THE EU BLUE ECONOMY REPORT 2023









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This Report was prepared by the European Commission Directorate General for Maritime Affairs and Fisheries, and the Joint Research Centre (JRC). It was prepared by unit MARE A4: Economic Analysis, Markets and Impact Assessment and units JRC C6: Economics of Climate Change, Energy and Transport, JRC C7: Knowledge for the Energy Union and JRC D2: Ocean and Water in collaboration with other Commission services.

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FOREWORD

The year 2022 was marked by high spikes in energy prices. Initially caused by the post-pandemic economic recovery, they were amplified by the unprovoked Russian invasion of Ukraine and the effects of the global response and the ensuing high inflation rates.

The European Commission responded with various measures, including the REPowerEU plan, advancing efforts on the 'Fit for 55' package, and issuing the Communication on Energy Transition in the EU Fisheries and Aquaculture in February 2023. In addition, the EU aquaculture and fisheries sectors have access to continued support from the European Maritime, Fisheries and Aquaculture Fund (EMFAF) and programmes such as the BlueInvest and the InvestEU Blue Economy Fund.

But changing times also mean adapting to new formats. I am delighted to announce a new feature of the EU Blue Economy report. Starting from this edition, this annual flagship publication of the Directorate-General for Maritime Affairs and Fisheries and the Joint Research Centre of the European Commission will be published in a shorter and more concise format. Furthermore, it will be connected to and incorporated into the wider EU Blue Economy Observatory, which we jointly launched last year.

I hope this report will be a guide on your journey towards sustainability, helping you to achieve the targets of the European Green Deal.

Welcome aboard and enjoy your exploration.

Virginijus Sinkevičius,
EU Commissioner for Environment, Oceans and Fisheries

CONTENTS

EXECUTIVE SUMMARY

In a new format, the **sixth edition of the EU Blue Economy Report** continues to analyse the scope and size of the Blue Economy in the European Union. Its main objective remains to provide support to policymakers and stakeholders in the quest for a sustainable development of oceans, coastal resources and, most notably, to the development and implementation of polices and initiatives under the European Green Deal in line with the new approach for a sustainable Blue Economy. Through its economic evidence, the *Report* also seeks to serve as a source of inspiration to investors.

The sixth edition of the *Report*[1] focuses on a summarised data analysis, trends and drivers of the **Blue Economy established sectors** (i.e., those that traditionally contribute to the Blue Economy), as well as of ***Blue Biotechnology*** and ***Ocean Energy***. This edition includes as well a brief analysis on the impacts of Russia's invasion of Ukraine on some of the Blue Economy sectors. The report also contains a section following the **Energy transition communication**[2], which comprises an analysis of **the energy transition in the Blue Economy**. It assesses GHG emissions taking into consideration different species, fishing techniques and their production phases. The report ends with a section analysing **climate change and coastal impacts**. This section summarises findings related to the future dynamics of coastal flood impacts, adaptation and ecosystem services, along the EU-27 coastline.

This edition also takes advantage of the **Blue Economy Observatory** platform, which provides more timely and regular updates of the Blue Economy data. Further analysis will be published throughout the year, as the most recent data become available, and sectors or topics are highlighted.

The Blue Economy established sectors include *Marine living resources*, *Marine non-living resources*, *Marine Renewable energy*, *Port activities*, *Shipbuilding and repair*, *Maritime transport* and *Coastal tourism*.

The analysis of these sectors is based on data collected by the European Commission from EU Member States and the European Statistical System. Fisheries and aquaculture data were collected under the EU Data Collection Framework (DCF). Analyses for all other established sectors are based on Eurostat data from Structural Business Statistics (SBS), PRODCOM, National Accounts and tourism statistics[3].

The Blue Economy's emerging and innovative sectors include *Marine renewable energy* (i.e., ocean energy, floating solar energy and offshore hydrogen generation), *Blue biotechnology*, *Desalination*, *Maritime defence, security and surveillance*, *Research and Infrastructure* (submarine cables, robotics). However, in this edition of the Blue Economy Report we are only providing an assessment of the *Blue biotechnology* and *Ocean energy sectors*. These sectors offer significant potential for economic growth, sustainability transition, as well as employment creation. For the emerging sectors data are not fully available in the public domain. Analyses are provided for the EU-27 as a whole and by sector and industry for each Member State (MS). The methodology[4] followed in this report is detailed in the EU Blue Economy Observatory[5].

Established sectors of the EU Blue Economy generated a gross value added (GVA) of €129 billion in 2020, that is, a 30% decrease compared to 2019, due to COVID-19 impacts. Gross operating surplus (profit) at €43.6 billion was 40% lower and total turnover at €523 billion decreased by 22% compared to 2019. COVID-19 measures such as stringent public health measures and imposed lockdowns, travel restrictions, event cancellations and closure of food services and hotel industries affected the different Blue Economy sectors, with some such as *Coastal tourism* among the most impacted. These established sectors directly employed almost 3.34 million people in 2020, a 26% decrease compared to 2019. (Table 0.1).

Table 0.1 EU Blue Economy established sectors, main indicators, 2020

Indicator	EU Blue Economy 2020
Turnover	€523.0 billion
Gross value added	€129.1 billion
Gross profit	€43.6 billion
Employment	3.34 million
Net investment in tangible goods	€6.6 billion
Net investment ratio	5.1%
Average annual salary	€25 950

Notes: Turnover is calculated as the sum of the turnover in each sector; it may lead to double counting along the value chain. Nominal values. Direct impact only. Net investment excludes Maritime transport and Coastal tourism. Net investment ratio is defined as net investment to GVA.

Source: Eurostat (SBS), DCF and Commission Services.

For the established sectors, two sectors are particularly noteworthy: (1) ***Coastal tourism*** was the most impacted sector with a 58%-decrease in GVA and 40%-decrease in employment; however, it kept generating the largest share of employment and GVA in the EU Blue Economy, with 51% and 26%, respectively. (2) The ***Offshore wind energy*** sector is the only one that showed an increase in GVA and employment in 2020, while ***Shipbuilding and repair*** and ***Port activities*** only increased in persons employed.

As for emerging sectors, ***Ocean and Marine Renewable Energy*** will continue to be crucial in achieving the ambitious goals and targets of the European Green Deal, the EU Hydrogen Strategy[6], the Offshore Renewable Energy Strategy[7], as well as the REPowerEU Communication[8].

[1] This year's edition of the Blue Economy Report supersedes the 2022 Blue Economy Report.
[2] COM (2023) 100 final https://oceans-and-fisheries.ec.europa.eu/publications/communication-commission-energy-transition-eu-fisheries-and-aquaculture-sector_en
[3] Analysis in this report are provided for 2009-2020 period for the EU-27 as a whole and by the sector and industry for each Member State. New data for 2021 will soon be released on the Blue Economy Indicators.
[4] https://blue-economy-observatory.ec.europa.eu/methodology-estimation-established-sectors-data_en
[5] https://blue-economy-observatory.ec.europa.eu/index_en
[6] COM (2020) 301 final, July 2020, https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf
[7] https://ec.europa.eu/energy/sites/ener/files/offshore_renewable_energy_strategy.pdf
[8] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en.

In line with the Offshore Renewable Energy Strategy to increase offshore wind capacity[9], in January 2023, Member States agreed on new, ambitious long-term goals for installing approximately 111 GW of offshore renewable generation capacity by the end of this decade and around 317 GW by 2050[10].

One of the most dynamic sub-sectors in the field of ***Blue biotechnology*** is the algae sector. Available socio-economic estimates show that algae production in Europe generated an annual turnover well above €10 million in the MSs with the largest number of production facilities (France, Spain and Portugal).

