Chapter 1.

An overview of the ocean economy: Assessments and recommendations

This chapter summarises the key findings of the report and offers a set of recommendations to strengthen international co-operation in the sustainable management and development of the ocean economy of the future. It puts forward a working definition of the ocean economy which encompasses not only the ocean-based industries but also the natural assets and ecosystem services that the ocean provides. Focusing on the ocean industries, the chapter outlines the findings of the OECD Ocean Economy Database *and briefly presents the estimates of the current value added and jobs provided by the ocean economy worldwide. Turning its attention to the future, the chapter describes the principal forces driving the ocean economy forward, and estimates value added and employment in the global ocean economy by 2030. The results suggest rapid growth of most ocean industries over the next couple of decades, putting increasing strain on the ocean environment and its resources and posing significant challenges to ocean management. The chapter ends by proposing a set of recommendations for governments, business and research which could significantly enhance sustainable ocean management.*

The ocean and its resources are increasingly recognised as being indispensable for addressing the multiple challenges that the planet faces in the decades to come. By mid-century, enough food, jobs, energy, raw materials and economic growth will be required to sustain a likely population level of between 9 and 10 billion people. The potential of the ocean to help meet those requirements is huge, but fully harnessing it will require substantial expansion of many ocean-based economic activities. That will prove challenging, because the ocean is already under stress from over-exploitation, pollution, declining biodiversity and climate change. Hence, realising the full potential of the ocean will demand responsible, sustainable approaches to its economic development.

Introducing the ocean economy

At the centre of attention in this report on the economic development of the ocean is the future evolution of established and emerging ocean-based industries and activities. Broadly speaking, established ocean activities encompass shipping, shipbuilding and marine equipment, capture fisheries and fish processing, maritime and coastal tourism, conventional offshore oil and gas exploration and production, dredging, and port facilities and handling. Emerging ocean-based industries and activities are characterised by the key role played by cutting-edge science and technology in their operations. They include: offshore wind, tidal and wave energy; offshore extraction of oil and gas in deep-sea and other extreme locations; seabed mining for metals and minerals; marine aquaculture; marine biotechnology; ocean monitoring, control and surveillance. Looking further to the future, there are fledgling or, as yet, "unborn" industries which could potentially join this category. Examples are carbon capture and storage (CCS) and the management of ocean scale protected areas.

There is no hard and fast distinction between established and emerging industries. Indeed, some degree of overlap does exist, not least where segments of established ocean industries manifest clear indications of rapid growth and quite dramatic rates of innovation. For example, shipping and port activities are moving increasingly to highly sophisticated levels of automation; coastal aquaculture is well established in some countries, but at industrial scale it is becoming a highly science- and technology-intensive activity and is looking to expand further offshore; ocean monitoring and surveillance are benefiting from massive advances in satellite technology, tracking and imaging; and the cruise industry is turning its attention to new destinations such as the Arctic and Antarctica. Nonetheless, the division into established and emerging industries offers a pragmatic and manageable approach for the project.

The landscape of traditional maritime industries will be undergoing significant change in the coming decades. This is partly driven by global economic growth and increasing demand. In the shipping sector, for example, container traffic looks set to continue to grow very fast, with volumes likely to triple by 2035 (OECD, 2015). Fisheries production worldwide is expected to expand by around a fifth over the next ten years, although the main driver of overall production will be aquaculture (OECD and FAO, 2015). Even if improvements have been made in recent years, there is little or no room for further expansion in wild fish catch in the absence of strict management plans to rebuild stock abundance to biologically sustainable productivity levels. And in tourism, ageing populations, rising incomes and relatively low transport costs will make coastal and ocean locations ever more attractive. Concurrently, developments in traditional maritime industries will also be shaped by climate change, as shifts in temperature, ocean acidity and rising sea levels affect movements of fish stocks open up new trading routes, affect sea port structures, and create new tourist destinations and attractions, whilst destroying others.

Emerging ocean-based industries offer vast opportunities for addressing many of the big economic, social and environmental challenges facing humankind in the years ahead. These emerging ocean industries are developing and applying a range of science and technological innovations to exploit the ocean's resources more safely and sustainably, or to make the oceans cleaner and safer and to protect the richness of their resources. The activities differ considerably in their stage of development: some are relatively advanced while others are still in their infancy. To bring them on stream on a scale that would allow them to contribute in a meaningful way to global prosperity, human development, natural resource management and green growth will require considerable research and development (R&D) effort, investment and coherent policy support.

Such efforts, however, need to be shaped and directed with a view to the future, which is why this project has its sights set on 2030 and beyond.

Economic activities in an ocean environment

Management of economic activities in the ocean needs to be put into the physical context in which it operates: a fluid, buoyant, three-dimensional environment that covers about two-thirds of the planet's surface. The obvious – and in some cases less obvious – differences between land and sea have important implications as to how human activities are managed in the two very different environments. Nonetheless, although these differences affect the context and outcomes of marine operations, many of the concepts and techniques deployed in marine planning and management tend to be borrowed from practices on land.

Box 1.1. **What makes the ocean economy different from a land-based economy?**

Difference #1: The sea is much larger than land

Implication: Natural marine processes, ecosystems and species are not confined to maritime legal boundaries. Different legal regimes apply to a single activity depending on where it takes place, even within the jurisdiction of a single coastal country (territorial waters, contiguous zone, economic exclusion zone), and is further compounded by the interests of other countries in areas beyond national jurisdiction (international waters).

Difference #2: Water is less transparent than air

Implication: Remote sensing technology is not able to penetrate deep below the sea's surface. This makes it much harder and much more expensive to know what's going on in the water column and the seabed. Marine research and monitoring costs are extremely high, which helps explain why we know much less about what goes on in the ocean than about what happens on land.

Difference #3: The sea is more three-dimensional than land

Implication: Marine life occurs from the sea surface down to the deepest ocean trench, while on land only comparatively few species (i.e. those with the ability to fly) can sustain themselves above the land surface. The same also applies, to a certain extent, to human activities. This renders two-dimensional maps less useful, and increases the complexity of marine spatial planning and management. It also makes it more difficult to study the marine environment, how it works, how it is affected by human activities (see difference #2), and how the ocean benefits the economy and human well-being.

Box 1.1. **What makes the ocean economy different from a land-based economy?** (*continued*)

Difference #4: The sea is fluid and interconnected

Implication: What happens in one place may affect what happens elsewhere, as pollutants and alien species are carried by ocean currents and/or vessels to much greater distances than on land.

Difference #5: Marine species can potentially travel much longer distances than terrestrial ones

Implication: This makes the management of human activities that use marine resources particularly difficult, as they are accessible to almost anyone.

Difference #6: Aggregations or clusters of animals in the water column can shift rapidly from one location to another

Implication: The mapping of these species and their movements is more difficult, and measures to protect or manage them need also to shift in time and space accordingly.

Difference #7: Nutrients and pollutants can be retained for several decades until they are returned by ocean circulation

Implication: There can be significant time lags between the periods when certain human activities take place and the time when their impacts occur, potentially placing significant burdens on future generations.

Difference #8: Lack of ownership and responsibility in the ocean are even less favourable to sustainable development than on land

Implication: Private utilisation of the ocean and its resources is usually dependent on licenses or concessions from public authorities. National authorities have the power to allow private activities in areas under the jurisdiction of the coastal state; the International Seabed Authority can license activities in the area, but in international waters, private activities have much fewer controls. Common property regimes are even scarcer than on land given the mobile nature of many marine resources, which makes the exclusion of non-authorised users extremely difficult.

Difference #9: Humans do not live in the ocean

Because the sea is not our natural environment, our presence is dependent on the use and development of technology. Our sparse presence in the sea also makes it much more difficult, and costly, to exercise adequate law enforcement.

Sources: Crowder and Norse (2008); Douvere et al. (2007); Douvere (2008); Ehler and Douvere (2007); Grilo (2015); Norse and Crowder (2005).

The ocean economy as a cluster of interconnected industries

Ocean industries are not developing in isolation, neither from one another nor from the ocean environment of which they are part. On the contrary, they interrelate and interact with other activities and their ocean surrounds in a myriad of different ways. But as long as maritime industries and the exploitation of marine resources are perceived as individual and separate activities, approaches to their development and their sustainable management risk remaining piecemeal and limited in their effectiveness.

Recent history has demonstrated time and again that once closely interconnected clusters of economic activities begin to be perceived as an economic system or "economy" rather than as a fragmented collection of individual sectors, they garner more attention and benefit from more coherent strategic approaches to their development.

Examples abound. With the advent and rapid expansion of information and communication technology (ICT) in the second half of the 20th century, the notion of the "information economy" became a household name. Also about that time, most governments around the world were developing separate plans for the construction and renewal of transport systems – rail, road, air, water, energy systems, ICT networks, water provision and treatment, etc. Not until it became increasingly clear that all these systems and networks are closely interconnected did one begin to see the emergence of more integrated "infrastructure" planning (OECD, 2007). More recently, the different segments of the space sector with their highly complex and steadily globalising value chains have come to see themselves as the "space economy", reaching from launchers, satellite construction and operations down to everyday applications in farming, transport, meteorology and global communications (OECD, 2011). Similarly, the different strands of the relatively young biotechnology sector – health and medicine, agriculture and food, industry – have come to be perceived more and more as a "bioeconomy" (OECD, 2009), to such an extent that there are now over 30 countries around the world with "bioeconomy" in their strategic goals (German Bioeconomy Council, 2015).

Differences in terminology

The terminology relating to the ocean economy is used differently around the world. Commonly used terms include: ocean industry, marine economy, marine industry, marine activity, maritime economy and maritime sector. "Ocean" is usually used in Ireland and the United States, whereas "marine" is widely used in Australia, Canada, France, New Zealand and the United Kingdom. "Maritime" is frequently used by the European Union, Norway and Spain. Often terminologies are also translated differently into English when they are taken from Japanese, Korean or Mandarin. The present report will endeavour to distinguish "maritime" and "marine" as follows: "maritime" will be understood as "being connected with the sea, especially in relation to seafaring, commercial or military activity", while "marine" will be understood as "of, found in, or produced by the sea, 'marine plants'; 'marine biology'".

While "industry" embodies only market-based activities in the private and public sectors, the term "economy" is better suited to capturing the notion of both market-based and non-market goods and services.

