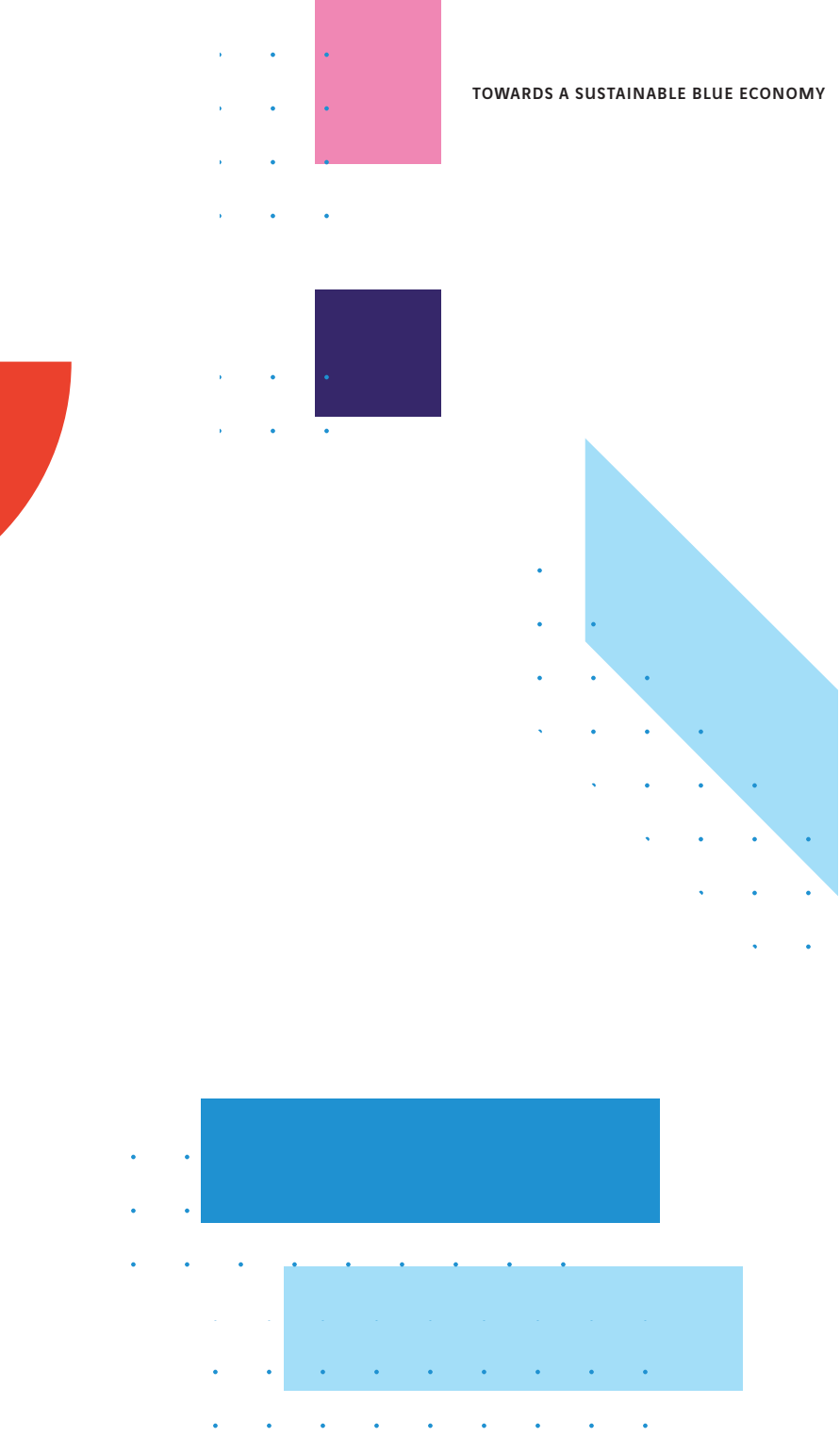
SCAN THE CODE TO WATCH THE REPLAYS

2022: a pivotal year for the ocean

Whether through attempts to better understand it or debates on how to protect it, the ocean drew a lot of attention in 2022, a banner year for the sustainable blue economy.

October 31st-November 12th, 2021	**In Glasgow, a step forward for the ocean** Held in Scotland, the 26th edition of the Conference of Parties (COP) culminated with the adoption of the Glasgow Climate Pact, whose preamble recognizes the importance of protecting the oceans.
February 9th-11th, 2022	**Brest: from commitment to action** Gathered by France at the initiative of Emmanuel Macron, 41 States committed to preserving marine biodiversity and fighting ocean pollution and overexploitation.
March 17th, 2022	**Leonard Event Cycle - Sustainable investment in the oceans** How can we encourage public decision-makers, the industrial sector, and investors to take part in the transition to a sustainable blue economy? **Find out more on p. 14**
April 13th, 2022	**Leonard Event Cycle - Marine renewable energies: the promises of swell and wind** The untapped potential of marine renewable energies is inspiring numerous innovations. Can the ocean become an engine of the energy transition? **Find out more on p. 26**
June 23rd, 2022	**Leonard Event Cycle - A phantom threat? Coastal areas and rising sea levels** How can we help protect our societies from rising sea levels? How can we help them adapt to this new threat? **Find out more on p. 31**
June 27th, 2022	**Sustainable Ocean Alliance raises record-breaking amount** In June 2022, the Sustainable Ocean Alliance raised a record $15 million to fund innovative start-ups and projects aimed at restoring the ocean's health.
June 27th-July 1st, 2022	**International mobilization in Lisbon** "Let's have no illusions. Much more needs to be done by all of us, together," said UN Secretary General António Guterres during the United Nations Ocean Conference in Lisbon, where states announced close to 700 voluntary commitments to protect the oceans.
October 3rd, 2022	**Leonard Event Cycle - Ports: new hubs of the energy and mobility transitions** How can ports become testbeds for the sustainable solutions of tomorrow? **Find out more on p. 43**
October 15th, 2022	**The Tara Océan Foundation's Microbiomes mission sails home** Schooner Tara returned to the port of Lorient (France) after two years in the South Atlantic. Its mission: to better understand marine microorganisms and their interactions with pollution and the climate.

(CREDIT: SHIFAAZ SHAMOON - UNSPLASH)



I. SUSTAINABLE BLUE ECONOMY: A TRANSITION UNDER PRESSURE

A rich source of biodiversity offering invaluable ecosystem services, the ocean is the source of promising scientific and technological innovations, major investment opportunities, and new hopes in the fight against global warming. A growing number of actors are mobilizing to help protect and regenerate marine ecosystems. Keep reading for an overview of the challenges and prerequisites of a sustainable blue economy!

Investing in our oceans' future

The oceans cover 70.8% of the planet's surface. Essential to climate regulation and the preservation of biodiversity, they are directly threatened by the consequences of human activity. How can we encourage public decision-makers, the industrial sector, and investors to take an active role in the transition to a sustainable blue economy, a keystone of the ocean's regeneration?

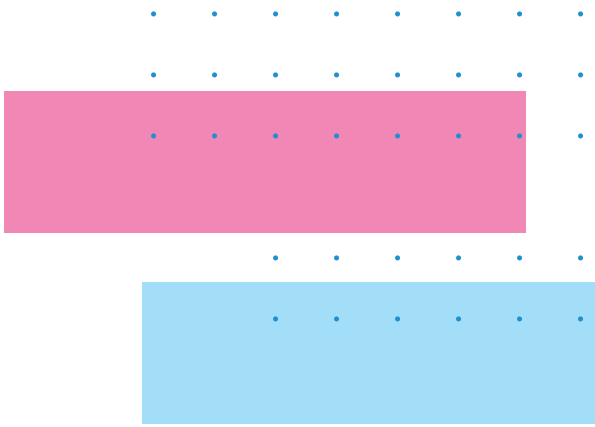
This article is based on a debate hosted by Leonard on March 17th, 2022. Scan the code to watch the replay.

FROM LEFT TO RIGHT: LUDIVINE SERRIERE, CATHERINE CHABAUD, CHRISTIAN LIM, EMILIE GARCIA, GENEVIÈVE PONS
(CREDIT: LEONARD)

Innovating to regenerate the oceans

Without innovation, there can be no sustainable blue economy. Fortunately, says Christian Lim, Managing Director of SWEN Capital Partners, experiments are multiplying: French company Unseenlabs has developed nanosatellites outfitted with electromagnetic signal sensors that can detect and locate ships that have turned off their positioning beacons and thus combat illegal fishing. At the European level, Geneviève Pons, Vice-President of Europe Jacques Delors and president of the Starfish 2030 Mission (see p. 18), mentions the Iliad project, a digital twin of the ocean that allows for improved documentation of ocean acidification, rising sea levels, and biodiversity loss.

As noted by Catherine Chabaud, Member of the European Parliament, journalist, and yachtswoman, many innovations have yet to be invented, especially when it comes to designing infrastructure with a positive environmental impact that can help oceans regenerate. From now on, infrastructure at sea must provide environmental and social co-benefits and allow for a combination of uses (e.g., wind energy production and sustainable fish farming). Maritime transport, through which 90% of the world's goods are transported, will also have to become more sustainable: for Émilie Garcia, Head of ESG Climate – Innovation Department at Bpifrance, solutions in this area will come from projects in the fields of port electrification, ship renovation, wind energy, and biofuel development.



“We have been talking about conservation for a long time, but the word is no longer adequate. What is there to conserve now that we have destroyed a large part of the ocean? Regeneration is what is needed.”

— *Christian Lim, Managing Director, SWEN Capital Partners*

Funding is key

To see the light of day, these innovative projects will require significant funding. However, as Geneviève Pons points out, investments in the blue economy are still often slowed down and redirected towards priorities deemed more urgent or profitable. Faced with this challenge, public investors are mobilizing: in 2021, the European Commission allocated 700 million euros to the support of the sustainable blue economy; in 2020, the French BPI launched a climate plan supported by specific financing and investment mechanisms and dedicated funds. Private investors are equally involved: SWEN Blue Ocean, the €95 million fund managed by Christian Lim, invests in ocean regeneration by supporting start-ups that combine positive systemic impact and market opportunities. Three areas are specifically targeted: the fight against ocean pollution (plastic, agricultural and chemical, and underwater noise pollution), ocean overexploitation, and climate change solutions. Christian Lim is noticing a growing interest in ocean regeneration among investors: institutions (BPI, Ifremer) as well as banks, insurance companies, pension funds, and large European and American family offices are all investing in the Blue Ocean fund.