The Blue Economy is linked to many other economic activities and its effects on employment, income and well-being go beyond the above-mentioned sectors.

[9] From its 12 GW to 300 GW by 2050, complemented with 40 GW of ocean energy and other emerging technologies by 2050.
[10] https://energy.ec.europa.eu/news/member-states-agree-new-ambition-expanding-offshore-renewable-energy-2023-01-19_en

CHAPTER 1

GENERAL OVERVIEW AND ECONOMIC CONTEXT

This chapter describes the general context and the relevant background information in which economic data presented in this report should be interpreted, as well as a high-level overview of the established sectors.

1.1. GENERAL ECONOMIC CONTEXT

The Gross Domestic Product (GDP) of the EU-27 decreased from €14 019 billion in 2019 to €13 470 billion in 2020 because of the COVID-19 pandemic, and the employment rate for persons aged 20-64 dropped to 72.4%, down by 0.7 percentage points in comparison to 2019, when 193.6 million people were employed[11]. Despite the COVID-19 pandemic took a huge toll on the EU Economy, the EU Blue Economy remained relatively stable during 2020.

The unprovoked Russian invasion of Ukraine has affected the EU Economy and the Blue Economy sectors in different ways, ranging from increases in oil and marine diesel prices, to trade restrictions, and supply chain bottlenecks. The impact on the different sectors will depend on the extent and duration of the conflict and retaliation measures.

The Russian invasion of Ukraine further exacerbated the spike in energy prices driven by COVID-19 in late 2021 and in 2022. Marine-diesel prices doubled from 2021 to 2022[12], leading energy costs to increase from 13% of revenues in 2020 to an estimated 35% in 2022.

Nonetheless, in 2022, the EU economy expanded, highlighting its resilience. The GDP of the EU-27 was estimated at €15 810 billion, up from €14 535 billion in 2021 and €13 470 billion in 2020[13], and projected to expand by 0.8% in 2023[14]. Labour markets have also continued to perform strongly, with employment estimated at 193.5 million in 2022, and unemployment rate at 6.1% in December 2022, the lowest since 2000[15].

The EU Economic sentiment[16] continued improving in late 2022, softening the foreseen economic contraction in the first quarter of 2023. Employment gains, further decrease in the savings rate and fiscal support supported the private consumption indicator while, the recovery of construction activity, in the last quarter of last year, sustained the supply side.

1.2. OVERVIEW OF THE EU BLUE ESTABLISHED SECTORS

The established Blue Economy sectors continue to be a major contributor to the EU Blue Economy, and it is in these sectors where more complete, accurate and comparable data are available. The seven established sectors considered in this report are *Marine living resources*, *Marine non-living resources*, *Marine renewable energy*, *Port activities*, *Shipbuilding and repair*, *Maritime transport* and *Coastal tourism*. Each sector is further divided into subsectors as summarised in Table 1.1. These subsectors are at the same time divided into activities.

Table 1.1 The Established Blue Economy sectors and their subsectors

Sector	Sub-sector
Marine living resources	Primary production
	Processing of fish products
	Distribution of fish products
Marine non-living resources	Oil and gas
	Other minerals
	Support activities
Marine renewable energy	Offshore wind energy
Port activities	Cargo and warehousing
	Port and water projects
Shipbuilding and repair	Shipbuilding
	Equipment and machinery
Maritime transport	Passenger transport
	Freight transport
	Services for transport
Coastal tourism	Accommodation
	Transport
	Other expenditure

Eurostat's Structural Business Statistics (SBS) data are used for all established sectors, with the exception of the primary sector[17] activities in the *Marine living resources* sector that use DCF data. In addition, data from Tourism expenditure survey and from the EU Tourism Satellite Accounts were used for the *Coastal tourism* sector.

In addition to the established sectors, this 2023 Blue Economy Report also analyses *Ocean energy* – which includes marine renewable energy sources other than offshore wind energy – and *Blue biotechnology*, which includes algae production and processing that are not included in the *Marine living resources* sector. For these two sectors, less complete data are available, partly because they are not fully captured by the statistical classification of economic activities due to their emerging nature.

Although only the direct contribution of the Blue Economy sectors is considered here, all sectors have indirect and induced effects on the rest of the economy. For example, in *Shipbuilding and repair*, most of the value added is from upstream and downstream activities. This means that beyond its specific contribution, it has significant multiplier effects on income and jobs in many sectors of the economy.

1.3. THE EU BLUE ECONOMY

The Gross Value Added (GVA) of the Blue Economy established sectors in **2020 was €129.1 billion** (contributing **1.1%** to the

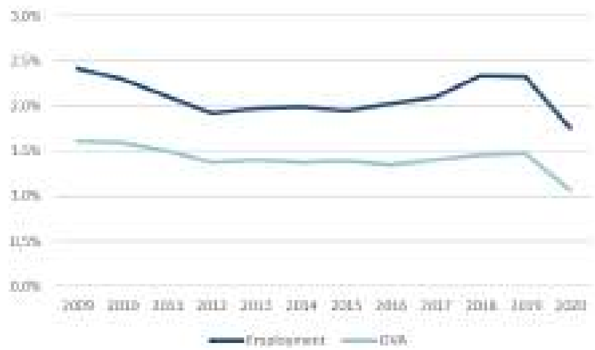
[11] The national GDP and employment data have been extracted from Eurostat.
[12] In the first 9 months of 2022, marine fuel prices averaged close to 1.00 EUR/litre, with peaks well above 1.00 EUR/litre, which was more than double the 2021 average. Source: EUMOFA Macroeconomic dashboard. Macroeconomic (eumofa.eu).
[13] GDP data for 2022 and 2021 have been extracted from Eurostat.
[14] European Economic Forecast, Winter 2023. https://economy-finance.ec.europa.eu/system/files/2023-02/ip194_en_1.pdf.
[15] Employment (labour force aged 15-74) and unemployment rate are extracted from the European Economic Forecast, Winter 2023.
[16] Glossary: Economic sentiment indicator (ESI) - Statistics Explained (europa.eu).
[17] Capture fisheries and aquaculture.

EU-27 economy), a 30%-decrease from **€185.4 billion (1.5%** of the EU-27 economy) in 2019. Turnover in the Blue Economy decreased 22% from **€671.3 billion in 2019** to **€523 billion in 2020**. Employment decreased 26% from **4.50 million** in 2019 to **3.34 million in 2020 (1.8%** in terms of contribution to the EU-27 economy) (Figure 1.1)[18].

In 2021, household expenditure on fishery and aquaculture products in the EU-27 grew 7% from 2020, continuing the upward trend already registered between 2019 and 2020[19].The year 2021 saw overall growth in the total value of EU trade flows of fishery and aquaculture products, and it also initiated a period of economic recovery from the 2020 pandemic crisis. In February 2022, the total value of EU trade of fishery and aquaculture products plummeted. This is linked to the unprovoked Russian invasion of Ukraine[20], which affected oil prices and created bottlenecks in the supply chain globally. It also contributed to a spike in energy prices. As a result, a significant part of the EU fisheries fleet was not able to cover their operational costs in 2022, forcing many vessels to stay in port[21]. Furthermore, with the fifth package of sanctions (8 April 2022), the EU prohibited to provide access to EU ports to all Russian vessels[22], then expanded the ban to locks on 21 July 2022.

The seven established sectors of the EU Blue Economy generated a GVA of €129 billion in 2020; that is, a 30%-decrease compared to 2019, and a 16%-decrease compared to 2009. Gross operating surplus (profit) at €43.6 billion was 40% lower and total turnover[23] at €523 billion, decreased by 22% compared to 2019 (Figure 1.2).