Definition and concept of the ocean economy

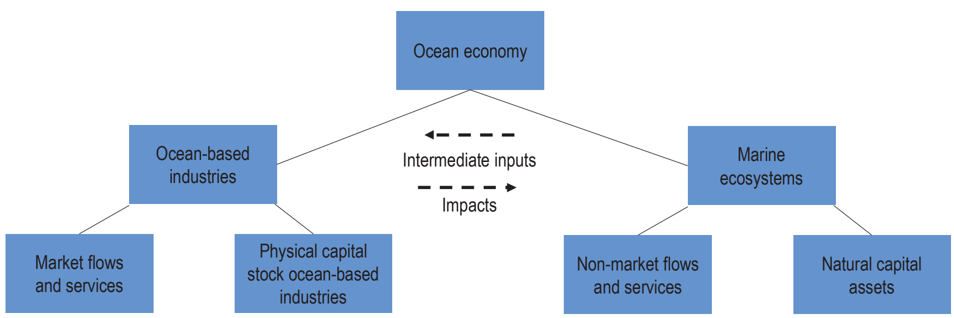
In addition to the differing terminology, there is still no universally accepted definition of the ocean economy. For example, for the European Commission (Ecorys, 2012), "the maritime economy consists of all the sectoral and cross-sectoral economic activities related to the oceans, seas and coasts. This includes the closest direct and indirect supporting activities necessary for the functioning of these economic sectors, which can be located anywhere, including in landlocked countries."

A similar definition is suggested by Park (2014) after conducting a meta study about existing different worldwide definitions and perceptions of the ocean economy: "The ocean economy are the economic activities that take place in the ocean, receive outputs from the ocean, and provide goods and services to the ocean. In other words, the ocean economy can be defined as the economic activities that directly or indirectly take place in the ocean, use the ocean's outputs, and put the goods and services into the ocean's activities."

The present report, however, considers that any definition of the ocean economy is incomplete unless it also encompasses non-quantifiable natural stocks and non-market goods and services. In other words, the ocean economy can be defined as the sum of the economic activities of ocean-based industries, and the assets, goods and services of marine ecosystems.

Figure 1.1 summarises this concept. Ocean-based industries can be divided into market flows and services and physical capital stock of the industries. Marine ecosystems represent natural capital and non-market flows and services. In many cases, marine ecosystems provide intermediate inputs to the ocean-based industries. An example is coral reefs. They provide shelter and habitat for fish nurseries and unique genetic resources, while at the same time providing recreational value for maritime tourism. Conversely, ocean industries can impact the health of marine ecosystems, e.g. through discharge if ship waste or pollution from oil spills.

Figure 1.1. **The concept of the ocean economy**



However, rigorous inclusion of the value of ecosystem assets and services in quantitative assessments, i.e. ecological accounting, is a new research field that only in recent years has begun to attract more significant interest (see further below).

Scope of the ocean economy

Ocean-based industries

It is conspicuous in studies of the ocean economy (see Chapter 6) that the sectoral scope of the ocean economy varies considerably by country. The number of categories chosen can range from 6, as in the case of the United States, to 33 in the case of Japan. Some industries may be excluded from the ocean economy in one country but not in another. Moreover, there are significant differences among countries in the delineation of the classifications and categories used. Internationally agreed definitions and statistical terminology for ocean-based activities do not yet exist (Park, 2014).

This report proposes the following scope (Table 1.1) for categorising established and emerging ocean-based activities, bearing in mind earlier remarks about overlapping definitions and the existence of highly dynamic emerging activities within traditional ocean industries. Explanations of each sector are offered in Annex 1.A1.

Table 1.1. **Established and emerging ocean-based industries**

Established	Emerging
Capture fisheries	Marine aquaculture
Seafood processing	Deep- and ultra-deep water oil and gas
Shipping	Offshore wind energy
Ports	Ocean renewable energy
Shipbuilding and repair	Marine and seabed mining
Offshore oil and gas (shallow water)	Maritime safety and surveillance
Marine manufacturing and construction	Marine biotechnology
Maritime and coastal tourism	High-tech marine products and services
Marine business services	Others
Marine R&D and education	
Dredging	

It should be noted, however, that due to lack of comprehensive and consistent data sets, not all of the above industries are covered in detail in this report (see Chapter 6).

Marine ecosystems

In addition to the market flows and services and the physical capital stock of ocean-based industries, the ocean economy also consists of marine ecosystems. Marine ecosystems encompass oceans, salt marshes and intertidal zones, estuaries and lagoons, mangroves and coral reefs, the water column including the deep sea, and the sea floor (Kaiser and Roumasset, 2002), all of which provide intermediary services relevant for ocean-based industries.

The interactions of society, economy and environment exercise an important influence on marine ecosystems through their dynamics and their broader biogeochemical cycle. This is because ecosystem services are dependent on one another and exhibit complex interactions that generate trade-offs in the delivery of one ecosystem service relative to the delivery of others. For the ocean economy, this is relevant because these interactions determine indirectly the viability of ocean-based industries. By way of illustration: coastal run-off and eutrophication, acidification through increasing greenhouse gas (GHG) emissions, and poor water quality through pollution lead to changes in fish migration patterns and even extinction of fish stocks. All are examples of how human activity indirectly intervenes in the functioning of marine ecosystems, thereby undermining the economic viability of the ocean economy.

Measuring the value of marine ecosystems is a difficult and complex exercise, but research efforts in the area have gathered considerable momentum in recent years. Estimates of the size of the benefits of marine ecosystem services suggest that these are considerable (for a review of a selection of such studies see Annex 1.A2), but much work remains to be done. Hence, as noted above, while many aspects of ecosystem services are taken into account here, the quantitative focus of this report is on ocean-based industries.

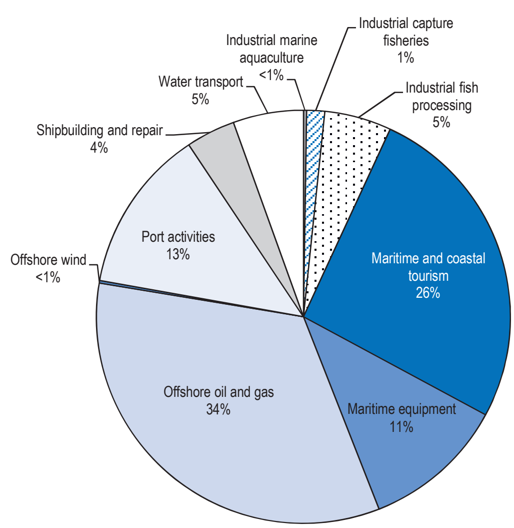
Ocean-based industries contribute roughly USD 1.5 trillion (2.5%) to global gross value added

The global ocean economy, measured in terms of the ocean-based industries' contribution to economic output and employment, is significant.

Calculations on the basis of the OECD's *Ocean Economy Database* value the ocean economy's output in 2010 (the base year for the calculations and subsequent scenarios to 2030) at USD 1.5 trillion in value added, or approximately 2.5% of world gross value added (GVA). To compare an industry's contribution to the economy across countries, the share of total GVA is preferred to the share of GDP. The System of National Accounts (SNA) recommends using GVA at basic prices for this purpose. The difference between total industry GVA and total GDP is taxes less subsidies on products, which varies across countries. This adjustment is made at the aggregate (total economy) level because, while time series of taxes less subsidies on products may be available by product, they are not generally available by industry. Furthermore, it should be noted that this study took the year 2010 and Revision 3 of the International Standard Industrial Classification of All Economic Activities (ISIC) as baselines in order to maximise the completeness, consistency and comparability of available data.

Offshore oil and gas accounted for about one-third of total value added of the ocean-based industries, followed by maritime and coastal tourism (26%), ports (13%) – measured as total value added of global port throughput – and maritime equipment (11%). The other industries accounted for shares of 5% or less (Figure 1.2). While the share of industrial capture fisheries is small (1%), it should be noted that inclusion of estimates of the value added generated by artisanal capture fisheries (mainly in Africa and Asia) would add further tens of billions of USD to the capture fisheries total (see Chapter 6 for detailed estimates).

Figure 1.2. **Value added of ocean-based industries in 2010 by industry**



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Note: Artisanal fisheries are not included in this overview.

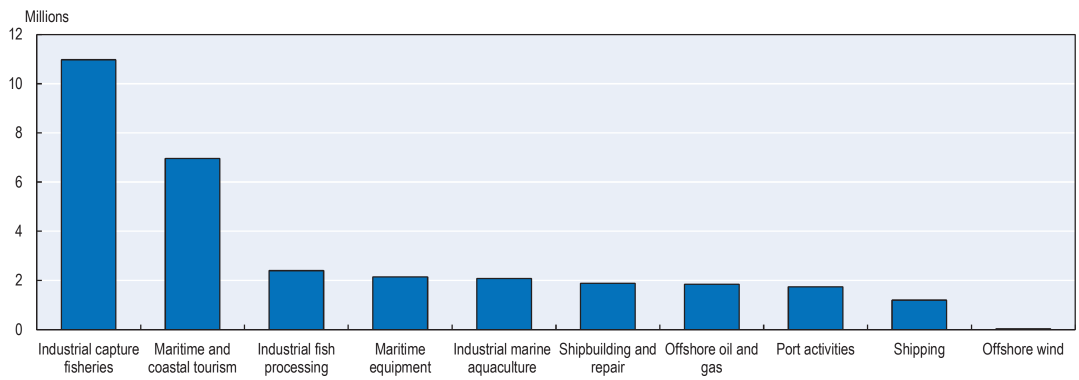
Source: Authors' calculations based on OECD STAN, UNIDO INDSTAT, UNSD, World Bank (2013); IEA (2014); OECD (2014); and various industry reports.

The ocean-based industries contributed some 31 million direct full-time jobs in 2010, around 1% of the global work force (and about 1.5% of the global workforce actively employed). As Figure 1.3 indicates, the largest employers were industrial capture fisheries (36%) and maritime and coastal tourism (23%). The remaining industries accounted for shares of between less than 1% and 8%.

A number of qualifying remarks are in order here. First, the percentage share of total employment accounted for by capture fisheries would increase markedly if total jobs in artisanal fisheries were to be included, adding around 100 million fishers for capture fisheries and aquaculture (including inland activities) to the overall total. Second, in addition to industrial fish processing, there are millions of people (mainly women) involved in artisanal fish processing (see Chapter 6 for more details on capture fisheries, aquaculture and fish processing).