Starfish 2030, a European ambition

Launched in 2020 by the European Commission as part of the Horizon Europe Program, the Starfish Mission aims to regenerate marine and aquatic ecosystems by 2030 by focusing on five areas, which will give rise to flagship projects: governance, knowledge-sharing through education, direct protection of targeted environments, the fight against pollution, and the sustainable blue economy. In this area, the mission aims to accelerate decarbonization, by launching several experiments in the Baltic Sea by 2026. With over 14 million tons of plastic ending up in the ocean every year, Starfish also seeks to prevent, minimize, eliminate, and remedy oceanic pollution, by supporting research into substitutes, the circular design of products, and the reuse of waste. A test planned in the Mediterranean should make it possible to better monitor major sources and flows of pollution. Finally, the transition to a sustainable blue economy will require improved governance: as holistic, systemic, and interdependent as the oceans, it will have to give rise to the appointment of a European Commission Vice-President responsible for orchestrating actions dedicated to the ocean's health.

> **“To successfully transition to a sustainable blue economy, three fundamental issues must be addressed: investment, innovation, and training ”**
>
> — *Geneviève Pons, President of the Starfish 2030 mission*

WHEN FINANCE TURNS BLUE

To become sustainable, the blue economy will require colossal investments. It will imply simultaneously financing the decarbonization of sea freight (see p. 50), the deployment of marine renewable energies (see p. 25), and the adaptation of infrastructure, ports, and human activities to rising sea levels (see p. 31). The finance sector is already preparing for this, as evidenced by a committed fund and an innovative exchange-traded fund (ETF).

In 2021, SWEN Capital Partners created a fund named SWEN Blue Ocean, whose mission is to invest in innovations that can help regenerate the ocean and combine systemic impact with return on investment. Blue Ocean focuses on combating overfishing, pollution, and climate change; among other projects, it has invested in the development of red algae that can be used to feed cattle and thus reduce methane emissions, and in Unseenlabs, a French company with small-scale nanosatellites that can geolocate ships that turn off their positioning beacons to degas or fish illegally.

BNP Paribas Asset Management recently created an ETF that allows individual investors to support companies involved in several areas of the sustainable blue economy: ecotourism and coastal preservation, renewable maritime energy, sea products, pollution reduction, and sea freight.

GENEVIÈVE PONS KEYNOTE AT LEONARD:PARIS
(CREDIT: LEONARD)

Starfish 2030: mission regeneration

Led by the European Commission and a part of the Horizon Europe framework program, the Starfish 2030 mission brings together innovators, researchers, and financial institutions to work on the regeneration of marine and aquatic ecosystems. To this end, the mission acts in several interconnected areas: knowledge-sharing through education, governance, direct protection of targeted environments, the fight against pollution, and the blue economy. After a first survey conducted in December 2020, Starfish will deploy geographical and thematic "flagship projects" that will be tested locally before being extended to the rest of Europe.

- Surface area of the European maritime space: **17 million km²**
- **5 pillars of the Starfish mission:** enriching knowledge and creating an emotional connection; achieving zero pollution; improving governance; regenerating marine and aquatic ecosystems; decarbonizing our oceans, seas, and waters.
- **6,600 responses collected** during the survey conducted by Ifremer on behalf of Starfish 2030 in November 2020.
- **Over 40 institutional partners,** including the French National Centre for Scientific Research (CNRS), the French Biodiversity Office, the Ocean & Climate platform...

Marine pollution, a planetary challenge

Did you know that a plastic bottle discarded on a mountaintop will almost inevitably end up at the bottom of the ocean? Most human activities generate waste and pollutants that end up in the sea. This phenomenon spares no corner of the ocean and endangers marine biodiversity and human health. And while civil society, entrepreneurs, and scientists are working relentlessly to clean up the seas, a fundamental change is required to reduce the amount of waste produced and improve its management.

Sea pollution starts... on land

Though it brings up images of degassing and oil leaks, 80% of marine pollution actually comes from land. Human activities are responsible for most of it through industrial emissions, agricultural runoff, waste discarded on coasts, or discharges into rivers[1]. 85% of this marine pollution (underwater noise pollution excluded) is composed of plastics, half of which are single-use, but also industrial granules, agricultural inputs, coatings, paints[2] ... And the scale of the phenomenon is considerable: 11 million tons of plastic are dumped into the oceans every year[3], and a layer of plastic waste twice as large as Texas is currently floating on the Pacific Ocean[4]. But marine pollution goes beyond plastic waste: chemicals, nutrients, hydrocarbons, but also rubber, metal, or wood are all found in the ocean[5], in addition to noise and light pollution.

A threat to life under the sea and on land

Waste, which accumulates along coasts and estuaries as well as on the surface of the sea and on the seabed[6], has devastating consequences on marine biodiversity and, consequently, on human activities and health. Plastic, which is non-biodegradable and decomposes into microplastics, is highly detrimental to marine life: in the North Sea, 94% of bird stomachs contain plastic[7]. Many animals confuse plastics with food and ingest them (plastic bags, in particular, remind sea turtles of the jellyfish they usually feed on[8]) or are attracted by their smell and appearance (as is the case for sea birds)[9]. According to the European Commission, plastics increase the mortality of marine animals but also lead to a deterioration of the ocean floor and a destruction of natural habitats.

Other pollutants have equally deleterious effects on marine biodiversity: by over-stimulating the production of phytoplankton, an accumulation of phosphorus and nitrogen can affect the services provided by marine ecosystems, including CO_2 capture and oxygen generation[10]. Light pollution disrupts the natural cycles (reproduction, migrations…) of many marine animals[11]. At the end of the food chain, the damage caused by pollution on ocean ecosystems also affects human health, particularly through the consumption of fish that have ingested plastic. More broadly, plastic pollution, whatever its source, significantly impacts human health: microplastics have been detected in human lungs, livers, and kidneys, and even in placenta[12]. Finally, marine pollution also weighs on the economy: in 2014, the United Nations Environment Programme (UNEP) estimated the annual cost of plastic pollution in the oceans at $13 billion.

Finding the underlying cause behind the symptoms

For several decades, states have been working to curb ocean pollution: as early as 1972, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter aimed to protect the marine environment, as did the London Protocol more recently.

The effect of technology and innovation should not be underestimated, just like grassroot actions to clean up coastlines and estuaries. But these solutions have a limited impact considering the rate at which pollutants currently penetrate the oceans. It is upstream, on land and among citizens and companies, that efforts to fight marine pollution must be undertaken. Encouraging recycling, the reuse of plastics, or their replacement by other materials, but also raising awareness of efficient waste management and improving governance and international coordination are all essential means of combating ocean pollution[13].

(CREDIT: NAJA BERTOLT JENSEN - UNSPLASH)

Deep-sea exploration and exploitation: beneath the waves, a new Eldorado?

Only four persons have explored the deep sea… That's three times less than the number of astronauts who have set foot on the Moon! Although the deep seabed, which covers an area of 320 million km², remains largely unexplored, we already know it contains countless valuable minerals, raising the interest of many. Yet while the exploitation of this new Eldorado offers many opportunities… it comes with significant dangers.

When the future of humanity lies under the sea

At the bottom of the ocean hides a world worthy of Jules Verne's novels: fields of polymetallic nodules home to extraordinarily diverse species and a high concentration of metals, underwater mountains strewn with cobalt-infused crusts… A world that remains largely mysterious: according to the French Senate, only 2% of the seafloor has been determined with a resolution of 1 meter and 20% with a reasonable resolution, while 95% of deep-sea biodiversity remains unknown. A comprehensive mapping of the French maritime domain's seabed, the second largest in the world, would take… up to 60 years, the French Senate estimates[14].

While they remain little-known, seabeds are already highly coveted: widely accessible to exploitation, they contain cobalt, manganese, nickel, lithium, barium, and other rare metals. These materials are crucial to the manufacturing of electric batteries and thus to electrification, a pillar of the green transition, as well as for a variety of economic sectors (automotive, advanced technologies, aeronautics, etc.) on which states' competitiveness and strategic autonomy depend. French soils, for instance, contain iron sulfides, gold, silver, indium, germanium, as well as nickel, cobalt, and lithium[15]. But other resources attract equal interest: deep-sea biodiversity could prove a breeding ground for future innovations in medicine and pharmacology, chemistry, nutrition, and more. "The potential is tremendous," Françoise Gaill, Director of research at the CNRS, told the French weekly *L'Express*. "All in all, 90% of genetic sequences deposited in patent banks come from deep hydrothermal zones"[16].

States and economic actors are therefore eager to explore and ultimately exploit seabeds. The International Seabed Authority (ISA), the only organization competent to authorize the exploitation of the "Area" (the maritime zone located outside of national exclusive economic zones), has already granted more than thirty authorizations to research institutes, governments, and companies from 22 countries (mainly for the Clarion-Clipperton zone, in the eastern Pacific Ocean[17]). Exploitation and mining activities could begin very quickly. Norway has chosen to grant the first authorizations to exploit its exclusive economic zone as early as next year, while last year the State of Nauru, in the Pacific, informed the UN of its wish to begin metal extraction.

Unclear risks

It is still hard to assess the potential effects of these mining operations, which involve breaking and scraping the ground and will therefore induce the suspension of toxic sediments released from the ground. According to Pierre-Marie Sarradin, head of the Ifremer research unit on the study of deep-sea ecosystems, this phenomenon can alter the chemical composition of the water and the surrounding soil[18]. Without thorough knowledge of deep-sea ecosystems, which we only know to be extraordinarily rich in genetic material, it is difficult to measure the impact of these sediments and the precise effects of extraction. In addition to destabilizing ecosystems and releasing carbon sequestered in marine soils[19], extraction will also raise geopolitical issues, as interest in underwater resources may fuel tensions and conflicts between states. Such is already the case for other marine resources, as evidenced by Russian-American tensions over hydrocarbons in the Arctic Ocean or the recent gas dispute between Israel and Lebanon. These risk factors must lead to a better understanding of these ecosystems, which will help assess the margin of maneuver for exploitation and balance the extraction of essential resources and the preservation of deep-sea ecosystems.

Towards a ban on extraction?