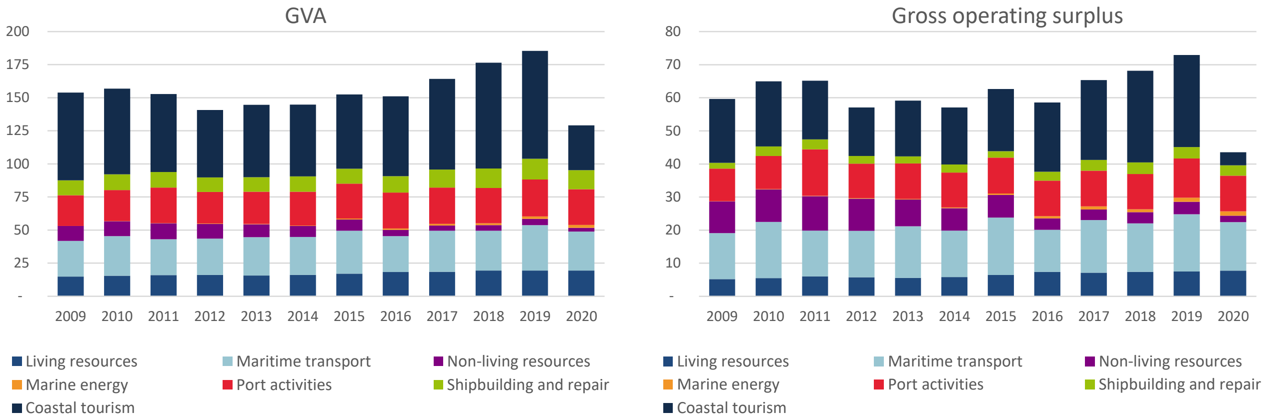
Figure 1.1 Contribution of the Blue Economy to the overall EU economy



These established sectors directly employed almost 3.34 million people in 2020, a 26%-decrease compared to 2019 (Figure 1.3).

These figures show the magnitude of the impact generated by the COVID-19 pandemic on the EU blue economy. In particular, *Coastal tourism* was the most impacted sector with a 58%-decrease in GVA and 40%-decrease in employment, followed by *Maritime transport* and *Non-living resources*. Only *Offshore wind energy* showed an increase in GVA ad employment in 2020.

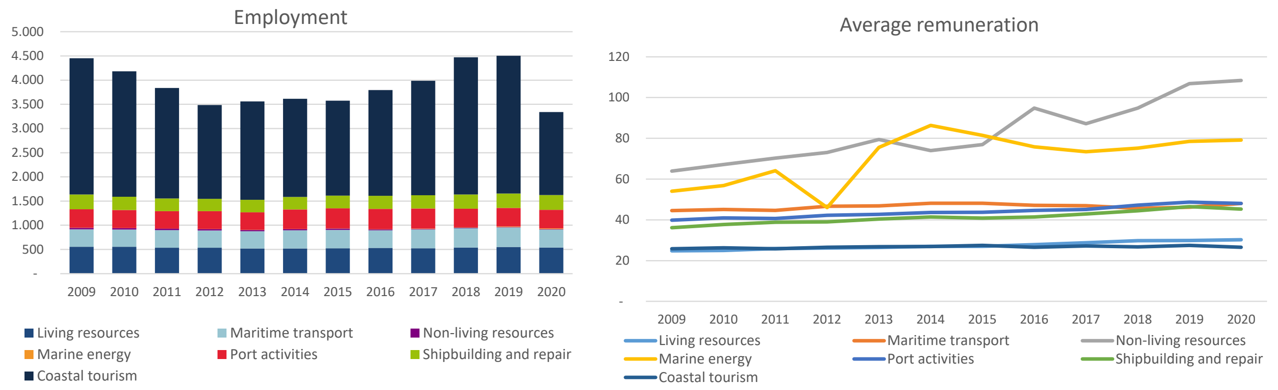
Figure 1.2 Size of the EU Blue Economy, € billion



Source: Own calculations based on Eurostat (SBS) and DCF data

[18] Data on the Blue Economy extracted from the Blue Economy Indicators (In-depth Analytical Tool).
[19] The EU Fish Market 2022. P.15 Paragraph 1: https://www.eumofa.eu/documents/20178/521182/EFM2022_EN.pdf/5dbc9b7d-b87c-a897-5a3f-723b369fab08?t=1669215787975
[20] Idem, Paragraph 2.
[21] COM/2023/100 On the Energy Transition of the EU Fisheries and Aquaculture sector. https://oceans-and-fisheries.ec.europa.eu/publications/communication-commission-energy-transition-eu-fisheries-and-aquaculture-sector_en
[22] https://www.consilium.europa.eu/en/press/press-releases/2022/04/08/eu-adopts-fifth-round-of-sanctions-against-russia-over-its-military-aggression-against-ukraine/
[23] Considering turnover can lead to double counting along the value chain since the outputs from one activity can be the inputs of another activity (i.e., intermediate consumption). This may particularly affect some sectors, such as Living resources and Shipbuilding and repair. For example, the value of a fish could be counted several times in the Marine living resources sector, when caught in the primary production sub-sector, then when processed in the Processing of fish product sub-sectors, and finally when sold in the Distribution of fish products sub-sector.

Figure 1.3 Employment (thousand people) and the average remuneration per employee (€ thousand) in the EU Blue Economy



Source: Own calculations based on Eurostat (SBS) and DCF data.

Despite this decrease, *Coastal tourism* kept generating the largest share of employment and GVA in the EU Blue Economy, with 51% and 26%, respectively. It was then followed by *Maritime transport* with 11% and 23%, *Port activities* with 12% and 21%, *Living resources* with 16% and 15%, and *Shipbuilding and repair* with 9% and 11%. *Marine renewable energy* generated 0.4% of the employment and 2% of the GVA, while *Non-living resources* 0.3% and 2%, respectively (Table 1.2).

Gross remuneration per employee for the EU Blue Economy established sectors has increased steadily since 2009. Average gross remuneration per employee was lowest in the *Coastal tourism* and *Living resources* sectors; while it was highest for the *Non-living resources* and *Marine renewable energy* sectors.

The *Non-living resources* and *Marine renewable energy sectors* have quite different employment trends. *Marine renewable energy* is a relatively new sector, and as such it is characterised by high growth. *Non-living resources*, on the other hand, is a mature sector, which is declining, among other things as a consequence of the EU policies adopted to reduce dependency on oil and gas.