It is worth noting therefore at this juncture that the report's estimates for value added and employment in the ocean economy are extremely conservative. In addition to the qualifying remarks above, several important activities in the ocean economy (e.g. marine business and finance, ocean surveillance, marine biotechnology) are not captured due to lack of data.

Figure 1.3. **Employment in the ocean-based industries in 2010 by industry**



StatLink http://dx.doi.org/10.1787/888933334627

Note: Artisanal fisheries are not included in this overview.

Source: Authors' calculations based on OECD STAN, UNIDO INDSTAT, UNSD, World Bank (2013); IEA (2014); OECD (2014); and various industry reports.

Forces shaping the evolution of the ocean economy to 2030

The ocean economy of the next 20 years or so is being driven primarily by developments in global population, the economy, climate and environment, technology, and ocean regulation and management (see Chapter 2).

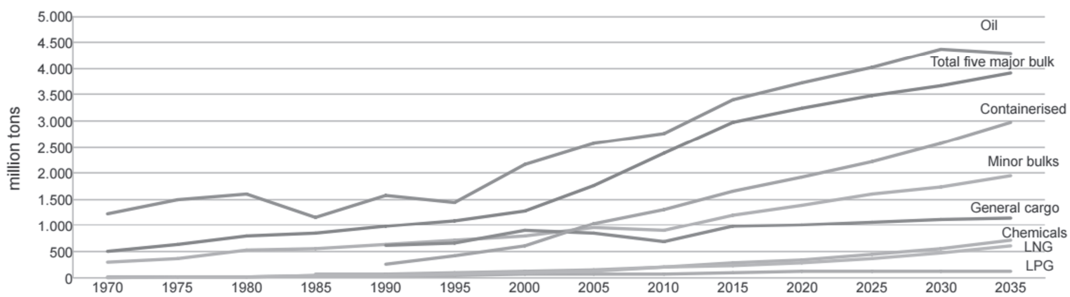
Population

Population growth, urbanisation and coastal development are at the heart of growth in the ocean economy. By 2050, an extra 2 billion people at least will need to be fed, raising demand for fish, molluscs and other marine foods from fisheries and aquaculture; as consumers they will stimulate sea-borne freight and passenger traffic, shipbuilding and marine equipment manufacturing, as well as exploration for offshore oil and gas reserves. Ageing populations will continue to target coastal locations for holidays, cruise tourism and retirement homes, and motivate the medical and pharmaceutical communities of the world to accelerate marine biotechnological research into new drugs and treatments.

Global economic growth and international trade

Along with population, the economy is one of the most dynamic drivers of developments in the maritime economy. Although the long-term prospects for global economic growth, and for the OECD area as a whole, remain modest, GDP per capita is expected to rise significantly over the next few decades. Global freight trade could more than triple by 2050. Since around 90% of international freight is carried by sea, the impetus to the shipping business and ports will be considerable.

Figure 1.4. **Growth in global seaborne trade 1970-2035**



Source: SEA (2015).

With an expanding share of world production located in the People's Republic of China (hereafter "China"), India and Indonesia (almost 40% by 2030 and around 50% by 2050), and concomitant increases in incomes and wealth, especially in the burgeoning middle classes of the emerging economies and some of the rapidly developing countries, a gradual shift in trade patterns eastwards is inevitable. The consequences for ocean industries are huge. Careful consideration is already being given by shipping lines and shipbuilding companies to likely future changes in markets, routes, types of cargo and types of vessel that will be required. Higher incomes and upward consumption trends point to greater demand for marine tourism and especially cruise tourism. They also point to big shifts in dietary habits, which are expected to lift demand for fish and other marine products to new heights.

Food

In light of the expected increase in world population to 2050 and demand for food, the ocean clearly has an important part to play in supplementing the food supplies generated by agriculture. Indeed, in many parts of the world, marine produce will continue to be a prime source of protein and vitamins for millions of people, especially as the growing middle classes shift their spending to high-end protein products. However, the ocean's capacity to perform that role is increasingly undermined by overfishing and depleted stocks in many parts of the world as well as by the impacts of land-based pollution, not least the run-off of fertilisers and agricultural waste into coastal and estuary zones, which threatens marine life habitats, fish stocks, molluscs and so on. Growth in global capture fisheries is therefore expected to remain more or less flat over the next ten years or so. The increase in world demand for seafood will need to be absorbed by a significant expansion in aquaculture, especially in marine aquaculture. However, scaling up marine aquaculture will necessitate addressing a series of challenges ranging from the availability of additional sites and better management of the problems of disease and escapees, to dealing with the effects of climate change and reducing animal protein in feed based on wild fish catch.

Energy

Energy issues pervade the full range of maritime industries, both as energy users and energy suppliers. Market price levels and market volatility are crucial factors in the viability of offshore oil and gas exploration and production, as underlined by recent decisions to scale back, defer or abandon several offshore projects, since they are particularly capital intensive. Nonetheless, despite low oil prices, a good number of high-profile offshore projects have seen their development continue. In contrast to producers of hydrocarbons, consistently high oil and gas prices are an essential ingredient for the continuing progress of offshore wind and ocean renewables, as well as for the development of aquaculture-based algal biofuels. However, offshore wind is likely to continue to benefit from government subsidies in the years to come and, as capacity grows, from efforts to reduce production and running costs. Both factors should help offshore wind build more resilience to fluctuations in oil and gas markets. The global market for ocean energy systems (tidal, wave, ocean current, etc.), on the other hand, is not expected to scale up significantly in the medium term, but the longer term potential is enormous. Both offshore wind and ocean energy capacity should eventually benefit from the historic COP21 agreement and its support for renewable energy (see, for example, the recommendations submitted to the Paris COP21 by the Ocean and Climate Platform[1]).

Ocean environment

An important constraining factor on the development of the ocean economy could prove to be the expected further deterioration in the health of the ocean (see Chapter 3 for a detailed discussion). The ocean plays an important part in regulating the planet's climate, and is intricately linked with the Earth's land mass and atmosphere. Its ecosystem services include the regulation of atmospheric and marine carbon dioxide concentrations, the provision of oxygen, the hydrothermal convection cycle, the hydrological cycle, coastal protection and vital contributions from marine biodiversity. As anthropogenic carbon emissions have risen over time, the ocean has absorbed much of the carbon, leading to ocean acidification, rising sea temperatures and sea levels, shifts in ocean currents and so on. Concern about the future impact of climate change on the ocean's health is widespread and mounting. Indeed, following the Paris COP21 conference, the Intergovernmental Panel on Climate Change (IPCC) will be publishing a special report on the ocean, notably the effects of climate change on biodiversity, the functioning of marine ecosystems and the role of those ecosystems in helping regulate the planet's climate.

The implications for ocean ecosystems and marine diversity are considerable and are resulting in biodiversity and habitat loss, changes in fish stock composition and migration patterns, and higher frequency of severe ocean weather events. The consequences are being – and will continue to be – felt by fishing and aquaculture operations, the offshore oil and gas industry, vulnerable low-lying coastal communities, shipping companies, coastal and marine tourism, and marine bio-prospecting for medical and industrial purposes. The prospects for ocean health and ocean users are further aggravated by land-based pollution, in particular agricultural run-off, chemicals and macro- and

1. Available at: www.ocean-climate.org/?page_id=2876.

micro-plastic pollutants which feed into the ocean especially from rivers. In these matters, developing countries tend to be much harder hit than industrialised nations.

At the same time, however, changes in the ocean climate are set to create new business opportunities. This is illustrated, for example, by events in the Arctic, where the ice cap is expected to continue to melt in coming years, opening the Northern Sea Route (NSR) for commercially viable shipping. According to the latest modelling results (Bekkers, Francois and Rojas-Romagosa, 2015), a shortening of sailing times between north-east Asia and north-western Europe by around one-third compared to current use of the Southern Sea Route through the Suez would transform the NSR into one of the busiest shipping routes in the world, bring about a major shift in bilateral trade flows between Asia and Europe, and trigger a reorganisation of global supply chains both within Europe and between Europe and Asia. At the same time, receding ice cover would open the way for new economic opportunities ranging from oil and gas exploration to mining, fishing and tourism, introducing, however, further potential risks to the vulnerable Arctic environment.