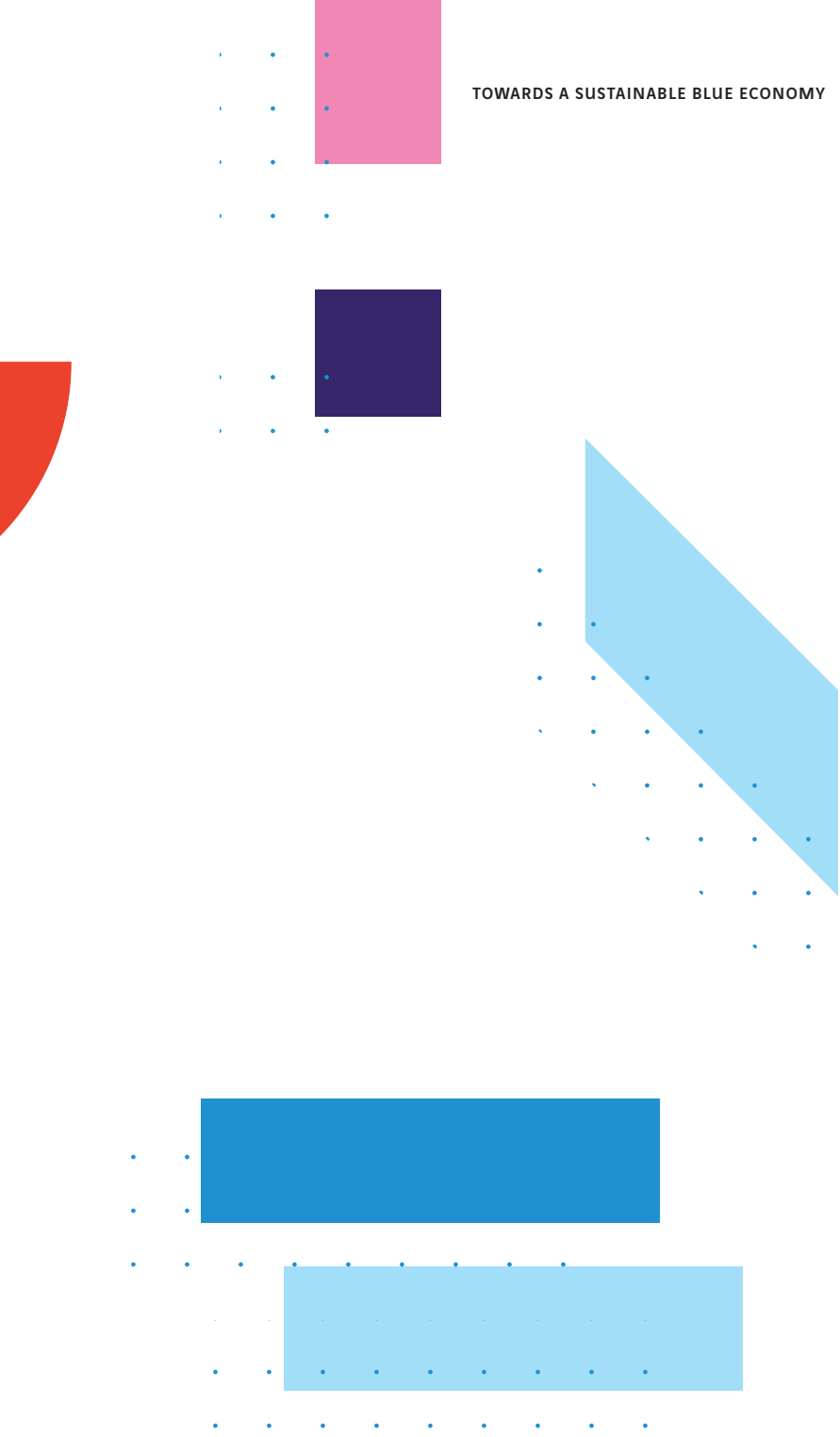
In addition to the creation of marine protected areas, several governments and environmental associations are now calling for a ban or at least strict control of deep-sea exploitation: at its congress in Marseille in 2021, the International Union for Conservation of Nature (IUCN) called for a moratorium on ocean floor mining. In the wake of a French Senate report that concluded it was too early to authorize exploitation given our limited knowledge of its potential effects, Emmanuel Macron took a stance against it on June 30th, 2022, during the United Nations conference on the ocean in Lisbon[20]. The French President recently confirmed this position in a speech delivered at COP27 in Sharm el-Sheikh (Egypt) on November 7th, 2022.

CURIOUS TO KNOW MORE?

—

- [In French] Senate. Abysses : la dernière frontière ? Information report by Mr. Teva ROHFRITSCH, made on behalf of MI Fonds marins No. 724 (2021-2022) - 21 June 2022. URL: https://www.senat.fr/notice-rapport/2021/r21-724-notice.html
- Michael Lodge. The International Seabed Authority and Deep Seabed Mining. United Nations. URL: https://www.un.org/fr/chronicle/article/lautorite-internationale-des-fonds-marins-et-lexploitation-miniere-des-grands-fonds-marins
- [In French] Fondation de la Mer. Les grands fonds marins – Quels choix stratégiques pour l'avenir de l'humanité ? URL: https://www.fondationdelamer.org/wp-content/uploads/2022/06/Les-Grands-Fonds-Marins.pdf

(CREDIT: SHAUN DAKIN - UNSPLASH)



II.

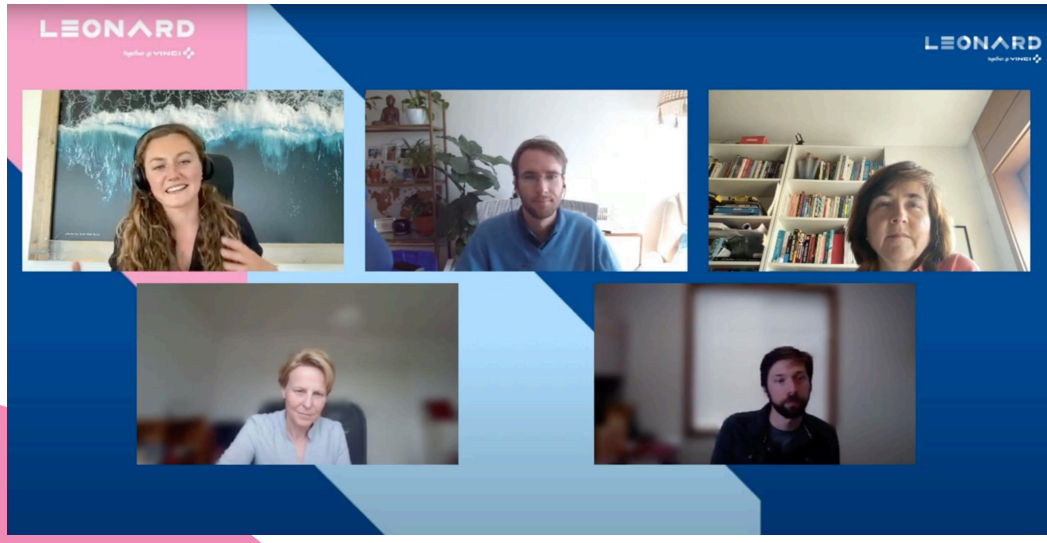
MARINE RENEWABLE ENERGIES: FIGUREHEADS OF THE ENERGY TRANSITION?

In 2022, the war in Ukraine caused an unprecedented energy crisis on the Old Continent. At the same time, commitments to the energy transition are becoming increasingly ambitious, and the deadlines ever tighter. In the face of this complex equation, a promising path is opening up: the development of marine renewable energies.

Harnessing the untapped power of swell and wind

Energy represents a major socio-economic and environmental challenge for the coming decades, with enormous strategic, economic, and financial stakes. Wind, tides, and ocean currents make the seas an inexhaustible source of energy. The international race to find the best technologies for exploiting this potential has begun, and the possibilities are countless: wave energy, tidal energy, ocean current energy, and thermal gradients are all governed by different physics, creating a wide array of potential solutions. We spoke with a panel of experts on the technologies that are shaping the future of this new mix of renewable energies.

This article is based on a debate hosted by Leonard on April 13, 2022. Scan the code to watch the replay.



YUKI ESSER, MARCUS LEHMANN, RITA SOUSA IRINA LUCKE, ROBERT CAVAGNARO
(CREDIT: LEONARD)

An industry with enormous potential

Marine energy technologies will play a significant role in powering ocean economy end-use applications (e.g., by contributing to the electrification of the shipping industry) and in large-scale climate remediation and CO_2 removal technologies, says Robert Cavagnaro, of Pacific Northwest National Lab, a US Department of Energy Research Laboratory with a large portfolio in marine energy research.

Rita Sousa, a partner in Faber's ocean and climate tech fund (a €40M fund launched in January 2022) mentions significant market opportunities: the offshore wind energy market is estimated to reach $87 billion by 2026, growing at a compound annual rate of 13%, while the tidal and wave energy market should grow by 40% annually and is valued $ 3-5 billion. These figures show the need for early-stage startups to devise new technologies and serve this market demand. Faber actively invests in such startups, seeking out innovative deep-tech companies developing high-impact solutions for ocean sustainability and climate action. One vertical within the fund focuses on technologies with the potential to increase the efficiency and longevity of offshore renewables, a market where Sousa sees strong potential.

Marcus Lehmann, the CEO of Calwave (see below), a wave energy tech provider based out of the Lawrence Berkeley National Lab, notes that 30% of the EU and the US electricity demand could ultimately be served by marine energy. Additionally, approximately 120 GW of offshore wind are currently installed and planned with a 50% capacity factor, which means about 60 GW of excess capacity are available globally, says Lehmann. This means offshore wind developers should anticipate the moment when tidal and wave energy are ready for utility-scale farms, as there will be significant opportunity in colocating them and placing them on the same export infrastructure, thereby increasing the capacity factor, reducing cable payoff time, and multiplying synergies, from spare parts to maintenance.

> **"We rely a lot on the possible emergence of a silver bullet like fusion, but we also need to start leveraging resources that are already available."**
>
> — *Marcus Lehmann, co-founder and CEO of Calwave*

Significant challenges ahead

For Irina Lucke, of Omexom, a VINCI Group service provider for the lifecycle of offshore power plants, one main challenge lies in setting clear goals. If we aim to fight climate change and help marine energy reach the next level, says Lucke, we must discuss priorities and co-use as early as possible and avoid the mistakes made with offshore energy. Co-use with the shipping and fishing industries, environmental actors, the navy, and other actors is proving to be a pain point because the discussion began too late in the process, creating frustration for many stakeholders.

For Robert Cavagnaro, marine energy actors must show that the technology works and provides real value to the markets it serves. This means taking these technologies to places with high energy costs, where they have the potential to impact people's lives greatly. For Cavagnaro, the industry must also better convince other actors that marine energy technologies are safe, by communicating on their benefits for the environment. In the US, the offshore wind industry has been hampered by NIMBY ("Not in my backyard") sentiment, an experience marine energy should learn from, says Cavagnaro, who also highlights the importance of sustaining strong government-industry partnerships, immune to political fluctuations, for bringing these new technologies to market.

Where to go from here?

The next step should be a commitment to the energy transition at the European Union level and the setting of a clear roadmap, starting with the goal we want to reach and working backwards, says Irina Lucke.

For Rita Sousa, additional specialty private funding and VC funding must now be brought in to back the new generation of marine energy entrepreneurs and bring them from pilot to market. Sousa also mentions facilitating the navigation of the regulatory framework to allow these marine energy solutions to scale up.

For Marcus Lehmann, the emphasis should be on finding mechanisms to finance early-stage technologies and incentivize the first 500MW or 1GW, bridging a gap not currently covered by traditional financing, which comes in only later, when technologies have significantly matured.