Table 1.2 Overview of the EU Blue Economy by sector

Persons employed (thousands)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Living resources	556.5	555.1	536.1	536.7	520.7	518.5	521.7	529.9	525.2	539.9	550.7	539.4
Non-living resources	34.4	31.6	29.8	30.4	27.7	28.1	27.5	17.9	12.5	11.1	10.1	9.5
Marine energy	0.4	0.6	0.9	1.0	1.2	1.7	4.0	5.1	7.0	8.3	10.6	12.3
Port activities	381.5	372.4	359.4	367.3	363.5	403.3	413.9	418.1	415.6	385.2	382.6	385.6
Shipbuilding and repair	306.8	274.7	263.4	255.5	256.6	258.8	264.1	269.2	274.8	292.8	299.1	305.5
Maritime transport	357.4	354.5	363.1	356.2	356.3	375.8	383.1	367.6	384.6	398.1	403.1	371.6
Coastal tourism	2,816.0	2,595.5	2,285.3	1,939.0	2,033.7	2,029.7	1,960.1	2,187.8	2,366.6	2,839.0	2,846.7	1,717.4
Blue economy jobs	4,453.0	4,184.4	3,838.1	3,486.1	3,559.9	3,616.0	3,574.4	3,795.6	3,986.3	4,474.3	4,502.8	3,341.3
National employment	184,570	182,166	182,277	181,282	180,464	181,981	184,044	186,964	189,678	191,831	193,604	190,062
Blue economy contribution (%)	2.4%	2.3%	2.1%	1.9%	2.0%	2.0%	1.9%	2.0%	2.1%	2.3%	2.3%	1.8%
GVA (€ million)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Living resources	14,945	15,467	16,033	16,086	15,637	16,082	17,083	18,386	18,431	19,375	19,425	19,378
Non-living resources	11,190	11,325	11,935	11,237	9,684	8,215	8,431	4,723	3,940	4,291	4,704	2,810
Marine energy	41	115	167	189	297	396	723	991	1,299	1,397	1,926	2,145
Port activities	23,201	23,381	26,876	23,957	24,252	25,492	26,431	27,210	27,429	26,577	27,935	26,939
Shipbuilding and repair	11,263	11,815	11,750	10,912	11,060	11,607	11,264	12,383	13,540	14,748	15,650	14,469
Maritime transport	26,913	30,004	27,108	27,419	29,049	28,785	32,476	27,088	31,032	30,123	34,244	29,509
Coastal tourism	66,380	64,713	58,882	50,922	54,711	54,223	56,003	60,283	68,535	79,954	81,513	33,872
Blue economy GVA	153,932	156,820	152,750	140,723	144,691	144,800	152,410	151,064	164,206	176,466	185,396	129,121
National GVA	9,536,725	9,853,556	10,150,557	10,211,897	10,319,741	10,555,397	10,938,710	11,228,272	11,689,383	12,095,625	12,535,146	12,094,906
Blue economy contribution (%)	1.6%	1.6%	1.5%	1.4%	1.4%	1.4%	1.4%	1.3%	1.4%	1.5%	1.5%	1.1%

Source: Own calculations based on Eurostat (SBS) and DCF data

1.4. THE BLUE ECONOMY ESTABLISHED SECTORS ACROSS MEMBER STATES

In absolute terms, the four largest Member States (Germany, Spain, Italy and France) are the largest contributors to the EU Blue Economy when it comes to both employment – with a combined contribution of 55% – and GVA – combined contribution of 57%. Denmark is the fourth largest contributor to the EU Blue Economy in terms of GVA (11%), together with Italy and Spain. However, it represents only 3% of employment in the EU Blue Economy.

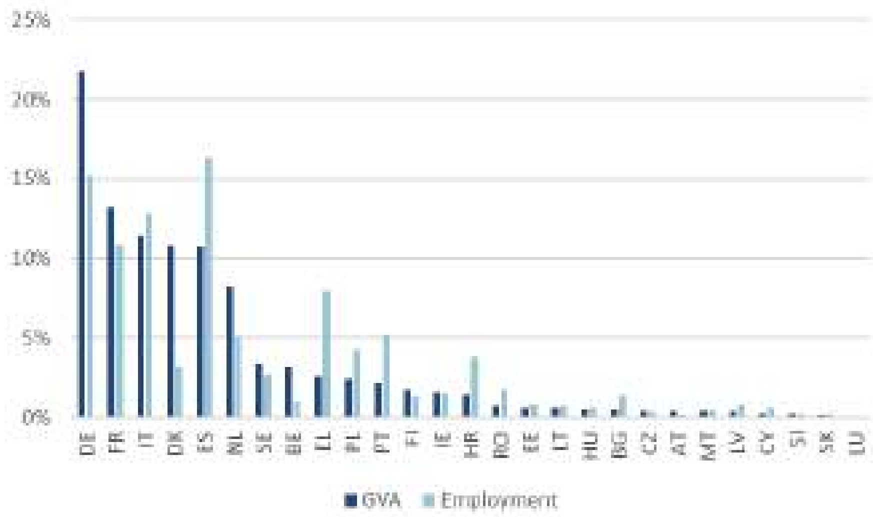
In 2020, the contribution of the established Blue Economy sectors to the overall EU economy was 2.8% in terms of employment (up from 2.3% in 2019) and 1.1% in terms of GVA (down from 1.5% in 2019). The decline in the overall contribution of the Blue Economy in 2020 in terms of GVA is driven by *Coastal tourism*, whose economic activities were among those hit the hardest in the whole economy, with a reduction of more than 58% in GVA and 40% in employment. This signals that the EU Blue Economy grows and shrinks faster than the EU overall economy, given its reliance on *Coastal tourism*, which tends to grow faster when the economy is expanding, but also to shrink faster during downturns.

The contribution of the Blue Economy to the national economies varies widely across Member States.

In terms of employment, its share ranges from 8% in Croatia to 0.1% in Luxembourg; when it comes to GVA, it ranges from 5% in Denmark to less than 0.1% in Luxembourg (Figure 1.5).

In general, the Blue Economy is a more significant contributor to national GVA and employment in insular Member States or those with archipelagos: Denmark, Croatia, Malta, Greece, Cyprus and Portugal. Estonia is an exception with its Blue Economy contributing to 5% of total employment.

Figure 1.4 National contribution to the EU Blue Economy, percentage (EU28 = 100%) in terms of employment and GVA



Source: Own calculations based on Eurostat (SBS) and DCF data

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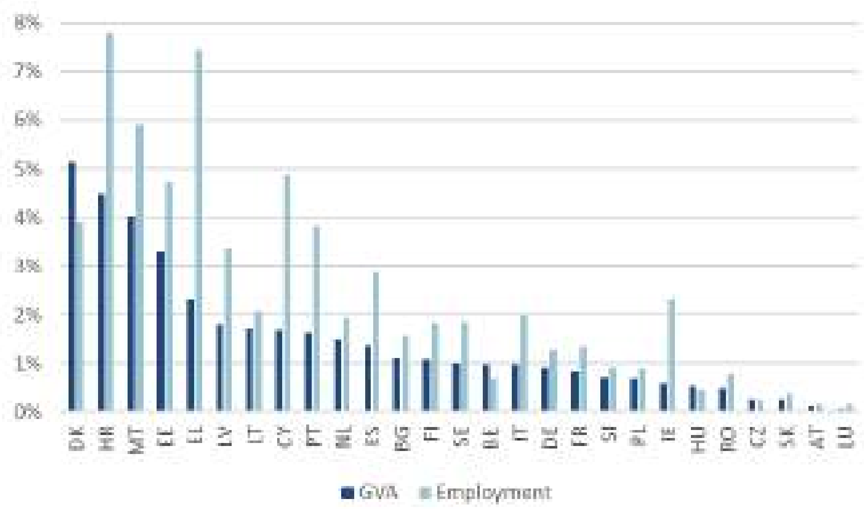
Figure 1.5 Relative size of the Blue Economy, as share (percentage) of blue jobs and GVA in the national economy



Source: Own calculations based on Eurostat (SBS) and DCF data

CHAPTER 2
ESTABLISHED SECTORS

2.1. MARINE LIVING RESOURCES

The *Marine living resources* sector encompasses the harvesting of renewable biological resources (**primary sector**), their conversion into food, feed, bio-based products and bioenergy (**processing**) and their **distribution** along the supply chain.The EU is the sixth largest producer of fishery and aquaculture products (behind China, Indonesia, India, Vietnam, Peru and the Russian Federation), covering around 2% of global production[24]. However, overall production has been rather stable in the last few decades. The EU has slightly more than 56 100 active vessels landing about 3.9 million tonnes of seafood worth €5.8 billion; at the same time, the aquaculture sector reached a production of about 1.2 million tonnes worth €3.9 billion in 2020. The EU *Marine living resources* sector has been heavily impacted by external factors in recent years. The Trade and Cooperation Agreement (TCA), following BREXIT, gradually reduces the share of EU fishing opportunities in UK waters stocks from 2021 to 2025. The COVID-19 pandemic and public health interventions depressed demand and disrupted supply chains for many fishing businesses[25]. Since the military invasion of Ukraine by Russia in February 2022, energy and fuel prices have increased sharply and have remained relatively high, heavily impacting the sector.