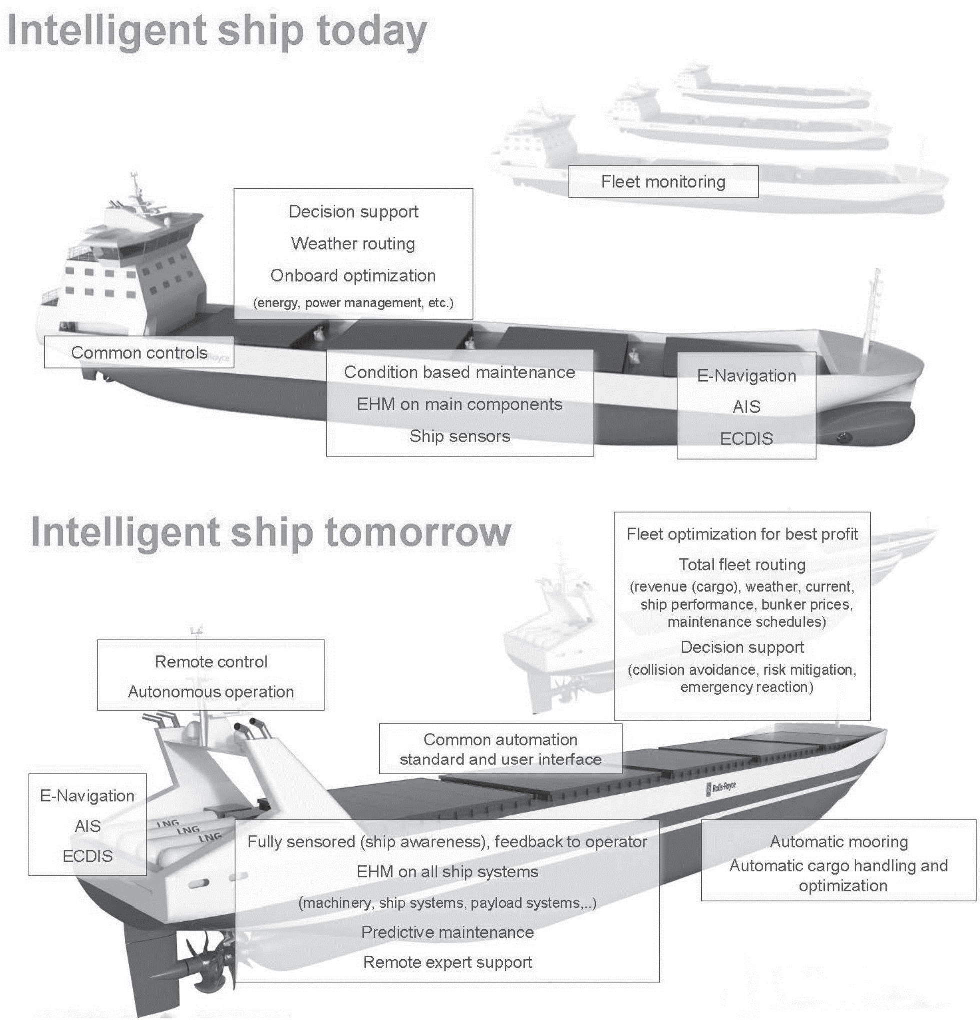
Science, technology and innovation

In the coming decades, scientific and technological advances are expected to play a crucial role both in addressing many of the ocean-related environmental challenges mentioned above and in the further development of ocean-based economic activities. Innovations in advanced materials, subsea engineering and technology, sensors and imaging, satellite technologies, computerisation and big data analytics, autonomous systems, biotechnology and nanotechnology – every sector of the ocean economy stands to be affected by these technological advances. By way of illustration: commercial shipping appears to be on the verge of the introduction of autonomous ships and greater use of new fuels; oil and gas and seabed mining companies are all looking to robotics for their subsea operations; marine aquaculture is building on advances in biotechnology to improve fish health and welfare and reduce dependence on wild fish catches for feed; renewable ocean energies are making increasing use of advances in new materials and sensors; fisheries, maritime safety, ocean observation and environmental assessment will continue to benefit from the great strides that are being made in satellite technologies (communications, remote sensing, navigation); and cruise tourism is scaling up its on-board digital facilities for passengers and crew to unprecedented levels.

Some of these innovations are set to generate incremental benefits, others, however, are likely to prove more transformative and even disruptive, especially where they involve combinations of innovations from multiple technological domains.

Examples include: the near-term prospect of e-navigation being implemented in the shipping industry; the convergence of multiple technologies (biotechnology, satellite and sensor technologies, etc.) revolutionising the battle against offshore oil pollution; the great strides expected in seafloor mapping; the anticipated increasing use of multi-purpose offshore platforms; and the spread of ocean-scale undersea observatories (see Chapter 4 for more detail on these examples).

Figure 1.5. **Towards the autonomous ship of the future**



Source: Levander (2015).

International regulation and governance of the ocean economy

In a context of such rapid change as that outlined above, regulation and governance will struggle to keep up (see Chapter 5). The world is increasingly multi-polar in its power structure: there is the emergence of numerous countries and regions vying for economic power and the benefits that can be derived from projecting their growing economic power on to the geopolitical stage; new state players demonstrating their strength in particular crucial sectors – such as energy and other natural resources, space technologies, ICT – which allows them to assume a strategic importance in the global arena often far in excess of their size; and the appearance of new non-state actors such as city regions, urban clusters, international non-governmental organisations and foundations, which have seen their influence in the world grow as the high concentrations of knowledge, skills, financial clout and scale/network efficiencies raise their profile internationally. These developments are leading to a fragmentation of power and growing difficulty in forging international consensus on global and regional issues that are key to the ocean environment and ocean industries. Whether this involves climate change and

GHG emission levels or the governance of the high seas and area beyond national jurisdiction (ABNJ), the protection of marine biodiversity or international conventions on maritime safety, the path to international agreement appears increasingly complex and painstaking. At least for the foreseeable future, regulation of ocean activities is expected to continue to be largely sector-driven, with efforts focusing on the integration of emerging ocean industries into existing regulatory frameworks.

The ocean economy in 2030

Clearly the future of the ocean economy is being shaped by many different factors. These are reflected to varying degrees in a plethora of forecasts and projections on ocean industries produced in recent years by a wide range of international organisations, government agencies, industry associations and research establishments. Obtaining a coherent picture of the likely future of the ocean economy as a whole is very difficult, since all these studies use different methodologies, various time horizons and different assumptions (e.g. regarding global economic growth and trade). And since they are for the most part single-sector studies, the inter-linkages among the various ocean sectors cannot be captured.

Modelling the ocean economy's industries suggests that some of them have the potential to outperform average world economic growth

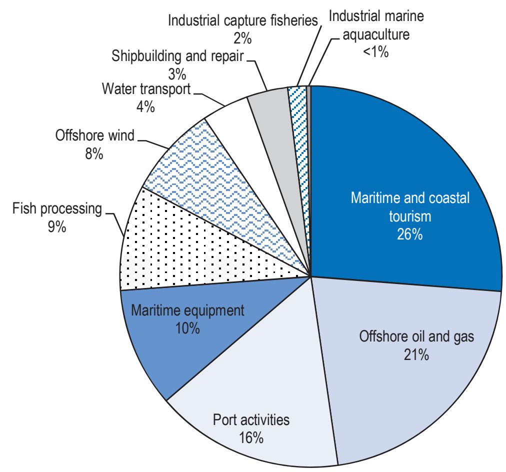
The "Future of the Ocean Economy" project endeavours to mitigate these shortcomings by projecting the development of the global ocean economy as a whole to 2030 on the basis of an enhanced ocean-industry database and a model based on broadly consistent assumptions and parameters. The projection is a business-as-usual scenario, or baseline scenario, which assumes a continuation of past trends, no major policy changes, no abrupt technological or environmental developments, and no major surprises. Value added and employment growth from the ocean-based industries continue to progress along the same trajectory to 2030 as in the past reference period. The model designed for this project requires country- and industry-specific employment and physical capital stock to be extrapolated under the assumption that past growth rates continue until 2030.

Global value added in the ocean economy "business-as-usual scenario" is estimated to grow to more than USD 3 trillion (in constant 2010 USD) by 2030 (Figure 1.6) and maintain its share of world total GVA (projected to reach about USD 120 billion by 2030) at around 2.5%. Maritime and coastal tourism, including the cruise industry, is expected to take the largest share (26%), followed by offshore oil and gas exploration and production with 21% and port activities with 16% (for further details see Chapter 8).

Again, these estimates are considered highly conservative. First, they do not yet include a good number of ocean-related sectors for which adequate data are presently not available. Second, they understate activity in certain sectors (such as shipping) for which numerous countries have had to be excluded due to lack of data. Third, the modest growth expected in some large industries (e.g. offshore oil and gas) masks comparatively high rates of growth expected in others (e.g. marine aquaculture, offshore wind, fish processing, port activities) and holds back overall average growth in the ocean economy as a whole (see Table 1.2).

These results suggest that many parts of the ocean economy have the potential to outperform the growth rate of the global economy as a whole. Indeed, such a conclusion is supported by a substantial number of sector-specific forecasts and projections conducted by a host of international organisations and agencies, industry associations and research institutes (see Chapter 7). They indicate strong growth in volume terms over the coming 15 years in shipping, shipbuilding and repair, port activity, marine supplies, marine aquaculture, offshore wind and marine tourism. They expect less strong growth in capture fisheries and offshore oil and gas. Ocean renewable energy, marine biotechnology and CCS are also considered to possess considerable potential, the scaling-up of which, however, is unlikely to happen before 2030.

Figure 1.6. **Value added of the ocean economy in 2030 in the business-as-usual scenario**



StatLink http://dx.doi.org/10.1787/888933334632

Note: Artisanal fisheries are not included in this overview.

Source: Authors' calculations based on OECD STAN, UNIDO INDSTAT, UNSD; Lloyd's Register (2014; 2013); World Bank (2013); IEA (2014).

Ocean industries also have the potential to make an important contribution to employment growth

In 2030, the ocean-based industries in the business-as-usual scenario are anticipated to employ over 40 million people, broadly unchanged over 2010 at more than 1% of the global workforce (of around 3.8 billion). A majority are expected to be working in the industrial capture fisheries sector and the maritime and coastal tourism industry. With the exception of capture fisheries, all the ocean industries selected here are likely to see their global employment levels grow at a faster rate than that of the global workforce as a whole. The majority of jobs in the ocean economy would be accounted for by maritime and coastal tourism and capture fisheries. The data for shipping cover high income, emerging and developing countries, but should be interpreted with caution since they only include direct full-time employment (see Chapter 8 for further details on employment).

The compound annual growth rate of the value added generated by the ocean-based industries combined between 2010 and 2030 is estimated at 3.5%, broadly similar to the growth rate of the total GVA of the global economy. At almost 30%, growth of employment in the ocean based-industries over the 20-year timeframe is expected to outpace that of the global workforce (around 19%). Table 1.2 presents a sector-by-sector comparison of the results of the projections to 2030 for the annual average growth rates of value added and employment for the ocean economy.

Table 1.2. **Overview of estimates of industry-specific growth rates in value added and employment between 2010 and 2030**

Industry	Compound annual growth rate for GVA between 2010 and 2030	Total change in GVA between 2010 and 2030	Total change in employment between 2010 and 2030
Industrial marine aquaculture	5.69%	303%	152%
Industrial capture fisheries	4.10%	223%	94%
Fish processing	6.26%	337%	206%
Maritime and coastal tourism	3.51%	199%	122%
Offshore oil and gas	1.17%	126%	126%
Offshore wind	24.52%	8 037%	1 257%
Port activities	4.58%	245%	245%
Shipbuilding and repair	2.93%	178%	124%
Maritime equipment	2.93%	178%	124%
Shipping	1.80%	143%	130%
Average of the total ocean-based industries	3.45%	197%	130%
Global economy between 2010 and 2030	3.64%	204%	120%[1]

1. Based on projections of the global workforce, extrapolated with the UN medium fertility rate.

Source: Authors' calculations based on OECD STAN, UNIDO INDSTAT, UNSD; Lloyd's Register (2014; 2013); World Bank (2013); IEA (2014); FAO (2015).