> **Innovative start-ups in their early stages now have the opportunity to respond to a strong market demand by putting forward new technologies.”**
>
> — *Rita Sousa, partner in the Faber Ocean / Climate tech fund*

OFFSHORE WINDFARM: WHEN ARTIFICIAL INTELLIGENCE PREDICTS OFFSHORE WIND TURBINE FAILURES

To help wind energy reach its potential, power generation systems must become more efficient on an operational and infrastructural level. Wind turbines are purposely installed far from the coast, in environments that are hard to access and subject to harsh weather conditions, creating significant technical challenges and complicating human intervention. This makes technical problems very costly: a generator failure can cost up to €50,000 per turbine, while shipping a replacement generator can take up to 30 days. Faced with this situation, Omexom Offshore (VINCI Energies) and Leonard’s AI program have developed Offshore Windfarm, a new artificial intelligence solution designed to detect generator damage in advance in order to immediately ship a replacement part and thus limit the wind turbine’s downtime. The Offshore Windfarm project models the typical behavior of each wind turbine by analyzing periods of normal operation. The difference between this model and the actual data is used to detect an abnormal situation and alert maintenance. This solution allowed Omexom Offshore to proceed with the advance replacement of a generator on the Riffgat site, northwest of German island Borkum. This is the first time predictive maintenance has been used to improve the reliability and availability of wind energy.

RENEWABLE MARINE ENERGY:

A LOOK AT FUTURE SOLUTIONS WITH FOUR INNOVATIVE STARTUPS

WAVE ENERGY
ELECTRICITY SYSTEM

Calwave (USA) is a California-based wave energy tech provider whose technology operates at a distance from the coast, where energy capture is more efficient, and is fully submerged, thus easily sheltered from storms. It received the U.S. Wave Energy Prize in 2016 and has secured $19M in contracts with the US Department of Energy, allowing it to upscale to a second product line.

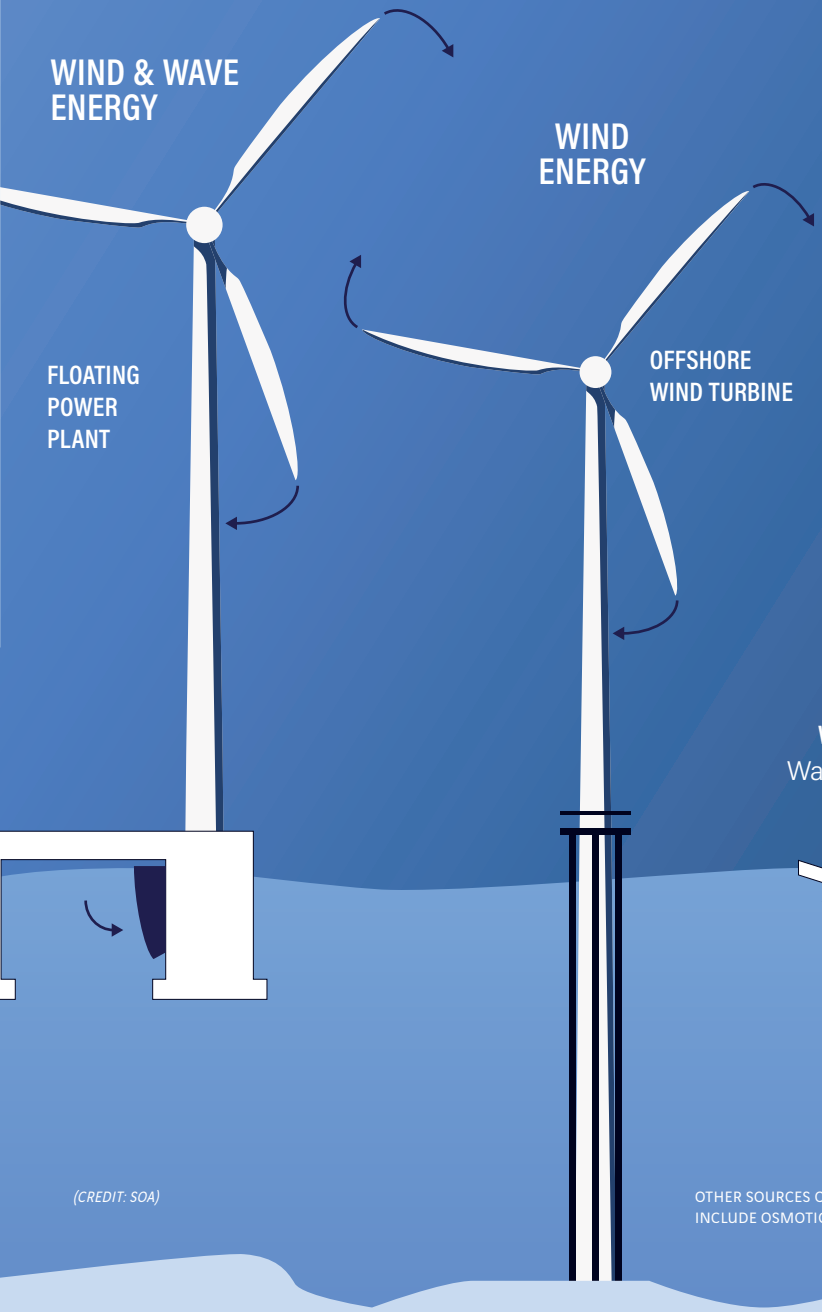
Founded in 2011, Ecowave Power (Israel) produces clean, affordable electricity from ocean and sea waves, using a technology that is attached to the shoreline. Floaters are attached to existing structures such as jetties and move up and down, producing and sending clean energy to the grid. Ecowave has since secured 325 MW of projects worldwide.

WIND ENERGY
ELECTRICITY SYSTEM

Floating Power Plant (Denmark) is taking combined floating wind-and wave-technology to market. Its technology consists in a floating platform built out of modular panels, a turbine, a single-point mooring system, and a subsea grid to bring the power to shore. It is currently conducting certification testing and seeking out large-scale grid-connected projects, focusing on the electrification of oil-and-gas and of remote islands.

THERMAL ENERGY
COOLING SYSTEM

SWAC (Sea Water Air Conditioning)/Geocean, a VINCI Group company incubated at Leonard, saves energy by leveraging the temperature of the ocean and the sea to produce cooling, the need for which is expected to triple within the next 30 years. SWAC pumps and circulates ocean water in an open or closed loop to cool buildings. The technology's potential is significant for islands, which struggle to produce clean energy and have strong cooling needs.



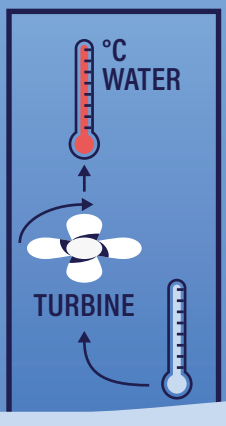
(CREDIT: SOA)

WAVE ENERGY

WAVE POWER
Wave movement

THERMAL ENERGY

Difference in temperature between surface water and deep-sea water



OTHER SOURCES OF RENEWABLE MARINE ENERGY INCLUDE OSMOTIC, CURRENT AND TIDAL.

Key figures: Marine renewable energies

Installed capacity of marine renewable energy power generation facilities in 2019:	535 MW[21]
Installed capacity of offshore wind turbines:	12 GW[22]
Goals set by the European Union for ocean energy:	1 GW in 2030 40 GW en 2050[23]
Amount of public and private investment in tidal and wave energy in 2021:	€70M[24]
In Europe, tidal and wave energy capacity installed in 2021:	681 KW[25]
Estimated size of the global market for wave and tidal energy:	€535M between 2010 and 2050[26]

III.

ADAPT, RESIST, CREATE: COASTAL AREAS AND RISING SEA LEVELS

Sea levels rose by 29 cm in the 20th century; they are now rising by 3.7 mm per year. With almost half of mankind living less than 150 km from the coastline, how can we best prepare our societies and territories to this phenomenon?

A phantom threat? Coastal areas and sea level rise

There is no longer any doubt about it: sea levels are rising at a rate unprecedented in recent history. How can we protect and adapt our societies and territories in the face of this unavoidable phenomenon with major consequences? The question is complex: naturally mobile, a variety of phenomena influences coastlines at different scales. And their adaptation to rising sea levels raises important social acceptability issues in these often densely populated areas.

This article is based on a debate hosted by Leonard on June 23rd, 2022. Scan the code to watch the replay.

The coastline: from a line to a space

The rise in sea levels is a complex phenomenon. As noted by Françoise Gaill, research director at the CNRS, sea levels were long assimilated to a line, an easily measurable mathematical element. This strictly scientific vision has given way to an interpretation influenced by social sciences: the coastline is now seen as a strip that takes into consideration human systems and the influence of the hydrosphere. Further, coastlines are not fixed areas.

FROM LEFT TO RIGHT: LUDIVINE SERRIERE, PATRICK BAZIN, RAPHAËL CUVELIER, KARIM SELOUANE
(CREDIT: LEONARD)

As explained by Karim Sellouane, whose startup, Resallience, works to adapt territories and infrastructures to climate change, coastlines have constantly evolved according to climatic events and development conditions. Patrick Bazin, director of heritage management at the Conservatoire du Littoral, agrees with this observation and notes that coastlines are naturally mobile. Between 1706 (when the first reliable map of the Atlantic coast was drawn) and 1825, the coastline of the south of the island of Oléron had moved by 1km. Today, it is back to its 1706 location! The influence of climate change is thus compounded by a natural movement born from a very active sedimentary process.

Acting at the right scale

Faced with rising seas, several solutions can be implemented: to colonize the maritime space, to resist the rise, deal with it, or invent new adaptation models, says Françoise Gaill. For Raphaël Cuvelier, vice-president of the Ocean & Climate platform, the challenge lies in combining these different types of solutions by reconciling both protection and adaptation and by leveraging infrastructure (elevation of buildings) as well as nature-based solutions (mangrove systems and coral systems). Among these "soft" methods, Patrick Bazin cites flexible coastline management, which transforms natural environments into buffer zones. In Hyères, riprap built to protect the coastline was producing an erosion wave. The Conservatoire du littoral decided to remove it to recreate a beach, which successfully slowed down erosion.

To be effective, solutions must be implemented at the right scale. This is precisely the goal of the SEA'TIES Project (see page 37), born in 2015 to ensure that the ocean would be discussed during the Paris Agreements. As Raphaël Cuvelier explains, SEA'TIES chose to focus on urban areas, which concentrate populations, and therefore vulnerabilities. Solutions will indeed be local, even if the problems themselves come from a larger scale: Karim Sellouane mentions sedimentary transit along the African coast, which comes from the entire continent. "To think that solutions to coastline variation are exclusively local is to see only half of reality. On the one hand, there are hazards that local actors do not control, and on the other hand, there are very local adaptation needs".