Size of the EU Maritime living resources sector in 2020

The sector generated more than €19.4 billion in GVA in 2020, a 0.2%-decrease compared to 2019. Instead, gross profits increased by 3%, reaching €7.7 billion; while the reported turnover was about €119 billion. The sector directly employed almost 540 thousand persons, a 2%-decrease from 2019. Personnel costs totalled €11.8 billion. The annual average wage is estimated at €21.9 thousand, almost the same that in 2019 (Figure 2.1).

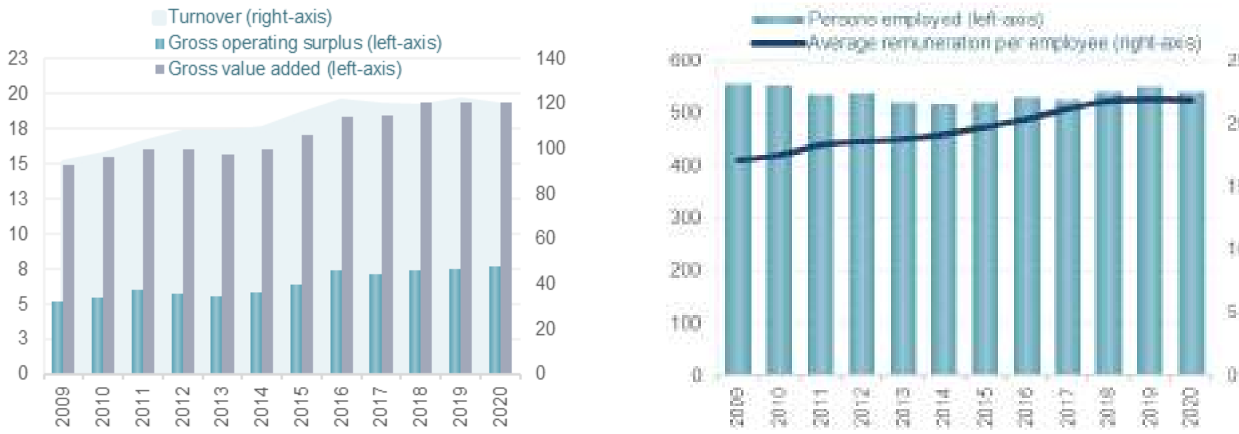
Results by sub-sector and Member State

Spain was the top employer in the sector with 22% of the jobs and 18% of the GVA, followed by Italy, France and Germany with 14%, 12% and 11% of employment, and by Germany, France and Italy when considering GVA, with 16%, 15% and 13% (Figure 2.2).

Employment: *Distribution of fish products* employed about 210 400 persons, accounting for 39% of the jobs, while *Primary production* employed 200 400 persons (37%) and *Processing of fish products* 128 500 persons (24%).

Gross value added: In 2020, *Distribution of fish products* generated €8.9 billion in GVA, about 46% of the sector's GVA, followed by *Processing of fish products* with €5.6 billion (29%) and then *Primary production* with €4.8 billion (25%).

Figure 2.1 Size of the EU *Marine living resources* sector, 2009-2020. Turnover, GVA and gross operating surplus in € billion, persons employed (thousand), and average wage (€ thousand)



Source: DCF and own calculation

Figure 2.2 Share of employment and GVA in EU Maritime living resources sector, 2020

Source: DCF and own calculations

[24] EUMOFA. 2022. The EU fish market, 2022 edition. Luxembourg: Publications Office of the European Union. DOI: 10.2771/716731.
[25] Carpenter, G., Carvalho, N., Guillen, J., Prellezo, R., Villasante, S., Andersen, J. L., ... & Zhelev, K. (2023). The economic performance of the EU fishing fleet during the COVID-19 pandemic. Aquatic Living Resources, 36(2).

Trends and drivers

The economic impact of the **COVID-19 pandemic** on this sector was somehow less harsh than initially expected; in fact, overall profits actually increased. The EU fishing fleet was more heavily impacted than other sectors, with a 7%-reduction in GVA and 10% in gross profit, but all indicators were positive in 2020[26]. This was partly due to low fuel prices that reduced operating costs of fishing, and to the early response from governments to support the sector[27].

The **Russian invasion of Ukraine** and subsequent high fuel prices are jeopardising the viability of the sector, in particular of the EU fishing fleet, which is largely fuel intensive and particularly vulnerable to fuel price increases. A 10-cent increase in fuel price per litre would lead to a profitability loss of around €185 million. Hence, the fishing fleet struggles to be viable in the short-term; but may not be viable in the long term, since it does not earn enough to be able to fully replace its capital factors (i.e., the fishing vessels) in the future.

High energy prices have also affected the aquaculture, processing and distribution industries. Prices of raw materials (e.g., soy, fishmeal and oil) have also been affected by the conflict, which means that overall prices in these industries are also influenced[28].

On the 21st of February 2023, the Commission presented a package [29] which includes four communications. The main objectives of the measures are to promote the use of cleaner energy sources and reduce dependency on fossil fuels as well as reduce the sector's impact on marine ecosystems. This package includes the Communication on the Energy Transition of the EU Fisheries and Aquaculture sector (see Section 4 on energy transition) with measures to improve the sustainability and resilience of the EU's fisheries and aquaculture sector. The Marine Action Plan to protect and restore marine ecosystems for sustainable and resilient fisheries [30], another communication presented in the package, proposes the phasing out of mobile bottom-contact gears in all marine protected areas (MPAs) by 2030 at the latest[31].

For more information, please visit the section on [Marine Living Resources] within the EU Blue Economy Observatory.

2.2. MARINE NON-LIVING RESOURCES

Marine non-living resources has been an important sector of the EU Blue Economy for many years. Since about a decade, the mature offshore oil and gas sector has been on a downward trend, in line with the net-zero emission targets and decarbonisation objectives of the EU. Nonetheless, it is expected that oceanographic research, the exploration of ocean resources, the exploitation of sources of energy and the extraction of raw materials from Europe's seas and oceans will play a crucial role in the transition to a sustainable Blue Economy, particularly in terms of enabling the development and large-scale deployment of low-carbon technologies[32].

For the purpose of this report, the *Marine non-living resources* sector comprises two main subsectors:

1. ***Oil and gas***: Extraction of crude petroleum, Extraction of natural gas, Support activities;
2. ***Other minerals***: Operation of gravel and sand pits; mining of clays and kaolin; it also includes extraction of salt.

Size of the EU Marine non-living resources sector in 2020

In 2020, the GVA generated by the sector amounted to €2.8 billion, corresponding to approximately one fourth of the GVA registered in 2009 (€11.2 billion). Since 2019, turnover registered a 28%-decrease (€9.4 billion), while gross profits shrunk by 49% (€1.9 billion) and GVA contracted by 40% (Figure 2.3).

Net investments in tangible goods registered a three-fold increase from 2019, reaching about €1 billion in 2020. Yet, they were still 58% lower than in 2009. The ratio of net investment to GVA was estimated at 36.2% in 2020, up from 6.9% in 2019. The ratio improved mainly due to the above-mentioned contraction in GVA, while new investments have been declining steadily due to the downsizing of the oil extraction sector and a widespread pushback on deep seabed mining, given its harmful impacts and largely unknown potential damages on marine ecosystems[33]. Overall, the sector has been in decline since 2012, mostly because of the sharp contraction in the oil and gas sub-sector.