Alternative scenarios suggest that only relatively small differences in total value added would be expected compared to the business-as-usual scenario

Two alternative scenarios are offered – sustainable growth and unsustainable growth – which shape the future ocean economy in two different directions, one accelerating and the other slowing the future development of the ocean-based industries by 2030 (see Chapter 8). The main drivers for these alternative scenarios were defined in an internal workshop with the Project Steering Group in 2014. Drivers shaping the scenarios included economic growth, technological development, governmental regulations, and the state of the climate and ocean environment by 2030.

- The "sustainable scenario" assumes high economic growth and low environmental deterioration due to the development of resource-efficient and climate-friendly technologies combined with a supportive governmental framework that provides the right incentives to allow the ocean economy to thrive economically while meeting environmental standards.
- The "unsustainable scenario" assumes low economic growth and serious environmental deterioration. Coupled with faster than expected climate change and low rates of technological innovation, the ocean economy experiences a challenging outlook beyond 2030.

Value added in the business-as-usual ocean economy is USD 1.5 trillion in 2010 and USD 3 trillion in 2030. In the "sustainable" scenario, value added in 2030 is more than USD 3.2 trillion. Value added in 2030 in the "unsustainable" scenario is around USD 2.8 trillion. The difference between the two alternative scenarios would be expected to grow with time. Similarly, employment of the ocean economy in 2030 in the sustainable scenario is almost 43 million jobs, whereas that figure would be around 7 million smaller in the unsustainable scenario. Nevertheless, these are conservative estimates since not every ocean-based industry is included and only direct employment and direct value added are included.

An expanding ocean economy leads to growing pressures on marine resources and ocean space

The future growth of ocean-based industries on a scale suggested by this report highlights the prospect of growing pressures on ocean resources and ocean space already under considerable stress, not least in economic exclusion zones (EEZs), where most of the activity takes place. The inability so far to deal with these pressures in an effective, timely way is attributed in large part to what is historically a sector-by-sector management of marine activities (see Chapter 9).

Much as a response to those growing pressures, recent years have seen a significant increase in the number of countries and regions putting in place strategic policy frameworks for better ocean management within their EEZs, based for the most part on ecosystem approaches and making use of various spatial planning and management instruments such as integrated coastal zone management (ICZM), maritime or marine spatial planning (MSP), and marine protected areas (MPAs). Some of these countries have their strategic policy framework already in place, while others are at various stages of design and implementation. At the root of this overall policy shift is the growing recognition that management of the ocean needs to be based on an ecosystem approach. The interrelationship among uses and processes in the coast and ocean makes it imperative that ocean governance be integrated, precautionary and anticipatory.

Currently, some 50 countries have some form or other of spatial ocean management initiatives underway. Eight countries have government-approved marine plans that cover about 8% of the world's EEZs. By 2025, more than 25 countries will have government-approved plans that will cover about 25% of the area of the world's EEZs.

However, the scale and scope of each initiative differs considerably between countries. Moreover, in light of the expected rapid future expansion of ocean industry activity around the world and the increasingly crowded ocean space, time is of the essence in extending effective integrated management to as many coastal countries as possible. However, many obstacles stand in the way of more effective integrated ocean management, which will need to be addressed in the near future. They include for example: lack of scientific knowledge and data on ocean environment – compounded by complexity and uncertainty of the ocean environment; insufficient use of the scientific and technological tools to gather, process and analyse those data; lack of relevant socio-economic data; and the challenge of balancing the perceived interests of stakeholders, the distributional implications and equity considerations. Furthermore, the science has been slow to catch up with policy requirements with respect both to assessing and communicating trade-offs among human uses of the ocean, and to identifying strategies to mediate those trade-offs.

Integrated ocean management offers significant opportunities for addressing these challenges, but needs better tools to work with

Three routes in particular offer themselves as means for addressing the above-mentioned shortcomings and for enhancing the effectiveness and diffusion of integrated ocean management:

- greater use of economic analysis (e.g. cost-benefit analysis – identifying and quantifying types of cost, types of benefit, valuation techniques) and economic instruments (e.g. taxes, fees, tradable permits)

- better use of innovations in science and technology (e.g. advances in satellite applications, especially in combination with other technological innovations in such uses as drones, unmanned airborne vehicles (UAVs), sensors, mapping, imaging) especially for gathering more and better data quality
- innovation in governance and stakeholder engagement (co-ordination across government agencies, and wider but more effective and cost-efficient stakeholder consultation).

Economic analysis and instruments are part of the toolbox required to improve measurement and valuation of ecosystem services. They are useful especially in cases of competing claims for ocean space and the search for an appropriate balance between use of maritime space and protection of the ocean and coastal environment. However, lack of data on economic parameters (such as the non-market value of key ecosystem services) and environmental phenomena (such as the condition and interaction of specific marine animal habitats) together with the hitherto patchy implementation of spatial planning, have meant that economic instruments have so far been under-utilised in the ocean environment context.

Science, technology and data analytics are not being fully and effectively harnessed to the ocean management process. The data challenges facing effective marine spatial planning and ocean management are considerable. There is a great deal of uncertainty as to what is in the ocean; very little is known of the interactive effects of different uses and users in the ocean; and the ocean is a dynamic environment undergoing significant changes because of climate change. Large information gaps remain. Data on the marine resource is fragmented, difficult to locate, and biased towards the physical and ecological characteristics of the resource. This is due in part to the historical single sector approach to planning in the marine environment and the earlier emphasis on the biophysical rather than economic and social processes associated with the marine environment. When data are available, there is a diversity of data sources and data formats for policy makers, researchers and the public to disentangle.

Governance and stakeholder engagement are key to effective ocean management, i.e. co-ordination across government as well as the engagement of all relevant stakeholders – scientists, business, user industries and associations – in the process. However, given their long history of sector-based approaches, current governance structures are usually not well suited to handle these co-ordination and consultation tasks effectively across sectors, especially where resources are moveable and renewable (e.g. capture fisheries) and/or stationary and mostly non-renewable (e.g. oil and gas deposits). Different bureaucracies are usually in charge of handling the permitting for different uses and users, but they tend not to co-operate well, if at all. Moving from sector-by-sector management to integrated ocean management is a major institutional change.

The three routes to help improve ocean management are set out in more detail in Chapter 9.

Recommendations: An agenda for international co-operation for a sustainable ocean economy

What is required to boost the long-term development prospects of emerging ocean industries and their contribution to growth and employment, while managing the ocean in responsible, sustainable ways? This report emphasises the importance of taking a holistic view of the ocean economy, a perspective that is reflected both in the main findings and in the structure and thrust of the proposals below. Rather than taking a sector-by-sector approach, the recommendations cut across disciplines and sectors to try to provide a more integrated perspective on what might be done to achieve a desirable balance between economic development and environmental sustainability in the ocean context in the coming years.

The recommendations are broken into four groups:

1. Foster greater international co-operation in maritime science and technology as a means to stimulate innovation and strengthen the sustainable development of the ocean economy.
2. Strengthen integrated ocean management.
3. Improve the statistical and methodological base at national and international level for measuring the scale and performance of ocean-based industries and their contribution to the overall economy.
4. Build more capacity for ocean industry foresight.

1. Foster greater international co-operation in maritime science and technology as a means to stimulate innovation and strengthen the sustainable development of the ocean economy

Innovation in ocean-related science and technology will play a key role in the sustainable development of the ocean economy for two inter-connected reasons.

First, the ocean economy is a global stage on which myriads of businesses and indeed countries are competing vigorously with one another for markets. How those competitive forces will play out in the future depends to a very high degree on the ability of businesses to continually renew, adjust, upgrade and reinvent their products, production processes and services. Innovation holds the key to their survival and economic success.

Second, business-as-usual expansion of economic activities in the ocean is not an option for the future, as it would further jeopardise the ocean's health and resources, thereby undermining the very basis on which the ocean industries themselves depend. Innovation will be a critical ingredient in the search for solutions that enable business opportunities to be developed while minimising the impact on the ocean environment and marine resources. The scale and complexity of the challenges involved are such that international co-operation on technological innovation in the ocean industries will become increasingly indispensable.

The scope for a government role in promoting innovation across and among ocean industries could be considerable and is worthy of further exploration. Three pathways are traced below.

1. Better exploit potential technology and innovation synergies among ocean industries

Why is it important?

A high degree of potential interaction exists among ocean-based activities – offshore wind and ocean renewable energy with offshore oil and gas operations; marine aquaculture, tourism, marine research and marine biotechnology with offshore structures and platforms – as well as among the technologies deployed in those activities. Benefits could be reaped in the form, for example, of lower costs from shared common infrastructure, cross-fertilisation of technologies and innovative processes, reduced impact on the marine environment and more effective planning of the use of limited ocean space.

These tasks are often performed by maritime industry clusters, acting as agents of cross-sectoral technology transfer and stimulators of innovation synergies, not least among small and medium-sized enterprises (SMEs). However, looking around the world, many clusters only encompass a small part of all the maritime sub-industries; some are public, others private or mixed; some clusters have little interaction among sectors and cannot perform the tasks of co-ordination and cross-sectoral exchange; yet others have no remit to pursue cross-industry science and technology innovation initiatives. Moreover, many countries and regions around the world have no active maritime industry cluster at all. Government policy can help create, strengthen, sustain and expand maritime industry clusters. But there is no one-size-fits-all policy approach, and much depends on local and national circumstances.

Looking more to the future, recent years have seen the emergence of numerous initiatives (many still at the planning stage) around the world to create specific centres of excellence aimed at leveraging the potential synergies of technological innovations across maritime industries, often in liaison with maritime clusters. These initiatives include, for example, the Sealab Innovation Centre (Mediterranean), the San Diego Blue Tech Incubator (United States), the Ocean Space Centre (Norway) and the Ocean Technology Alliance (Canada). Many take the form of public-private partnerships, opening up opportunities for governments to promote innovation in the maritime sector in a variety of different ways.

What should be done?