> **"The coastline is an interface with inputs, outputs, and changing occupations. It is through these dynamics that we must understand its adaptation."**
>
> — *Karim Selouane, founder of Resallience*

Fighting the rise in sea level is a question of spatial scales, but also of timescales. As Patrick Bazin notes, while the timing of sea level rise is long (decades or even centuries), the time of investment is shorter, not to mention that of the political mandate. Patrick Bazin recalls that the first call for projects by the French Ministry of Ecology to help local communities to think about relocation solutions was held in 2012; five municipalities submitted projects, four of their mayors were not re-elected in the following municipal elections. Responding to sea level rise also means taking up a major challenge: social acceptability.

> **When we talk about adaptation with elected officials, two major issues come to the fore: financial solidarity on an international scale and social acceptability.”**
>
> — *Raphaël Cuvelier, Vice-President of the Ocean & Climate platform*

A social acceptability challenge

Fighting against sea level rise is largely a question of social engineering: “we must co-construct with the population, which will not accept solutions it does not understand”, says Patrick Bazin. Among these controversial solutions: the relocation of populations, as planned by the Indonesian government for the city of Jakarta, or as Florida will no doubt have to do in the future, as its cities are now increasingly uninsurable due to the risk of flooding. How can we convince coastal populations to change their way of life? Through co-construction and education, says Raphaël Cuvelier. La Rochelle has launched a foresight project to reflect, with all local stakeholders, on an adaptation trajectory based on a scenario corresponding to the rise observed during the Xynthia storm + 20 cm. At the University of Caen, researchers have developed a video tool that visually models the rise in water level on a stormy day, showing waves rushing down the streets. A way to help local populations realize the danger and accept a debate around the solutions. “The field of social sciences applied to climate change is still in its infancy,” says Raphaël Cuvelier. “However, it can encourage people to enter into a positive dynamic, by visualizing a desirable future”.

FRANÇOISE GAILL KEYNOTE AT LEONARD:PARIS
(CREDIT: LEONARD)

ARCMARINE, RESALLIENCE: INNOVATION FOR COASTAL PRESERVATION AND ADAPTATION TO RISING SEA LEVELS

—

Traditional underwater protection materials are made from concrete with a very high carbon footprint that is often toxic for the environment. This realization prompted ARCMarine CEO Tom Birbeck to develop nature-based solutions to improve offshore construction projects. First by creating "marinecrete", a plastic-free, 98% recycled and carbon-neutral marine concrete, and then by developing "reef cubes", coastal defense structures designed to serve as breeding grounds and nurseries for sharks, rays, and cephalopods. Seven months after installation, native algae and kelp have colonized the structures and micro-life has conquered the rock pools. The startup is also working on a prototype for a green harbor tile. "We design with nature in mind from the beginning," says Tom Birbeck.

Using satellite data, knowledge of infrastructure and built environments, and climate data, Resallience models complex systems to show domino effects at different scales. Two projects specifically address the issue of sea level rise. The first offers micro states and island states planning and management tools to adapt to climate change under different scenarios. Thanks to a resilience performance diagnosis, hazard scenarios are built, allowing public actors to better assess social costs and the cost of physical damage to better size adaptation solutions. A second project, implemented in Senegal, has created a prototype methodology combining scientific and socio-economic data to scenario investments aimed at reducing the impact of sea level rise. The aim is to help stakeholders build a multi-hazard vision and co-construct the coastline of tomorrow.

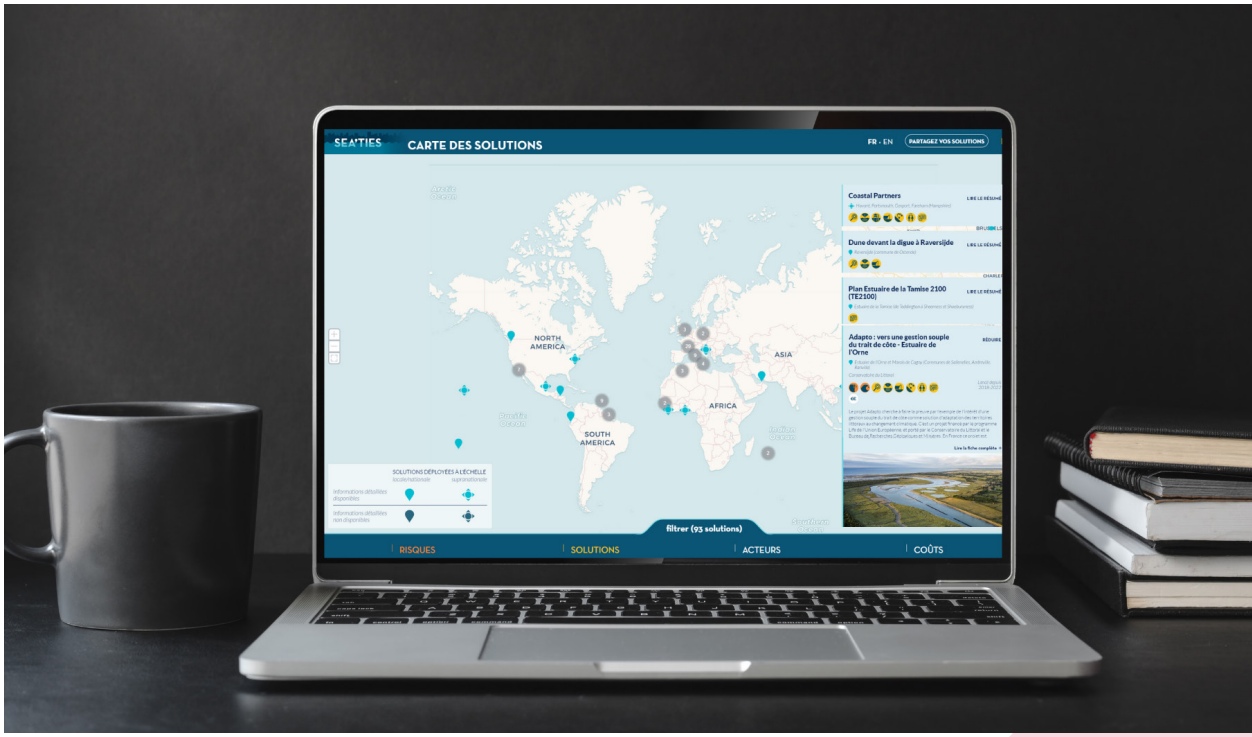
Sea level rise and coastal adaptation: key figures

Current average sea level rise:	3.2 mm per year[27]
Estimated rise in sea level by 2050:	+30 cm[28] (as much as during the entire 20th century[29]) and up to **+77 cm** by 2100
Estimated rise in sea level if glaciers and ice caps were to melt:	+65 m submerging Florida or Bangladesh[31]
Cost of the wall built to protect Jakarta from rising sea levels:	€35bn[32]
Share of the world's population living within 30 km of a coastline:	20%
Annual cost of flooding in coastal cities:	€750bn[33]
Beaches threatened with disappearance by 2100:	50%[34]
Length of the French coastline:	20,000 km[35]

SEA'TIES: cooperation in the face of sea level rise

Knowledge-sharing between cities faced with the same challenges is one of the keys to urban resilience. That is why the Ocean & Climate platform has designed the SEA'TIES project, which aims to spread knowledge of adaptation solutions across cities faced with rising sea levels. SEA'TIES collects data on solutions implemented in different coastal regions to identify replicable "best practices", then supports urban stakeholders wishing to implement these solutions, while promoting them to national and international bodies.

https://ocean-climate.org/seaties/



SEA'TIES MAPPING SOLUTIONS
(CREDIT: SEA'TIES)

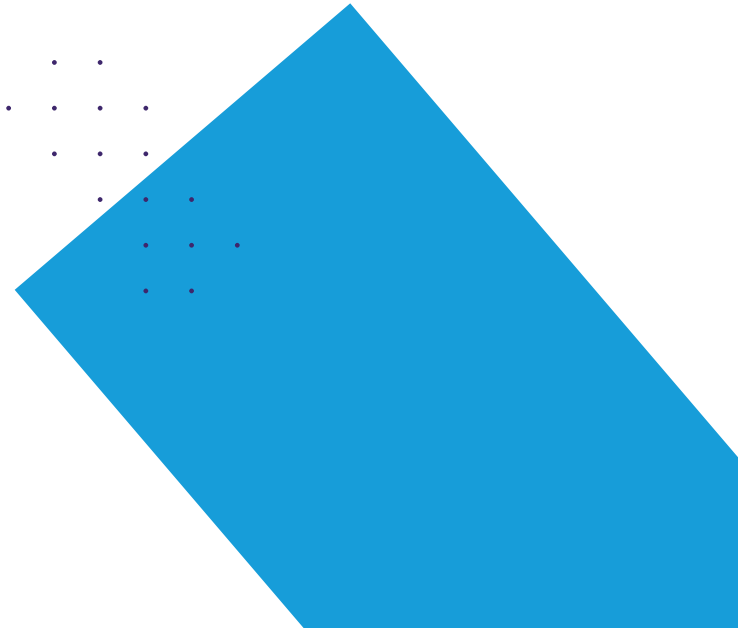
Oceans and cryosphere: the IPCC's warning

In September 2019, in Monaco, the 195 member states of the Intergovernmental Panel on Climate Change (IPCC) presented findings from a landmark report on the ocean and cryosphere (i.e., land surfaces where water is present in solid form). 100 authors from 36 countries analyzed some 7,000 publications and drew one conclusion: the warming of the ocean and cryosphere is accelerating and requires urgent and effective responses.

In this momentous study, IPCC scientists set out to demonstrate the interactions between the cryosphere and the oceans: predicting continued melting of land-based ice (glaciers, snow, permafrost, etc.), they anticipated the atrophy of 80% of small European, East African, Andean, and Indonesian glaciers by the year 2100[36] and credited the melting of the cryosphere for a rise in sea level that could reach 30-60 cm by 2100[37]. Climate change affects the oceans in additional ways: the warming (and therefore the expansion) of the seas, directly linked to that of the air, and their progressive acidification. These are all major destabilizing factors for marine ecosystems, whose supply of oxygen and nutrients is being depleted.

The IPCC also emphasizes the major risks that these transformations pose for human societies. Faced with rising sea levels, islands and coastlines will be particularly vulnerable: events that previously occurred once a century will occur every year by 2050 in many regions, increasing the risks faced by many coastal cities and small low-lying islands, the scientists note[38]. Ocean warming is also causing a loss of biodiversity that is detrimental to human health, as well as species shifts that can affect the economic health of communities that depend on fishing for their livelihoods[39]. At the same time, the melting of the cryosphere can trigger natural disasters with devastating effects on human societies: avalanches, floods, landslides...

Faced with these challenges, the IPCC calls for a consensus on ambitious measures, which should mainly aim to limit and reduce greenhouse gas emissions, in order to minimize the transformation of the ocean and cryosphere and the damage to ecosystems and societies that depend on them[40]. The IPCC scientists also call for controlled exploitation of ocean resources, the regeneration of ecosystems, as well as the pursuit of existing solutions: dikes, replanting of mangroves, adaptation of coastlines... These actions must be conducted simultaneously to preserve the oceans, whose fate is directly linked to ours.