Results by sub-sector and Member State

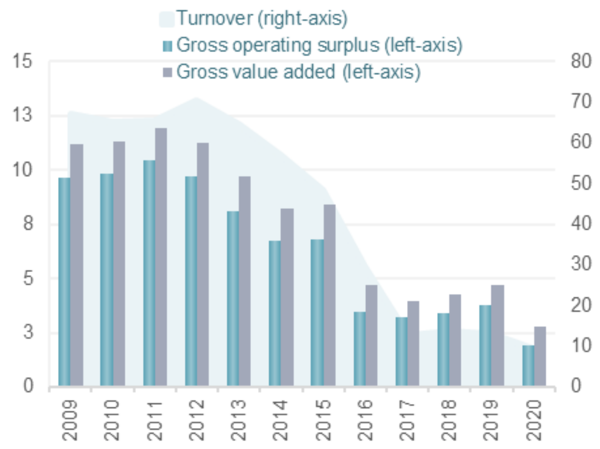
Denmark leads the *Marine non-living resources* sector, contributing with 27% of jobs and 60% of GVA, followed by the Netherlands with 21% of jobs and 17% of GVA; and Italy, with 20% of jobs and 16% of the sector's GVA.

Employment: Despite its steady contraction, the *Oil & gas* sub-sector employed about 8 130 persons, accounting for 86% of the jobs, while people employed in the operation and extraction of other minerals amounted to 1 360 (14%).

Gross value added: In 2020, *Oil & gas* generated €2.7 billion in GVA, about 95% of the sector's GVA, while *Other minerals* generated €144 million (5%).

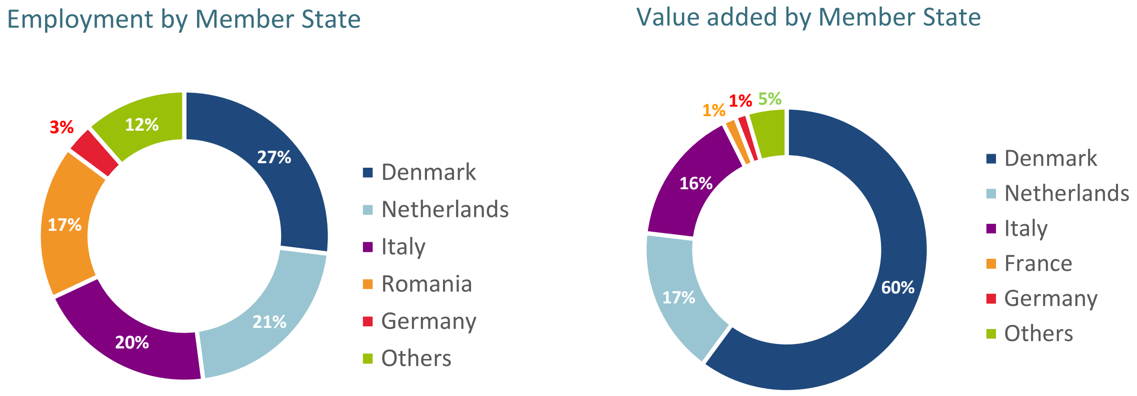
[26] STECF. 2022. The 2022 Annual Economic Report on the European fishing fleet. Publications Office of the European Union, Luxembourg, doi:10.2760/120462.
[27] Carpenter, G., Carvalho, N., Guillen, J., Prellezo, R., Villasante, S., Andersen, J. L., ... & Zhelev, K. (2023). The economic performance of the EU fishing fleet during the COVID-19 pandemic. Aquatic Living Resources, 36(2).
[28] STECF. 2023. Economic Report on the EU aquaculture (STECF-22-17). Publications Office of the European Union, Luxembourg, doi:10.2760/51391.
[29] Fisheries, aquaculture and marine ecosystems: transition to clean energy and ecosystem protection for more sustainability and resilience. Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_23_828.
[30] European Commission. (2023b). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions; EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries COM/2023/120 Final. Publications office of the European Union: Luxembourg. Available online at: https://oceans-and-fisheries.ec.europa.eu/system/files/2023-02/COM-2023-102_en.pdf.
[31] https://blue-economy-observatory.ec.europa.eu/eu-blue-economy-sectors/marine-living-resources_en
[32] EU Technical Expert Group (TEG) on Sustainable Finance. Financing a sustainable European economy. Technical report. June 2019.
[33] In June 2022, the European Commission adopted a new communication on international ocean governance that advocates for a ban on deep seabed mining until effective protection of the marine environment from adverse effects is ensured (JOIN (2022) 28 final).

Figure 2.3 Size of the EU Marine non-living resources sector, 2009-2020. Turnover, GVA ad gross operating surplus in € billion, persons employed (thousand), and average wage (€ thousand)



Source: Eurostat (SBS) and own calculations.

Figure 2.4 Share of employment and GVA in the EU *Marine non-living resources* sector, 2020



Source: Eurostat (SBS) and own calculations.

Trends and drivers

As most sectors of the economy, the *Marine non-living resources* sector was hit by the COVID-19 pandemic. Between 2019 and 2020, the sector's turnover contracted by 28% and its GVA by 40%. But the pandemic only worsened an already clearly declining trend triggered by the climate, biodiversity, environmental and international ocean governance commitments taken by the EU over the past decade.

More than 80% of the current European oil and gas production takes place offshore, predominantly in the North Sea, and with minor activity in the Atlantic and East Mediterranean. Most of the extraction fields are mature, with declining production and rising costs[34].

Therefore, domestic production in Europe is set to decline even further. As installations reach the end of their lifecycle, decommissioning of oil and gas infrastructure is increasing[35]. Decommissioning is also expected to accelerate due to the shift from fossil fuels to renewable and low-carbon energy sources. Nearly 200 platforms, 940 wells and 389 000 tonnes of topsides and sub-sea structures are expected to be decommissioned in the EU-27 by 2030, at an estimated cost of €4.8 billion[36]. As regards deep seabed mining, there is a broad consensus in the scientific community that the knowledge related to deep-sea environment and the impacts of mining not comprehensive enough to enable evidence-based decision-making to allow for proceeding safely with exploitation[37]. Impacts include direct biodiversity loss, contamination of commercially relevant species, noise pollution,

[34] Ecorys (2012). Blue Growth Study - Scenarios and drivers for Sustainable Growth from the Oceans, Seas and Coasts: Third Interim Report.
[35] European Maritime Spatial Planning (MSP) Platform. https://maritime-spatial-planning.ec.europa.eu/sector-information/oil-and-gas#1.
[36] European Commission (2021). Directorate-General for Energy. Study on Decommissioning of offshore oil and gas installations: a technical, legal and political analysis. Final report. September 2021.
[37] Drazen, J. C., Smith, C. R., Gjerde, K. M., Haddock, S. H., Carter, G. S., Choy, C. A., ... & Yamamoto, H. (2020). Midwater ecosystems must be considered when evaluating environmental risks of deep-sea mining. Proceedings of the National Academy of Sciences, 117(30), 17455-17460.

disruption of important ecological processes such as ocean carbon sequestration, etc.[38].

Against this backdrop, the EU confirmed in June 2022 that it will continue to advocate that the exploitation of marine minerals in the seabed and ocean floor beyond the limits of national jurisdictions should not start before the following conditions are met: i) sufficient scientific knowledge of deep-sea ecosystems and the potential effects of mining on marine ecosystems and their services is available; ii) adequate provisions for the effective protection of the marine environment from harmful effects of mining activities are in place, in line with the precautionary principle and the United Nations Convention on the Law of the Sea (UNCLOS); iii) it can be demonstrated that no harmful effects arise from mining technologies and operational practices. The EU will continue to contribute to the negotiations of the exploitation regulations at the International Seabed Authority (ISA) to achieve a robust framework for marine environment protection, including standards and guidelines for threshold values and normative standards. In parallel, the EU is supporting research to improve knowledge on deep sea ecosystems and on monitoring and supervising technologies[39].