- Comparative analyses and reviews of maritime clusters around the world are needed specifically with respect to their effectiveness in stimulating and supporting cross-industry technological innovations in the maritime domain. In particular, useful lessons could be drawn from examination of the role of central and regional governments in the clusters' innovation activities in terms of: the overall approach (e.g. "hands-on", "hands-off" or "enabling"); concrete measures such as financial support, incentives, de-risking; participation in the creation of requisite research infrastructures; or support for public/private and inter-firm co-operation and networks in order to promote a more efficient use of public and private resources and competences in innovation activity.
- Explore pathways for scaling up national maritime-cluster innovation schemes to international level, promoting network creation and collaboration among national clusters on specific maritime technology programmes around common sea basins and shared oceans; also, encourage alliances and bilateral agreements, not only with neighbouring clusters but also with more distant clusters where opportunities for co-operation are particularly rich.
- Initiate the creation of international networks for the exchange of views and experience with establishing centres of excellence, innovation incubators, etc. in the field of cross-industry maritime technologies, focusing in particular on key generic and enabling technologies.

2. Support efforts to accelerate more extensive mapping of the ocean floor

Why is it important?

A major impediment to our understanding and monitoring of environmental changes due to climate change, of the dynamics of marine ecosystems and of the ocean environment more generally, is a lack of knowledge of the ocean floor, particularly of the deep ocean. Recent advances in satellite altimeter technology and data management have made it possible to map the submarine topography of the planet's entire seafloor, but the resolution of this global data is low – 1.5 kilometres – and therefore short on detail. Mapping for much greater detail is a different matter. To date, only about 5% of the global ocean floor has been mapped in high resolution (usually by modern multi-beam sonar systems), and much of that is in national (EEZs) rather than in international waters. Biochemical, biological, habitat and deep-sea terrain mapping are much less developed and less widespread. Yet more detailed mapping is a critical tool in many respects: for detecting and observing at finer scales and at greater accuracies the undulations and composition of the seafloor; acquiring more detailed knowledge of entire marine ecosystems; protecting and tracking marine life; identifying natural resources, and regulating subsea resource exploration, extraction and equipment; siting offshore wind farms and marine aquaculture installations; preparing the terrain for hydrocarbon drilling operations and so on. Several major mapping initiatives are underway or planned, but mapping the remaining 95% is a Herculean task and would take many years to perform. The potential benefits of wider-scale mapping are huge, but prioritising the process is enormously challenging.

What should be done?

- Support international collaborative efforts led by international organisations (e.g. the International Hydrographic Organisation and the Intergovernmental Oceanographic Commission) and multilateral collaborations (e.g. the Atlantic Ocean Research Alliance) to map the ocean floor, notably in international waters and in the deep ocean, with a view to better understanding the physical and ecological consequences of climate change for marine biodiversity and key ocean services.
- Promote efforts to identify, explore and mitigate the barriers – economic, technical, legal, political – which hamper international co-operation in the sharing of existing seafloor mapping results among public institutions, research establishments and companies (e.g. oil and gas, offshore wind, seabed mining) active in ocean floor mapping, and explore the possibilities for pooling bathymetric and related data into data hubs accessible to the public.

3. Improve the sharing of technology and innovation among countries at different levels of development

Why is it important?

In all regions and at all levels of development, science, technology and innovation are prerequisites for sustainable long-term development. This applies no less to ocean industries, especially where they are a strategically important component of economic and social development. Particularly for developing countries with ocean-based activities, the creation, acquisition and adaptation of innovations in marine/maritime science and technology is a vital ingredient of efforts to tackle development challenges. Hence, advanced countries have an important responsibility to support developing countries, and in some cases also emerging economies, in the development of their scientific infrastructure and their policy capabilities in ocean-related activities. But in reality, the process can be a two-way street. Developed countries can benefit from the experience of emerging economies, for example, which may be less constrained by institutional and other "legacy" structures in building their science and innovation systems. Or from developing countries where century-old practices may embody useful knowledge for reshaping products and processes in modern business environments. The emphasis needs to be on capacity building and the creation of sustainable business opportunities in partnership with developing countries and the development of technologies that are appropriate to the sustainability challenges such countries face. Knowledge markets and networks can play an important role in the transfer of knowledge.

What should be done?

- Identify effective mechanisms and forums for the international sharing of good practices in the governance, design and implementation of innovation policy within the field of marine/maritime science and technology, among countries at different levels of development. Such mechanisms may include, for example, bilateral agreements, co-funding arrangements, collaborative projects, contract research and exchange of researchers. What is increasingly required, however, is also a better understanding of how knowledge markets and networks can facilitate access to the globalising knowledge market, supporting knowledge flows and transfers of intellectual property through such institutions as technology transfer offices, business incubators and multi-sector service provision centres.
- Promote collaboration among regional and national maritime industry clusters as a means of knowledge and best practice transfer. Where developing seafaring nations have no maritime clusters, governments should explore the potential advantages of helping create such clusters, in collaboration with industry and research, with a view to fostering innovation and technology exchange both within the country and with partner countries.

2. Strengthen integrated ocean management

As noted above, ocean activities are considered essential to meet future global challenges. However, pressures on the ocean environment – including over-fishing, pollution and habitat destruction – have continued to mount, not least as a consequence of growing ocean use. These pressures can be attributed partly to lack of knowledge and data on ocean processes and the impact of ocean industry activity, partly to a lack of effective management tools, and partly to what is historically a sector-by-sector based management of marine activities.

As stated above, recent years have seen a significant increase in the number of countries and regions putting in place strategic policy frameworks for better ocean management within their EEZs. However, given the acceleration expected in the use of the ocean and its resources over the coming years, it will be essential to step up both the effectiveness and the geographic spread of integrated ocean management around the world.

Three avenues could be pursued to achieve more effective and more widespread use of integrated ocean management: 1) make better use of economic analysis and economic instruments; 2) improve data collection, management and integration; 3) promote more innovation in governance structures, processes and stakeholder engagement.

1. Make better use of economic analysis and economic instruments in integrated ocean management

The ocean's natural assets and ecosystem services are an integral component of the ocean economy. Despite a growing body of research on identifying those assets and services as well as understanding and quantifying their contribution to the well-being and prosperity of humankind, our knowledge of the field remains quite poor. Similarly, while research into the complexities of the ocean environment and human activity therein has grown in recent years, prioritisation decisions on research investment have generally been guided by scientific interest without additional consideration of their potential economic utility, not least because cost-benefit analysis of investment in ocean observation and research is not well developed. Furthermore, management of activities in the ocean space has hitherto not made optimal use of economic instruments in its endeavours to achieve better outcomes and resolve potential conflicts among users of the ocean and its resources. On the contrary, management of the ocean environment has so far been dominated by the regulatory approach. Yet economists have long argued that market-based incentives, which apply monetary values, can in some cases be more efficient for environmental management than those based on "command-and-control" approaches (see Chapter 9).

Steps to address these issues are proposed below.

Improve measurement and valuation of the ocean's natural resources and ecosystem services

Why is it important?

Many ecosystem services are essential for human well-being, health, livelihoods and survival. Their degradation and the loss of biodiversity jeopardise their ability to maintain the flow of ecosystem services for present and future generations. Placing a value on ecosystem services in monetary units is key to communicating the importance of ecosystems and biodiversity to policy makers. Valuation can make for more efficient use of limited funds, and can offer guidance on user preferences and the relative value that current generations attach to ecosystem services. It can also help underpin decisions on the allocation of resources between competing uses. While substantial progress is being made towards circumscribing and valuing the role of ocean-based industries within the ocean economy, the route to valuing the ocean's natural resources and ecosystem services and measuring their economic contribution is proving infinitely more complex. In particular, assessments of ocean ecosystem services suffer from: limitations in data availability and reliability, a focus on specific regions and biomes, heterogeneity of conceptual models of values and differences in costing approaches.

What should be done?

- Work towards more comprehensive data collection and better accounting for the public goods and services provided by marine ecosystems as a tool for improving decision making and sustainable ecosystem management.
- Examine possibilities for improving methodologies to capture better the value of the ocean's natural assets and ecosystem services.
- In light of the growing body of knowledge on the interdependencies that exist within the ocean economy between ocean-based economic activities on the one hand and marine ecosystem assets and services on the other, explore how

alternative models of economic development might help attain a better balance between developing ocean use and preserving ocean health.

Evaluate the economic effectiveness of public investment in marine research and observation

Why is it important?

Fundamental scientific understanding of the ocean – its properties and behaviour, its health, role in climate change and influence on weather, etc. – is essential for understanding and managing ocean ecosystems. Equally, it is a vital pre-requisite for the sustainable operation of all ocean-based industries. Ocean observation therefore is a cornerstone of ocean science. A raft of infrastructures is required to perform modern ocean observation, including *inter alia*: ocean-going research vessels and autonomous systems collecting *in situ* data; satellite remote sensing, communications and global positioning; floating, submersible and fixed platforms and systems; modelling and computational infrastructure, as well as big data storage and management. At the international level, much is already being done via, for example, the work of UNESCO and the Intergovernmental Oceanographic Commission, the UN's Global Ocean Observation System (GOOS), the Census of Marine Life, as well as regional initiatives (e.g. Euro-Argo, the European Multidisciplinary Seafloor and water-column Observatory, and AtlantOS). Much of the investment in the research, data collection and infrastructure comes from public money. While numerous ocean observation initiatives have evaluated the effectiveness of their contribution to scientific fields of endeavour (such as ocean meteorology, measuring acidification, etc.), little effort has been undertaken to assess the economic value of the data produced. Yet, knowledge of that economic value could help generate much greater interest and financial participation in ocean research, and also help direct and, in some cases, prioritise research efforts.

What should be done?

- Initiate pilot projects, involving international collaboration of ocean research agencies, stakeholders and users, to explore the feasibility of assessing the economic value of ocean-related data. In a first phase, a selection of available and suitable data value chains could serve as case studies.

Strengthen the use of economic instruments and maritime and coastal spatial planning

Why is it important?

Economic instruments are designed to address the externalities associated with the use of natural resources by, for example, applying price-based instruments such as taxes, charges, user fees, individually transferable quotas, subsidies, payments for ecosystems and biodiversity offsets (e.g. habitat banking). Such economic tools are useful especially in cases of competing claims for ocean space and the search for an appropriate balance between use of maritime space and protection of the ocean and coastal environment. However, lack of data on economic and environmental parameters, coupled with high data-processing costs and the patchy implementation of spatial management to date, have meant that economic instruments have so far been underutilised in the ocean environment context. As a result, decision making and management have not been as effective and cost-efficient as they could be.