RespectOcean: federating actors committed to preserving the Ocean

To commit to a sustainable development compatible with the ocean's preservation, a hundred French companies and economic actors have joined the RespectOcean association, founded by yachtswoman Raphaëla le Gouvello.

Presided by Claude Fromageot, RespectOcean brings together diverse actors who wish to reduce their impact on marine and coastal ecosystems. The association's main missions are to help promote solutions and innovations, to encourage synergies between projects, and to participate in the rise of a sustainable blue economy.

http://www.respectocean.com/

(CREDIT: FRANCESCO UNGARO - PEXELS)

From Atlantis to Noah's ark: when humanity pictures its future on (and under) the water

Faced with rising sea levels and climate change, architects and urban planners are coming up with striking solutions, from floating cities to underwater habitats. While some of these ideas have no equivalent outside of literature or mythology, others are inspired by real-life experiences, some of which are several centuries old. All set out potential paths for life in an increasingly threatening environment.

Floating cities, an ancestral technology

Global warming has displaced 318 million since 2018[41], raising doubts over the sustainability of residential areas located in coastal zones. This debate has rekindled an interest in floating cities, particularly among island states and coastal metropolises, which are on the frontlines of sea level rise. Rather than fleeing the water, why not live on its surface? The idea has precedents, some of which are centuries old: nearly 500 years ago, seeking to protect themselves from attacks by the Incas, the indigenous people of Uros, in Peru, built islands made of reeds and totora, a local plant resistant to water. 120 of these islands still float on the surface of Lake Titicaca, where they are home to 1 300 inhabitants[42]. In the 1960s, architect Buckminster Fuller worked on "Triton City", a floating city project for Tokyo Bay, which never came to fruition[43].

These projects raise important technical challenges: first and foremost, there is the question of their safety and their performance at sea (flotation, interaction with the waves, resistance to storms, etc.), followed closely by issues of energy supply, waste management and mobility, all with a view to sustainability and preservation of the maritime environment. However, they have strong potential and are expanding the realm of urbanistic possibilities: in tomorrow's floating city, stadiums, schools, parks, and other amenities could well move from one place to another depending on events and demand[44].

These solutions' potential is not going unnoticed: new floating city projects are born every year. On Lake Eimer, near Amsterdam, the "Waterbuurt" project aims to build up to 18,000 floating houses, a promising solution in a country particularly exposed to rising water levels[45]. In the Maldives, a floating city built in a lagoon is expected to be completed by 2027 and will house nearly 20,000 people. Finally, in April 2019, a summit on floating cities organized by UN-Habitat, the MIT Center for Ocean Engineering, OCEANIX, and the Explorers Club resulted in a project to build a floating city prototype[46]. Two years later, in November 2021, South Korea, UN Habitat and OCEANIX entered into an agreement to build the world's first "sustainable floating city" in Busan[47].

A FLOATING CITY MADE OF PLASTIC WASTE - AEQUOREA BY VINCENT CALLEBAUT
(CREDIT: VINCENT CALLEBAUT ARCHITECTURES PARIS)

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Will we live in underwater cities?

Faced with the challenges of adapting to rising seas and reconciling environmental preservation with a growing world population, a second solution is emerging: underwater cities. Their technical complexity makes them a more uncertain (and rarer) option than floating cities, and to date, there are only a handful of underwater habitats, one of which serves as a training base for the US Navy and NASA astronauts. But the potential is significant: as an expert explained to the BBC, the state of existing technological know-how already allows for the construction of underwater colonies that can house up to 100 inhabitants[48]. Here, too, the technical challenges are impressive: it is impossible to build at more than 300 meters below sea level, because of extreme pressure, which would subject the materials to considerable stress and would impose long periods of decompression at each ascent to the surface[49]. Also, such colonies will require permanent control of oxygen and humidity levels and the development of extremely fast evacuation systems in case of danger. Finally, floating cities raise many technical issues, from waste disposal to the supply of food, water, and energy. But ideas abound in this area: underwater cities could use wave energy (see p. 29) or be supplied with electricity by solar panels located on the surface[50].

IV.

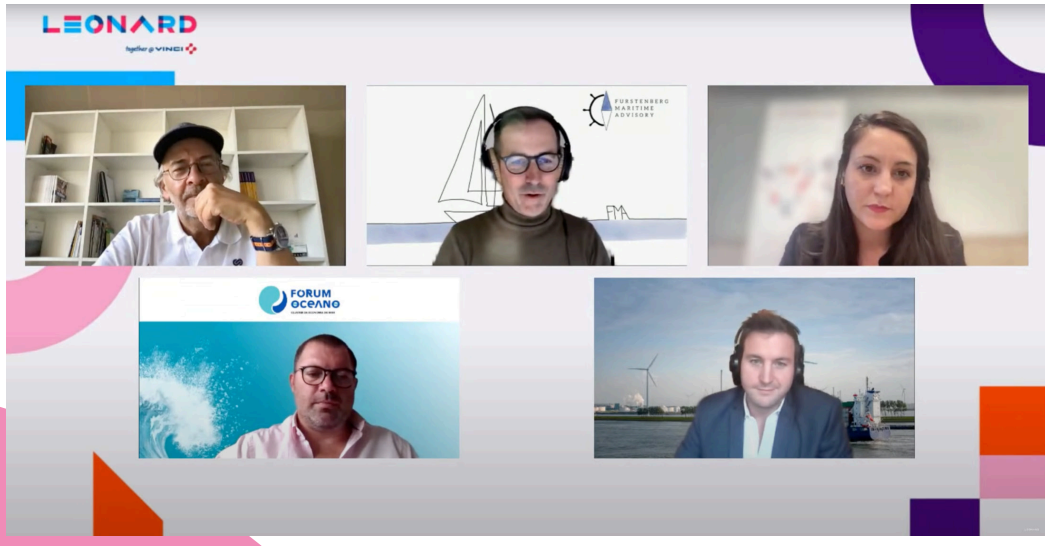
PORTS AND MARITIME INFRASTRUCTURE: TIME FOR REINVENTION!

Ports are undoubtedly the hubs of international trade. Because they concentrate logistics flows and are our primary interface with the oceans, port areas and their hinterlands are at the heart of the pursuit of a sustainable blue economy. From ports to sea freight, read on for an overview of the innovative solutions being invented today in ports all over the world.

Ports: new hubs of the energy and mobility transitions

Often close to vulnerable natural ecosystems, ports are in a privileged position to rise to the environmental challenge and lead the transition to a sustainable blue economy, by reducing their carbon footprint and becoming testbeds for tomorrow's energy, shipping, and aquaculture solutions.

This article is based on a discussion hosted by Leonard on October 3rd, 2022. Scan the code to watch the replay.



LOUIS-NOËL VIVIES, CONOR FURSTENBERG STOTT, LUDIVINE SERRIERE, RUBEN EIRAS, THIERRY DUCELLIER
(CREDIT: LEONARD)

Gateways to a sustainable blue economy

Ports are complex interfaces that involve a variety of stakeholders, from municipalities and shipping contractors to offshore windfarms... to the extent that it seems almost impossible to list all the roles involved in a port's life, notes Thierry Ducellier, head of sales at Sinay, a French startup offering maritime data solutions. Even our individual behavior, as demanding customers expecting their online orders to be delivered in 24 hours, has direct consequences on the operation and environmental impact of ports, says Ducellier. For Ruben Eiras, Secretary-General of Fórum Oceano, a large Portuguese cluster of blue economy companies, the responsibility of ports extends well beyond reducing their own footprint: they should instead strive to become hubs of the blue economy by focusing on their specificities. Large industrial ports and small fishing ports are not direct competitors and can increase their competitivity by capitalizing on their geographic and historic specificities. Certain industrial ports may be especially appropriate to the support of the floating offshore wind industry, says Eiras; while fishing ports, thanks to the absence of nearby industrial activities and the cleanness of their waters, may be appropriate sites for the development of onshore aquaculture facilities.

Ports' geographical, economic, and historical specificities are at the heart of the Atlantic Smart Ports Blue Acceleration Network (ASPBEN), a project financed by the European Maritime and Fisheries Fund and comprised of 15 entities from Portugal, Spain, France, Netherlands, Norway, and the United States. Its aim: to build an accelerator platform for the blue economy built on a network of mid-sized ports. ASPBEN has identified ten challenges based on the needs expressed by 33 ports situated along the Atlantic, from increasing operational efficiency to promoting marine energy or using port infrastructure to foster biodiversity. All in all, over 140 pilots are to be implemented by 70 startups selected from a pool of 200, supporting the idea that all ports have a unique culture, and that building trust and collaboration among ports is a steppingstone to successful innovation.

The challenges ahead: from clean energy to digitalization

Decarbonization is key to the advent of a sustainable blue economy. For Louis-Noel Viviès, the decarbonization of maritime transportation will hang on the development of affordable, green hydrogen, a transition in which large ports have a crucial part to play. Viviès mentions Singapore, a top bunking port home to one of the world's largest oil refineries. At the crossroads of countless maritime roads, the city-state could easily play a leading role by diverting 10% of the hydrogen it currently uses to produce diesel towards using hydrogen as a direct source of clean energy, says Viviès. Large ports, which are often primarily industrial sites, are in fact uniquely positioned to invest in clean energy sources.

> **To attract, ports must be interoperable and connected.”**
>
> — *Ruben Eiras, Secretary General of Fórum Oceano*

The transition to a blue economy also depends on digitalization, a promising way for ports to increase their operational efficiency while slashing their greenhouse gas emissions. "Paradoxically, ports tend to be very conservative, while their success depends on being open and connected. Without access to certain routes, a port is done for. Ports must attract, and to do so, they must be interoperable and connected", says Ruben Eiras. Yet a gap remains between theory and practice when it comes to digitalization. "Ports face many barriers: administrative complexity and politics often mean that testing solutions takes considerable time; by the time they are implemented, they are often obsolete", says Thierry Ducellier.

And digital solutions are not enough: while highly efficient, port community systems, for instance, require well-trained staff and interoperability. These challenges mean that while many ports have the financials means to invest in their digitalization, many can still not go through with it. Another piece of the solution to increased digitalization may lie in better information-sharing: technology can help predict ships' estimated arrival times, for instance, but "while the data is here, if it is not shared properly, it is not going to work", says Thierry Ducellier.

By overcoming these challenges, ports can go from historic catalyzers of trade and development, says Ruben Eiras, to ultimate testbeds for the solutions that will transform energy, shipping, sustainable aquaculture, and ocean monitoring. The next decades will show whether they can rise to the challenge and become pioneers of the blue economy.