For more information, please visit the section on Marine Non Living Resources within the EU Blue Economy Observatory.

2.3.-MARINE RENEWABLE ENERGY (OFFSHORE WIND)

Offshore wind energy is currently the only commercial deployment of a marine renewable energy source with wide-scale adoption. At the end of 2022, European sea basins were hosting around 50% of the world's total installed capacity. Starting with only a small number of demonstration plants[40] in the early 1990s, the EU now has a total installed offshore wind capacity of 17.5 GW across 11 Member States[41]. In 2022, 1.2 GW of new capacity were added to the grid (provisional data). The main EU producers of offshore wind energy are Germany, the Netherlands, Belgium and Denmark.

Given the significant growth of the offshore wind sector, both in terms of construction of wind parks, and of generation of green electricity, the EU Blue Economy Report has included *Offshore wind* as an established sector since 2021.

Size of the EU Offshore wind energy (production and transmission) in 2020

The sector generated more than €2.15 billion in GVA in 2020, an 11% increase compared to 2019. Gross profits accounted for €1.3 billion and the reported turnover was about €14.9 billion.

The sector directly employed almost 12.3 thousand persons, up from less than 400 persons in 2009. Personnel costs totalled €630 million. The annual average wage (excluding the Netherlands due to incomplete data), estimated at €55.1 thousand, almost 22% lower than 2009 (€70.4 thousand) (Figure 2.5).

Results by sub-sector and Member State

Germany currently leads in EU Offshore wind energy with 78% of jobs and 70% of GVA, followed by Denmark and the Netherlands with 9% of GVA and 7% of employmenty. The sector is undergoing a major expansion.

Employment: The top contributors, in descending order, included Germany with 78% (9.6 thousand persons), followed by Denmark (1.1 thousand persons), the Netherlands (almost 850 persons), and Belgium (more than 700 persons) in 2021.

Gross value added: The top contributors, in descending order, included Germany with 70% (€1.5 billion), Denmark (more than €400 million) and Belgium (more than €200 million). There is no data available for the Netherlands.

Gross profit: Germany produced 64% of profits (almost €850 million), followed by Denmark with 24% (more than €310 million), and then Belgium with the remaining 12% (more than €150 million). There is no data available for the Netherlands.

Net investment in tangible goods: Germany invested 45% (€440 million) of the total reported, followed by Denmark with 28% (more than €280 million), the Netherlands with 18% (€175 million), and then Belgium with the remaining 9% (€93 million).

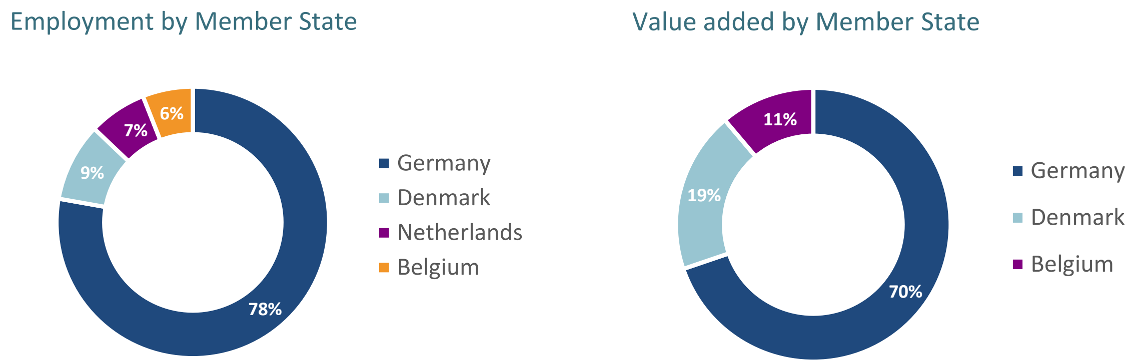
Turnover: Germany accounted for 84% (€12.5 billion) of the turnover produced, followed by Belgium with 9% (€1.3 billion) and Denmark with the remaining 7% (€1 billion). There is no data available for the Netherlands.

[38] Deep-sea mining science statement (https://www.seabedminingsciencestatement.org/). Accessed: 14 March 2023.
European Commission (2022a). Joint Communication on the EU's International Ocean Governance agenda. Setting the course for a sustainable blue planet. JOIN(2022). 28 final & Annex. 26 June 2022.
[40] The first offshore wind farm (Vindeby) was installed in Denmark in 1991 and decommissioned in 2017, after 25 years of useful life.
[41] JRC analysis based on GWEC (2022), WindEurope (2023) and 4C OFFSHORE (2022) WIND FARMS DATABASE.

Figure 2.5 Size of the EU offshore wind sector, 2009-2020: Turnover, GVA ad gross operating surplus in € billion (left) and persons employed (thousand), and average wage in € thousand (right)

Source: Eurostat (SBS) and own calculations

Figure 2.6 Share of employment (left) and GVA in EU offshore wind sector (right) in 2020



Source: Eurostat (SBS) and own calculations.

Trends and drivers

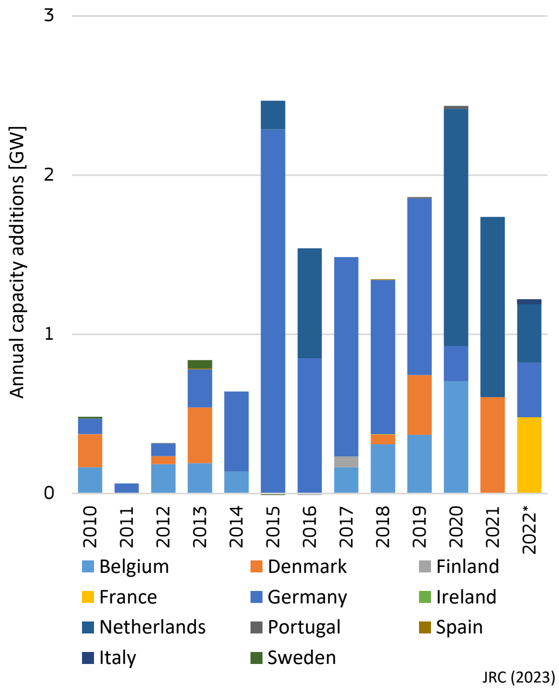
During the last decade, the wind energy sector has seen a strong increase in offshore wind installed capacity due to the development of larger sites and significant technological advances, such as larger wind turbines and improved reliability. Offshore wind has also learned lessons from the onshore wind sector with competitive tendering enabling a reduction in the price of energy generated. Offshore wind is expected to play a significant role in reaching Europe's climate neutrality targets. The European Commission Offshore Renewable Energy Strategy[42] was published in November 2020 as part of the EGD roadmap. The Strategy outlines the ambitions to deploy 300 GW of offshore wind energy by 2050, supplying about 30% of the EU future electricity, with an intermediate target of 60 GW by 2030. The development of floating offshore wind will contribute to achieving these targets, making it feasible to install turbines in deeper water. However, development challenges remain, and it typically takes about 11 years to get from the early stage of a wind farm development to its full completion, including generating electricity. Annual installation rates need to increase from 7 GW in the late 2020s to over 20 GW in the late 2030s[43]. In May 2022, the EC presented the REPowerEU Plan[44] in response to the global energy market disruption caused by Russia's unprovoked invasion of Ukraine. Among other measures, the plan envisages an accelerated rollout of renewables, thus increasing the target set out by the Renewable Energy Directive from 40% to 45% by 2030. With respect to wind energy, the REPowerEU Plan proposes an installed capacity of 510 GW by 2030, with no specific target for offshore wind. Moreover, the plan envisages the faster rollout of renewables through shorter permitting times.