This is beginning to change, as non-market valuation methods (e.g. choice experiments, travel cost methods) have begun to generate increasingly robust values associated with ecosystem services. However, while there are numerous examples of their successful application, their use in the marine spatial context remains on the whole underdeveloped.

What should be done?

- Encourage the diffusion and implementation of economic tools in marine spatial planning by establishing international platforms for the exchange of knowledge, experience and best practice. In addition to marine economists, participants in such platforms should include marine environmental scientists and representatives of government agencies, regulators and users.
- Enhance integration of the temporal dimension into ocean management through the use of foresight techniques, thereby ensuring that planning and management benefit from advance knowledge of likely future changes both in the ocean environment and in ocean economic activities.

2. Improve data collection, management and integration

Why is it important?

In order to develop, assess and communicate ocean management processes, scientists and policy makers require data to develop and implement appropriate, effective and measurable indicators that assess performance in relation to stated goals and objectives. Effective implementation is highly dependent on scientific knowledge about the marine environment and the actual and potential impacts of human activities upon it. Considerable emphasis is therefore placed upon the need for data gathering, monitoring and evaluation to improve the knowledge of a poorly understood environment.

The last decade has seen an explosion in the amount of data generated across all aspects of life. The processing costs associated with data are declining, while cloud infrastructure increases, enabling open source technologies at scale. At the same time, advances in application programme interface (API), data-processing algorithms and machine learning ensure that data may be turned into actionable insights.

However, integrated ocean management faces huge data challenges. These range from lack of knowledge as to what is actually in the ocean or how different uses and users interact in the ocean, to the ocean dynamics of climate change and the fragmentation of data. The tools available for data collection and ocean monitoring have increased significantly over the last decade and include ship missions, landers and observatories, vehicles, autonomous underwater vehicles (AUV) and satellites. However, while these tools are the current state-of-the-art in marine monitoring, the relatively high costs of these platforms limit their spatial and temporal density. Accordingly, the benefits of data obtained – for example, from space-based technology – have never quite reached a "tipping point" where the value of their contribution makes them indispensable to marine monitoring. Hence, new cost-effective methods and technologies for collecting data are required that capture the uncertainty, complexity and change associated with the marine environment.

What should be done?

- Develop effective but flexible data-collection frameworks involving: regular and sustained engagement of experts in a broad range of natural and social sciences and user knowledge; the identification of the best scales for collecting and reporting data; a coherent framework for analysis; the development of user-friendly, open-source, efficient and transparent tools for data visualisation, integration and sharing; and a set of clear, reliable and measurable indicators for monitoring the effectiveness of ocean management in terms of achieving objectives set during the planning process.
- Develop a flexible, integrated data commons for the evaluation and monitoring processes. Such a data commons involves, for example, better data integration and sharing, easier access, geo-referenced data and virtually interconnected interoperable systems. Using the best-available data, measurable objectives of the plan should be linked to distinct indicators and targets at each step, which can be refined over time.
- Monitor the research, development and innovation landscape for upcoming technological developments that could be utilised in the preparation, implementation and evaluation of integrated ocean management schemes. Specifically in the marine/maritime field, a range of highly sophisticated technologies is currently in the pipeline which could lead to major improvements in data collection and management. These include, for example, high-performance sensors, underwater vehicles, rapid advances in imaging and mapping technologies, bio-based traceability tools and the growing use of low-cost customised micro-satellites. However, major changes in some of the leading-edge technologies are likely to occur outside marine-based science and technology. Hence, particular attention needs to be paid to inter-disciplinary research and development which will play an essential role in better integration of data-gathering technology in marine planning and monitoring.

3. Promote more innovation in governance structures, processes and stakeholder engagement to improve integrated ocean management

Why is it important?

Integrated ocean management is essentially a political process. It requires co-ordination across government as well as the engagement of all relevant stakeholders – scientists, business, user industries and associations – in the process. However, given their long history of sector-based approaches, current governance structures are usually not well suited to handle these co-ordination and consultation tasks effectively across sectors, especially where resources are moveable and renewable and/or stationary and mostly non-renewable. Different bureaucracies are usually in charge of handling the permitting for different uses and users, but they tend not to co-operate well, if at all. As noted above, moving from sector-by-sector management to integrated modes of ocean management constitutes a major institutional challenge.

There are broadly accepted elements in the ocean management process. In marine spatial planning (MSP), for example, guidance published by UNESCO in 2009 and recently updated shows a systematic process, beginning with preparatory steps, such as defining the objectives of a marine plan, analysing existing conditions, including the mapping of maritime activities, deciding on a preferred spatial scenario and approving the final plan. Stakeholder engagement is integrated into the overall process. Similarly, there exists an integrated coastal zone management (ICZM) protocol for the Mediterranean which is being adapted and applied to other sea basins.

But there is no single, recognised process for carrying out integrated ocean management or for co-ordinating across government or for engaging stakeholders. Practices vary from place to place, due to different geographies, marine pressures, legal requirements, planning cultures and so on.

Moreover, wider and deeper consultation with stakeholders cuts both ways: it can strengthen considerably the legitimacy of the planning, but it can also considerably lengthen the duration of the planning and permitting processes. Meanwhile, however, maritime space will rapidly become more crowded as the ocean economy continues to grow at a fast pace.

What should be done?

- Efforts to improve communication and co-operation across government departments and agencies involved in integrated ocean management should be stepped up. While not necessarily fully transferable, lessons can be drawn from successful structural and procedural reforms that governments have conducted around the world to expedite processes for MSPs, ICZMs and marine protected areas (MPAs). Also outside of the marine domain, governments have made significant progress in joined-up government approaches (e.g. in the management of major risks) and stronger strategic centre-of-government roles, thereby providing a rich pool of experience from which to draw.
- The effectiveness of stakeholder's participation in ecosystem-based ocean management needs to be supported by the best available scientific knowledge. This can be achieved through the organisation of open panels, peer reviewing of documents, and strong scientific guidance, able to incorporate and organise the needed scrutiny of contributions from research groups, non-governmental organisations (NGOs), private players and local communities.
- Innovative mechanisms should be developed to allow for speedier implementation of what is becoming an increasingly complex stakeholder consultation context. Again, international comparison of experience and good practice in such matters offers significant opportunities, as the timespans for widespread consultation appear to vary considerably from country to country and setting to setting. For large stakeholder communities, use of sophisticated media technologies, online consultation tools, social networks and local action plans offer promising avenues to be explored.
- Particular attention should be paid to the governance of the deep ocean, which offers significant opportunities for cross-disciplinary, multi-sectoral and multi-stakeholder stewardship both with and beyond national jurisdictions.

3. Improve the statistical and methodological base at national and international level for measuring the scale and performance of ocean-based industries and their contribution to the overall economy

Why is it important?

Putting a value on ocean-based industries raises public awareness of their importance, offering them higher visibility. It raises awareness among policy makers, rendering the industries more amenable to policy action; it enables progress in their development to be tracked over time; it also enables their contribution to the overall economy to be tracked in monetary and employment terms; and it lends weight to the perception of ocean-based industries as an increasingly interconnected set of activities whose defining common denominator is the ocean, its use and its resources. Moreover, as ocean-based activities and particularly the emerging ocean industries continue to grow, competition around the globe will intensify, making it essential for governments and businesses to be able to compare and position the national ocean economy at international level. However, official, internationally consistent and harmonised datasets for the world's ocean industries are not well developed and exist only for a limited number of industries. For emerging ocean industries, global statistical coverage is particularly poor.

What should be done?

- Encourage government agencies and services to step up efforts to improve national statistical data sets, particularly regarding emerging ocean-based industries, including through closer collaboration with non-official sources (maritime clusters, business associations, research institutions, NGOs) with a view to adjusting and incorporating new data into national statistical frameworks.
- Further develop the OECD's *Ocean Economy Database* by: 1) consolidating and updating relevant ocean-industry data in an internationally comparable framework; 2) improving data verification and calculation methods; 3) extending where feasible the range of ocean-related activities to include *inter alia* marine/maritime education and research, marine biotechnology, renewable ocean energy, marine business and financial services, maritime safety and surveillance; 4) mapping current and future demand for ocean-industry related skills; 5) refining the scenario methodologies; and 6) making the data available to stakeholders on a "one-stop-source" basis.
- Identify new and novel ocean-based activities of the future (e.g. management of ocean-scale marine protected areas; decommissioning of offshore oil and gas platforms).

4. Build more capacity for ocean industry foresight

Why is it important?

As an inter-connected ensemble of economic sectors operating at regional and global scale, it is essential for members of the ocean business community to be able to identify the long-term opportunities and risks facing their operations worldwide and to take their investment decisions accordingly. Equally, it is in the vital interests of governments of coastal states but also of many land-locked economies to understand the implications of an expanding ocean economy for the design and implementation of policy – policies that shape the competitiveness of their national maritime industries and which affect the health of oceans within their national jurisdiction and beyond. Other stakeholders in science, research and society more broadly have similar information requirements. Projections, scenarios, forecasts and future studies all can have their place in efforts to identify future issues, anticipate upcoming problems or opportunities, and support decision making.

What should be done?

- In light of the expanding economic use of the ocean, make greater and more regular use of foresight and other forward-looking techniques to help anticipate 10-20 years ahead the likely future development of ocean-based industries, assessing the likely impacts of their development on the ocean environment and paying attention not just to existing industries, but also to the emergence of new ocean-related activities.
- Conversely, continue to use foresight and other forward-looking techniques to assess the likely long-term impacts of future developments in the ocean environment – rising sea temperatures and sea levels, acidification, declining oxygen levels, shifts in currents and circulation patterns, loss of biomass and biodiversity, pollution especially from land sources, etc. – on ocean-based industries.
- Maintain and further refine the OECD’s current capacity for modelling future trends in the ocean economy at global scale and ensure public accessibility of the results for governments, business and research.

Annex 1.A1.
Scope of the ocean-based industries

This report proposes the following scope for established and emerging ocean-based activities, bearing in mind earlier remarks about overlapping definitions. The following shows the complete list of definitions.