(CREDIT: DOMINIK LÜCKMANN - UNSPLASH)

ECOSUBSEA, NATURE METRICS, SINAY: DECARBONIZING PORT AND MARITIME ACTIVITIES

ECOsubsea (Norway) offers an innovative solution to the challenge of biofouling, the detrimental accumulation of biodiversity on hulls and maritime infrastructure. Since a 2008 ban on poisonous ingredients previously used to prevent this buildup, biofouling has become pervasive, leading species to "hitchhike" from one region to another, potentially causing considerable threats to local marine ecosystems and decreasing ships' fuel efficiency. Faced with this challenge, ECOsubsea has designed a robot that behaves like a vacuum cleaner, thanks to a patented principle that cleans ships' hulls without damaging their coating and uses the recovered biological material for biogas and green electricity production. Thanks to this groundbreaking solution, ECOsubsea recently removed 2 tons of biofouling from the hull of the Charles de Gaulle aircraft carrier and 78,500 tons from an oil rig in Norway. "We are strong believers in the idea that ports can play a vital role in decarbonizing shipping and stopping biodiversity collapse", says ECOsubsea CEO and founder Tor Østervold.

In recent years, companies, ports, and organizations have become acutely aware of the need to monitor and mitigate their impact on marine biodiversity. Yet unlike carbon, biodiversity is not easily measured. That is why Nature Metrics (United Kingdom) has developed a marine biodiversity monitoring solution based on environmental DNA. "E-DNA is the biological footprint that an organism leaves behind in the water for a few hours to a few days after it has left the area. We use a water sample to generate a list of all the species that have been in the area within that timeframe", says Samuel Stanton, Business Development Lead at Nature Metrics. The data is then presented in a highly engaging visualization that allows stakeholders to fully grasp the diversity of species in a given area. E-DNA allows for biodiversity comparisons between sites and provides a great way to measure the efficiency of biodiversity-restoration initiatives. While a conventional sample was unable to highlight the difference between a British oil refinery site and a neighboring nature reserve, E-DNA was able to show extreme differences in local biodiversity, creating clear data that speaks to stakeholders and allows for more informed decision-making.

Sinay (France) offers a data collaboration platform that helps the maritime industry better communicate and understand the impact of their activities on their environment. The company works to offer wind farms and port extensions the precise information needed to help them limit their environmental impact. Thanks to expert knowledge of the ocean, Sinay can recommend simple actions that can drastically reduce greenhouse gas (GHG) emissions: "without even talking about hydrogen or electrification, a mere two-knot decrease in a container ship's speed can reduce its GHG emissions by thousands of tons", says Thierry Ducellier, Sinay's head of sales. Sinay's cloud-based big data platform aggregates a wide variety of data to help ports monitor environmental metrics such as air or water quality in real-time and take appropriate measures when an issue arises. A necessary approach at a time when sustainability is bound to become synonymous with competitivity. On 9 November 2022, Sinay announced a new, 1.6-million-euro contract with the European Space Agency for the creation of a digital maritime platform.

"Blue Carbon": the role of marine biodiversity in capture

Marine biodiversity refers to the vast multitude of known and unknown living entities in the sea, from microorganisms, to plants, to animals[51]. But what role do the ocean's ecosystems and inhabitants play in capturing aquatic, "Blue Carbon?"

As our greatest protection against climate change, the ocean is considered by many the "lungs of the planet" and scientifically proven to be our largest carbon sink[52]. Generating 50% of the oxygen we need, the UN estimates it also "absorbs 25% of all carbon dioxide emissions and captures 90% of the excess heat generated by these emissions."

Some of the most important ecosystems that serve as carbon sinks and offer ecosystem services (benefits to humans[53]) include seagrass meadows, mangrove forests and kelp forests.

Seagrass meadows cover only 0.1% of the ocean bed, but store anywhere from 10 to 18% of all carbon in the ocean, according to a January 2020 study[54]. Sea grasses primarily trap CO_2 in sediment around their roots, stems and leaves.

These meadows also serve as nursery habitats and feeding grounds for grazing animals like manatees and endangered sea turtles[55]. Their ability to reduce the acidity of surrounding waters (resulting from ocean warming), protects biodiversity with exoskeletons (such as plankton and krill), an essential food source for whales. In the course of their lifetime, whales can absorb 33,000 kilograms of CO_2, on average[56] and upon passing, the carcasses sink, trapping carbon in ocean floor sediment.

Another coastal environment – lying at the intersection of land and sea, with roots like stilts – is the mangrove forest. The Nature Conservancy reports that these coastal systems are especially biodiverse, offering refuge to 341 threatened species worldwide.

As for ecosystem services, they trap up to four times as much carbon as trees and serve as a first line of defense against coastal flooding[57]. From an economic standpoint, they "prevent more than US$65 billion in property damages and reduce flood risk to some 15 million people[58]."

A final, essential aquatic forest ecosystem, the kelp forest, holds great promise for Blue Carbon capture. Previously overlooked – because when kelp forests deteriorate, they release carbon back into the environment – research increasingly shows that vertical ecosystems of brown algae serve as a carbon sink. They also store carbon in sediment and sequester it when plants sink to the deep sea. In 2016, Nature Geoscience published a paper estimating that these ecosystems store around 175 million tons of carbon annually[59].

(CREDIT: ALEXANDROS GIANNAKAKIS - UNSPLASH)

All of these invaluable ecosystems serve as a refuge from warming seas to their own biodiverse inhabitants and support the delicate balance of the ocean's food chain and the circulation of nutrients, including the locking away of carbon in sediment and on the ocean floor. As such, supporting the continued resilience of biodiversity across these ecosystems ensures their ability to continue capturing Blue Carbon.

Sea freight: an urgent need for decarbonization

Maritime transport of goods now accounts for 90% of world trade[60], and these flows are only increasing, thanks to the development of e-commerce and population growth. Each year, 10 billion tons of goods pass through the world's ports. The carbon footprint associated with these exchanges is also on the rise: according to Carbone 4, if sea freight were a country, it would be the sixth largest emitter of greenhouse gases in the world[61]. How can we decarbonize a sector upon which hangs the health of the global economy?

A rapidly growing carbon footprint

In 2018, some 54,000 merchant ships[62] emitted nearly 1 million tons of greenhouse gases (GHGs), accounting for close to 3% of global CO_2 emissions. Due to the strong growth in trade flows, these emissions[63] have increased by 30% since 1990, even as a slow decarbonization of sea freight was taking place: between 2008 and 2019, the amount CO_2 emitted per ton decreased by the same amount, thanks to the launch of more modern and energy-efficient ships and new operational practices[64]. These advances should not hide the fact that the International Energy Agency anticipates a 135% increase in the amount of carbon dioxide emitted by sea freight between 2018 and 2050[65].

A changing regulatory environment

The International Maritime Organization (IMO), an international governance forum for the maritime sector, issues binding standards applicable to international merchant ships and aimed at limiting their GHG emissions. These standards provide for the installation of power limiters[66] and systems to increase the hydrodynamics of ships, the assignment to each ship of a grade from A to E based on its actual carbon intensity[67], and a minimum level of efficiency for new ships[68]. By making it possible to better understand the emissions of each ship, these measures should, as the French Ministry of Ecology points out, "allow [...] States, financiers, clients or ports to implement [...] additional measures or incentive mechanisms such as bonus-malus[69]". These measures are part of the IMO's aim to cut the maritime sector's emissions by 50% by 2050. Its member states recently voted in favor of a targeted 11% reduction in CO_2 emissions between 2020 and 2026, an insufficiently ambitious objective in the eyes of the French government, which proposed a target of -22% for the period 2019-2030[70]. In accordance with its aim to reach carbon neutrality by 2050, Europe has set a more ambitious course: by the end of the year, following a decision by the European Parliament, sea freight should be integrated into the European CO_2 emissions trading scheme[71]. However, the IMF is pessimistic about this measure, stating that a tax of 75 cents per ton would only reduce emissions by 15%[72].

Wind, hydrogen, electricity: marine fuels of the future?

In addition to operational and energy efficiency solutions, as well as attempts at global regulation, technological solutions are emerging that aim to replace fossil fuels with cleaner energies. In this context, marine propulsion is attracting interest. A study estimates that up to 10,000 ships could use this method by 2030, avoiding the emission of 3.5 to 7.5 million tons of CO_2[73]. Neoline, a company based in Nantes (France), plans to launch a vessel powered by diesel engines in 2024-2025 to transport goods from France to the United States. This will reduce fuel consumption by 90% compared to a conventional cargo ship of the same size[74]. Also in Brittany, the Regional

Council recently launched the first vehicle-powered freight network, bringing together 150 companies[75]. Electricity and hydrogen, too, are raising high hopes: Norwegian group Yara is about to launch the Birkeland, the first fully electric and autonomous cargo ship[76], while Swedish company Green City Ferries has designed a carbon-neutral catamaran powered by electricity and hydrogen. Similar enthusiasm can be found in the methanol sector, with Maersk announcing an order for several vessels running on this fuel. While promising, these solutions have limitations of their own: as Carbone 4 points out[77], it will be difficult to propel large ships with battery electricity or hydrogen-powered fuel cells. Carbone 4 also highlights the high cost of synthetic fuels and the environmental cost of developing biofuels (land use, deforestation, etc.)[78].

FARWIND - GREEN SHIP

A spin-off of the École Centrale de Nantes, startup FARWIND aims to decarbonize sea freight by using innovative technologies, such as the energy ship:

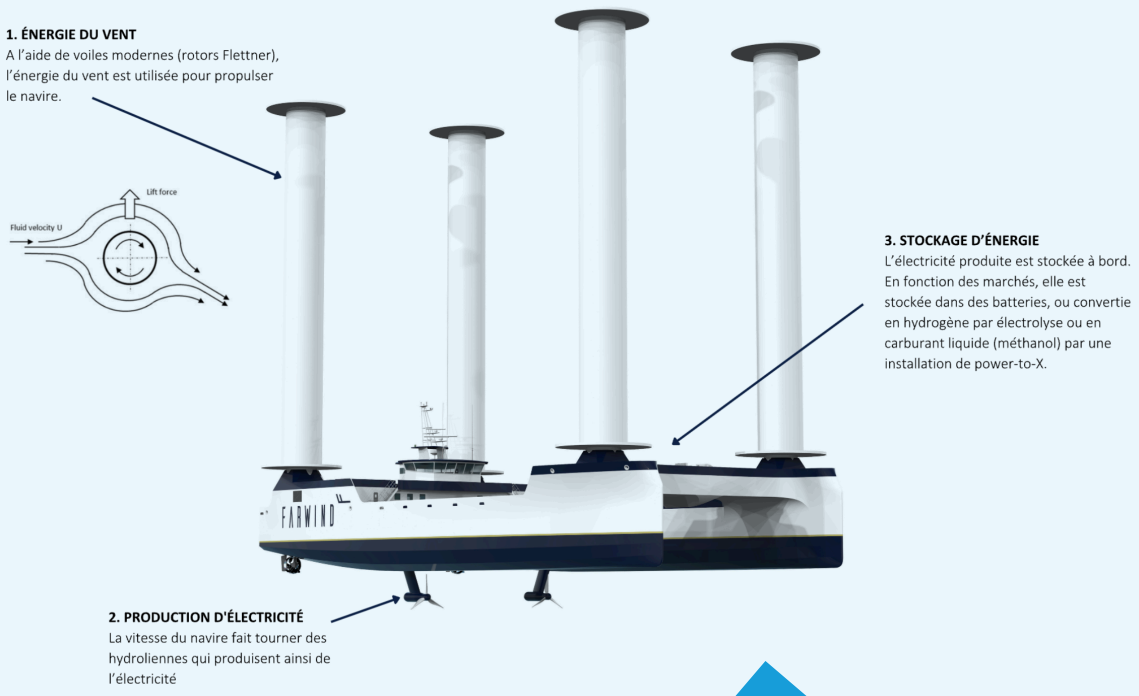
"At first, energy ships are ships propelled by the wind. In FARWIND's energy ships, wind propulsion is obtained using Flettner rotors, which are vertical rotating cylinders which convert wind into a propulsion force through the Magnus effect. Energy ships are equipped with water turbines which convert the ship's kinetic energy to electricity. Energy ships being mobile, the generated electricity must be stored on-board. Depending on customers' needs, the energy is stored in battery or converted in an energy vector."