Established industries:

- "Capture fisheries": the economic activity related to catch production.
- "Seafood processing": processing and distribution of seafood and micro- and macro-algae. In other words, it is the economic activity related to the preparation and preservation of fish, crustaceans and molluscs; production of fishmeal for human consumption and animal feed; as well as processing of seaweed.
- "Offshore oil and gas in shallow water": exploration and extraction of crude petroleum and natural gas from shallow-water offshore sources, including the operation and maintenance of equipment as well as exploration services related to this activity.
- "Shipping": the transportation of freight and passengers through the ocean, cargo handling, renting and leasing of water transport equipment and other services incidental to shipping and water transport.
- "Ports": the operation and management of ports, such as storage, loading and unloading activities.
- "Shipbuilding and repair": the manufacturing, repair and maintenance of ships, boats, offshore platforms and offshore supply vessels. Offshore platforms are the facilities that explore and develop oil and gas in the ocean, such as floating storage and offloading vessels (FPSO), fixed platforms, spars, Tension Leg Platform and so on. Offshore supply vessels (OSVs), which are offshore support vessels, are special vessels to support offshore oil and gas exploration and production. The reason for including offshore platforms and OSVs in this sector is that some shipbuilders produce offshore platforms as well as ships.
- "Marine manufacturing and construction": the industry that provides goods to multiple sectors. It can be defined as the economic activity that includes the manufacturing of marine equipment and materials, such as machinery, valves, cables, sensors, ship materials, aquaculture supplies and so on. Marine construction denotes the economic activity that is related to construction in the ocean (seabed cables, pipelines, etc.) and marine-related engineering, such as port development and construction.

- "Maritime and coastal tourism, including cruise industry": all tangible and direct facilities of ocean-related tourism and leisure activities, such as marine sports, recreational fishing, aquariums, excursions to underwater cultural habitats, etc., restaurants, hotels and seaside accommodation and campgrounds located in a place near or adjoining the coast. In addition, new forms and destinations of maritime tourism, such as Antarctic and Arctic cruise shipping, are also included in this sector.
- "Marine business services": the economic activities related to services that support ocean industries. The sub-sectors under it are marine insurance and finance, marine consulting, rental, technical services, inspection and survey, labour supply services and others related to this activity.
- "Marine R&D and education": activities relating to research and development, education and training. Even though research and development and education are different from one other, they are integrated into one sector, because in general the same organisations, such as a universities and research institutes, perform these activities.
- "Coastal flood defences": construction and management activities designed to protect coastlines from increasing coastal erosion and flooding due to changing sea levels. Strictly speaking, this is not an activity conducted in the ocean or in support of ocean industries, and so is often excluded from definitions of the ocean economy.

Emerging industries:

- "Marine aquaculture": the farm production of seafood and micro- and macro-algae.
- "Ultra-deep and deep water oil and gas": the economic activity related to the exploration and extraction of crude petroleum and natural gas from offshore sources, and includes the operation and maintenance of equipment as well as exploration services related to this activity.
- "Offshore wind energy": the production of wind energy by generating electricity offshore. The construction of wind parks in marine waters is included in shipbuilding since offshore wind parks are produced by shipbuilders.
- "Ocean renewable energy": the production of ocean renewable energy, such as tidal energy, wave energy, osmotic energy and ocean thermal energy conservation (OTEC).
- "Marine and seabed mining": the production, extraction and processing of non-living resources in seabed or seawater. This includes minerals and metals from the seabed (in the deep sea), diamonds in estuary waters, marine aggregates (limestone, sand and gravel) and seawater dissolved minerals extraction.
- "Maritime safety and surveillance" describes the economic activity related to products and services in different maritime domains, ranging from pollution and fisheries control to search and rescue, customs and costal defence by government and public or private organisations.

- "Marine biotechnology": the economic activity related to "[t]he application of science and technology to living organisms from marine resources, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services".[1]
- "High-tech marine products and services": diverse areas such as advanced sensing and communications, data management and informatics, marine robotics and artificial intelligence, materials sciences and marine engineering. These technologies support activity in a number of marine sectors such as oil and gas, transport and shipping, fisheries and aquaculture, coastal tourism and safety, security and surveillance. They also underpin development in emerging sectors such as marine renewable energy, marine environmental monitoring and resource management.
- "Others" signifies economic activities not classified above but nonetheless in the course of development, e.g. seawater desalination for fresh water usage (agriculture irrigation, consumer and commercial use) and carbon capture storage.

1. The OECD general definition for biotechnology, which is available at www.oecd.org/health/biotech/statisticaldefinitionofbiotechnology.htm, has emerged as a global standard according to the workshop "The Long-Term Potential of Marine Biotechnology").

Annex 1.A2.
Measuring the value of marine ecosystems

Estimates of the size of the benefits of marine ecosystem services suggest that these are considerable. De Groot et al. (2012) provide global estimates of a number of ecosystems and services, including for open oceans, coral reefs, coastal systems, and coastal and inland wetlands. They find that the total value of ecosystem services ranges from USD 490/year[1] for the total bundle of ecosystem services that can potentially be provided by an "average" hectare of open oceans, to almost USD 350 000/year for the potential services provided by an "average" hectare of coral reefs. Even the global value of individual natural capital assets, such as corals, is estimated at nearly USD 797.4 billion (Cesar, Burke and Pet-Soede, 2003). In some tourist destinations, the value of coral reefs can be up to USD 1 million per hectare and year, as is the case for Hawaii (Cesar, Burke and Pet-Soede, 2003). Another example for estimating the value of ecosystem services comes from carbon sequestration. The Global Ocean Commission (GOC) estimates the global economic value of carbon sequestration associated with seas and oceans to range between USD 74 billion and USD 222 billion per year (GOC, 2014). These numbers make clear that the contribution of marine and coastal ecosystems to the overall value of the ocean economy is very large indeed.

Ecosystem services range from tangible to intangible services (e.g. food production versus aesthetic value), which are sometimes separated into "goods" and "services". As Table 1.A2.1 indicates, marine and coastal ecosystem services can be divided into four categories: supporting, regulating, provisioning and cultural (De Groot, Wilson and Boumans, 2002).

Table 1.A2.1. **Marine and coastal ecosystem services**

Ecosystem service	Definition	Marine and coastal examples
Supporting	Ecosystem functions that support and enable the maintenance and delivery of other services	Photosynthesis, nutrient cycling, soil, sediment, sand formation
Regulating	Natural regulation of ecosystem processes and natural cycles	Water regulation, natural hazard weather regulation, carbon sequestration, shoreline stabilisation
Provisioning	Raw materials, food and energy	Raw materials (e.g. seabed deposits, such as manganese nodules, cobalt crusts and solid massive sulphides, sand, pearls, diamonds), food production (e.g. fisheries and aquaculture), energy (e.g. offshore wind, ocean energy, offshore oil and gas) Genetic resources (source of unique biological materials, and processes of industrial interest)
Cultural	Benefits related with experiences of natural environments	Tourism, recreation, spiritual values, education, aesthetics

Source: Adapted from De Groot, Wilson and Boumans (2002).

Putting an economic value on the contribution of ocean-based industries is difficult enough; it is even more difficult to identify and value ecosystems and their provision of goods and services (Barbier et al. 2011; Polasky and Segerson, 2009). The values that are attributed to ecosystem services depend on the stakeholders that benefit from these services (Vermeulen and Korziell, 2002). These values include both use and non-use values.

Use values arise when ecosystem services are used in a direct manner, whether in an extractive way (e.g. for income or food) or in a non-extractive way (e.g. for observation or recreation). Non-use values, on the other hand, reflect a valuing of indirect services, notably for the supporting and regulating functions of ecosystems, such as maintaining water quality and community traditions (indirect use). Non-use values also include what are called "option value" and "existence value" – the former being the value of knowing now that we are maintaining the potential to provide ecosystem services in the future, while the latter reflects the value of the ecosystem services due to their mere existence, independently of anyone's current or future uses of these services.

Quantifying non-use values is particularly complicated. However, economists have developed a variety of methods to estimate the value of goods whose market is either imperfect or non-existent. These include revealed preference and stated preference methods.[2] A useful reference to the economic valuations of ecosystems undertaken as part of the Millennium Ecosystem Assessment and The Economics of Ecosystems and Biodiversity (TEEB) exercise is TEEB (2011) edited by Brink. Since then, a comprehensive set of background papers and sectoral and country studies have become available (Kubiszewski et al., 2013; McVittie and Hussain, 2013; Russi et al., 2013).

Despite the efforts alluded to above, valuing ecosystem services remains challenging. It is an underdeveloped field, and the kind of techniques referred to here are neither widely deployed around the world nor well integrated into assessment and evaluation exercises. Recently initiated national efforts to address these gaps (for example in France, the Netherlands and the United Kingdom) are therefore to be welcomed. Looking to the future, valuation of ecosystem services must be considered a cornerstone in any effective strategy for managing the balance between human activity and the health of the ocean. As the European Union's Marine Strategy Framework Directive states, "applying an ecosystem-based approach to the management of human activities means ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status and that the capacity of marine ecosystems to respond to human-induced changes is not compromised, while enabling the sustainable use of marine goods and services by present and future generations."

In conclusion, while the main focus of this report is on ocean-based industries and activities, it is important to also bear in mind that the ocean's natural assets and ecosystem services are an integral part of the ocean economy. The project testifies to their importance by highlighting marine ecosystem aspects throughout the report, while at the same time recognising the need to intensify efforts to better understand and value ocean ecosystems.

Notes

1. Values converted to a common set of units, namely 2007 "international" dollars/year, i.e. translated into USD values on the basis of purchasing power parity.

2. Revealed preference methods estimate the demand for an ecosystem's goods and services through statistical analysis of individuals' willingness to incur costs related to benefits from the goods and services obtained. This method includes the travel cost method (TCM), Hedonic Price (HP) approach and averting behaviour approach (Koundouri, 2009). The common underlying feature is a functional dependency of environmental benefits on the consumption of a specific market good (weak substitutability). Cultural and recreational values are often measured by using this method. The stated preference method is based on surveys and questionnaires to measure in a constructed or hypothetical market the stakeholder's willingness to pay to enjoy and/or protect an ecosystem (Koundouri, 2009). Stated preference approaches include the Contingent Valuation Method (CVM) and Choice Experiments (CE).

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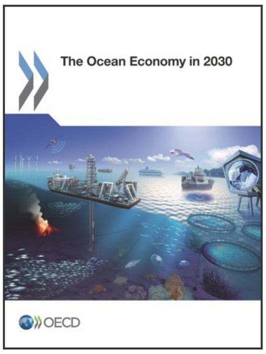

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