https://farwind-energy.com/fr/technologie/

KIWIN - GREEN SHIP

KiWin is one of the winning projects of the AMI CORIMER 2022, the results of which were announced during the Assises de l'économie de la Mer, on November 8th, 2022, in Lille (France):

"The challenge of the KiWin collaborative project, of which Beyond the Sea is lead partner, is to offer, thanks to a disruptive innovation, an aerotracted propulsion solution (automated ship traction by kite), designed to be used in hybridization on existing or future ships over 60 meters long, to contribute to the energy transition and the decarbonization of fishing vessels and trade."



FARWIND - GREEN SHIP
(CREDIT: FARWIND)

Glossary

Oceanic biodiversity

The cradle of life on Earth, oceans are also home to their own biodiversity. From plankton to blue whales, this biodiversity is thought to comprise 500,000 to 10 million species (not to mention some 10 billion microbial species!). As of today, only 240,000 of them have been inventoried[79].

Blue carbon

Derived from the decomposition of plants, wood, roots, and animals, blue carbon is the organic carbon stored by marine and coastal ecosystems, including salt marshes, sea grass beds, and mangroves[80]. These highly productive ecosystems create a gigantic carbon sink that plays a central role in climate change mitigation.

Blue economy

According to a now authoritative UNESCO definition, "the Blue Economy concept seeks to promote economic growth, social inclusion, and the preservation or improvement of livelihoods while at the same time ensuring environmental sustainability of the oceans and coastal areas."[81].

Protected area

According to the International Union for Conservation of Nature (IUCN), a protected area is "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values"[82].

Seabed mining

Refers to the exploitation of ocean resources, whether they be animal (fishing) or mineral (extraction of hydrocarbons, metals and substances buried in the ocean floor). Continued exploitation raises the question of the threats posed by these extractive activities to the balance of ocean ecosystems.

Blue finance

Blue finance is an emerging component of climate finance, with public and private (retail and institutional) investors financing the sustainable blue economy. The United Nations Environment Programme Finance Initiative (UNEPFI), the European Commission, the World Wildlife Fund (WWF), the World Resources Institute, and the European Investment Bank have jointly defined a list of 14 principles that should govern the financing of a sustainable blue economy [83], now a reference framework for banks, insurers, and investors.

Marine geothermal energy

Geothermal (literally, "heat from the earth") energy refers to the use of heat energy, i.e., temperature differentials between surface and deep waters, to generate energy through a heat pump (e.g., to supply heating and/or cooling to buildings).

Mangroves

Mangroves are forest formations (mainly made up of mangrove trees) that develop on tropical coastlines. They are extremely interesting from an ecological standpoint, as they simultaneously act as biodiversity reservoirs, protect soils from erosion, and provide many communities around the world with wood for construction and heating [84].

Ocean governance

Ocean governance is the joint management by states of oceans and their resources with a view to ensure their preservation and productivity[85]. It is governed by the United Nations Convention on the Law of the Sea of Montego Bay (1982), an international treaty that establishes areas of state jurisdiction by distinguishing between internal waters, territorial seas, contiguous zones, and EEZ. The high seas (60% of the earth's surface area), which do not belong to any State[86], fall outside the jurisdiction of the Convention.

Ocean regeneration

This term refers to the renewal of oceanic species (fauna and flora) threatened by human activities and global warming. Many blue economy stakeholders advocate for going beyond the mere goal to protect the oceans and setting a more ambitious objective: ocean regeneration.

Coastline

The coastline is the symbolic delimitation of the boundary between land and marine waters. It is mobile: erosion, accumulation of sediments, or the construction of polders and dikes can make it move[87]. Of the 3,420 km of coastline in France, 270 km are receding by more than 50 cm each year[88].

RAMPION WIND FARM (UNITED KINGDOM)
(CREDIT: NICHOLAS DOHERTY - UNSPLASH)

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The final word

— *Benjamin Lesage, Global coordinator @soalliance*

I met Benjamin Lesage in San Francisco in 2020. At the time, we shared the same mission: to monitor technology and write foresight briefs on major global trends for our respective companies, on my end for the VINCI group through Leonard and on his, for the BNP Paribas group. We had a long discussion about the upheavals our respective companies and ecosystems were facing, particularly in relation to climate change awareness. The role of the ocean was often mentioned but generally not well documented within our companies. Benjamin joining the Sustainable Ocean Alliance in 2021 has given us the opportunity to explore major challenges of the sustainable blue economy and to reflect together on prospects for the development of marine renewable energies, the future of ports and infrastructures, and the resilience of coasts and marine ecosystems. We hope that the events organized and summarized in this study will ignite fruitful collaborations in the interest of the planet and all those who inhabit it.

— *Ludivine Serrière, Innovation Program Manager, Leonard*

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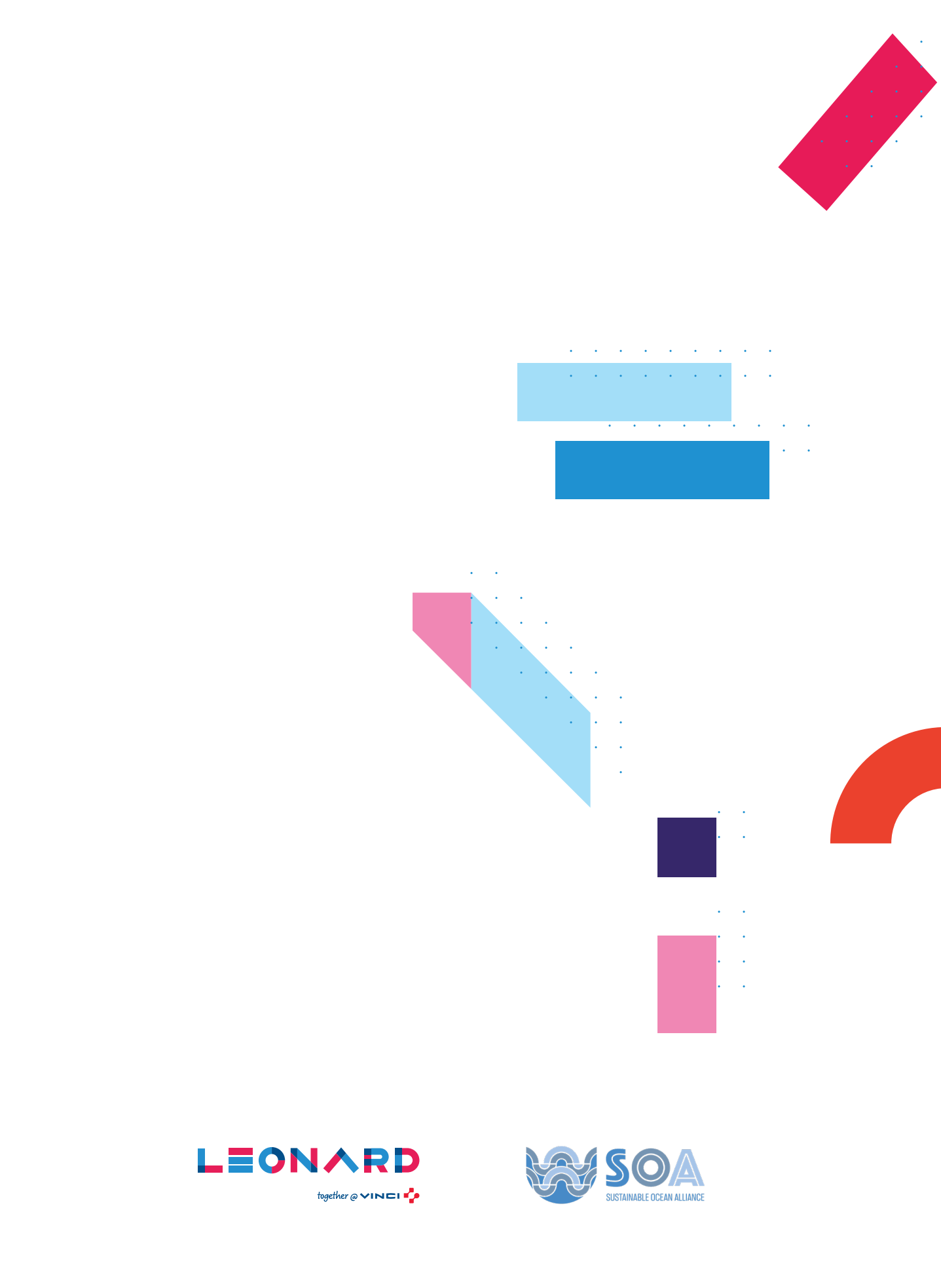
About

Leonard is the name of the VINCI Group's foresight platform and fast track for innovative projects, launched in July 2017. Why Leonard? To respond to some of the biggest challenges facing VINCI's businesses: digital revolution, faster innovation cycles and environmental transition. Within a transforming world, Leonard detects new trends, supports innovation, and brings together all the players involved in shaping the future of cities and regions.

leonard.vinci.com

In 2014, ***Sustainable Ocean Alliance (SOA)*** was founded by Daniela Fernandez, one of the 2019 Forbes 30 Under 30 and a member of the World Economic Forum Friends of Ocean Action. SOA activates young people, develops, and implements innovative solutions, and mobilizes an ocean workforce to restore the health of the ocean in our lifetime. We have built the world's largest network of young ocean leaders and supported innovative startups, nonprofits, and grassroots campaigns dedicated to solving the greatest threats facing our planet.

soalliance.org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