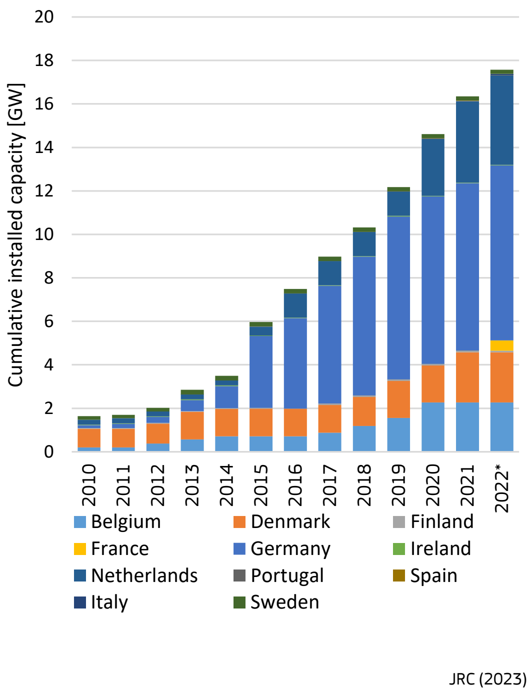
[42] An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future COM(2020) 741.
[43] Wind Europe (2019) Our energy, our future: How offshore wind will help Europe go carbon-neutral.
[44] REPowerEU Plan COM(2022) 230.

Starting as a first mover in the offshore sector, with the first offshore wind farm installed in Denmark in 1991, the EU is currently a global leader in offshore wind manufacturing. Nowadays, the EU *Offshore wind energy* sector grew to a cumulative installed capacity of 17.5 GW by the end of 2022 (Figure 2.7), with an increase of 1.2 GW in the last year. The largest additions for 2022 were in France (0.5 GW), the Netherlands (0.4 GW) and Germany (0.3 GW). Globally, China is leading the sector in terms of deployments and in 2022 it expanded its position as the world's largest offshore wind market with 27 GW of installed capacity, more than the UK (14 GW), Germany (8 GW) and the Netherlands (4 GW) combined.

For more information, please visit the section on [Marine Renewable Energy] within the EU Blue Economy Observatory.

Figure 2.7: EU Offshore wind energy capacity additions (left) and installed capacity (right), GW





Note: (*) = Preliminary data at the end of 2022.
Source: JRC based on, GWEC, WindEurope, 4COffshore.

2.4. PORT ACTIVITIES

The *Port activities* sector is crucial to the European economy. Ports are essential infrastructures of crucial commercial and strategic importance, and ports are gateways for EU trade and instrumental in supporting the free movement of goods and persons in Europe. Ports also enable economic and trade development through traditional activities such as cargo handling, logistics and servicing, while at the same time supporting a complex cross section of industries and facilitating the clustering of energy and industrial companies in their proximity. This may include ship building, chemical, food, construction, petroleum, electrical power, steel, fish processing, and automotive industries. All of these industries present a range of pathways towards decarbonisation and the transition to clean energy.

Size of the EU Port activities sector in 2020

In 2020, the GVA generated by the sector amounted to €26.9 billion, representing a 3.6%-decrease from the peak registered in 2019 (€27.9 billion). Gross profits registered a year-on-year drop of €1 billion, although they remained relatively steady across the past decade, at approximately €10.8 billion on average. Reported turnover, at €67.7 billion in 2020, was only marginally lower than in 2019 (€68.5 billion) (Figure 2.8).

Net investments in Port activities experienced a significant drop in 2020 (-45% year-on-year), largely caused by the COVID-19 pandemic, but are expected to pick up again in the coming years, given the ambitious decarbonisation targets set by the European Green Deal and the growing uptake of carbon-neutral technologies by the various energy-intensive industries gravitating around European ports[45]. The ratio of net investment to GVA was estimated at 2.3% in 2020, down from 4% in 2019, but considerably higher than 1.4% registered in 2017. Overall, the sector's turnover has been growing steadily since 2009, except in 2011 and 2018. The sector was affected by the COVID-19 pandemic, but has since embarked on a recovery path.

Results by sub-sector and Member State

Germany led the *Port activities* sector, providing nearly one fourth of sectoral employment and 22% of its value added, followed by the Netherlands with 17% of GVA; Spain (13%), France (12%) and Italy (8%). The latter four Member States contribute to a further 40% of the sector's jobs in the EU (Figure 2.9).

[45] EIT InnoEnergy (2022). A practical guide to decarbonising ports Catalogue of innovative solutions. June 2022.

Employment: A total of about 214 950 persons were employed in the *Port and water projects* sub-sector in 2020, representing 56% of total employment in the sector. The remaining 44% of the workforce (170 680 persons) was employed in *Cargo and warehousing* activities.

Gross value added: In 2020, the two sub-sectors (*Port and water projects* and *Cargo and warehousing*) generated an equal share of the sector's turnover, i.e., approximately €33.8 billion each.

Figure 2.8. Size of the EU Port activities sector, 2009-2020. Turnover, GVA ad gross operating surplus in € billion, persons employed (thousand), and average wage (€ thousand

Source: Eurostat (SBS) and own calculations

Figure 2.9 Share of employment and GVA in the EU Port activities sector, 2020

Source: Eurostat (SBS) and own calculations

Trends and drivers

Ports will play a pivotal role in achieving Europe's climate neutrality goals. Ports are responsible for a variety of direct and indirect carbon emissions within logistic activities, such as diesel-powered shore-side infrastructure (for moving containers, cranes etc.), non-renewable electricity consumption used to power buildings, lighting and various machinery, and other indirect emissions from the vehicles that use ports to deliver and load cargo, and their associated warehouses[46]. All of these activities hold considerable potential for reducing their carbon footprint, using a mixture of electrification (with renewable energy sources), greater energy efficiency, smart technologies to aid transport and delivery, and providing shore-side electricity for docked ships. Ports can become important producers and providers of clean energy solutions and heat for the economy. The deployment of green technology facilities, such as Onshore Power Supply (OPS) is becoming a requirement under the "Fit for 55" initiatives[47] and will require action from both port authorities and ship owners.

As they may provide landing points for the huge planned capacity of offshore wind, ports will be vital for the further development of this renewable energy source. Some ports also have potential to house the development of large-scale electricity storage, which will be needed for balancing fluctuating supply and demand, and for facilitating the transport of green hydrogen. Maintenance activities and construction works in ports provide further

[46] European Maritime Safety Agency (EMSA) - European Environment Agency (EEA) European Maritime Transport Environmental Report 2021.
[47] For example, the Alternative fuels infrastructure regulation (AFIR), EC proposal 2021, and the FuelEU maritime proposal (FEUM) EC proposal 2021

opportunities to decarbonise, utilising renewable energy, off-grid storage to power tools and switching from diesel-powered machinery to electrified options[48].

Due to the complex, multifaceted nature of ports, a coordinated strategy and a multi-pronged approach between port authorities and all port stakeholders, tailored to their own specific challenges, will be vital to maximise the uptake of carbon-neutral technologies. Ports will need to utilise a whole range of actions across all business areas to significantly reduce their emissions. Innovative technology already exists to enable significant gains in this space, and early uptake can harness a strong competitive advantage for those forward-thinking ports[49].

For more information visit the section on Port Activities within the EU Blue Economy Observatory.

2.5. SHIPBUILDING AND REPAIR

The EU shipbuilding industry counts approximately 300 shipyards where civilian and naval ships as well as platforms and other hardware for maritime applications are crafted. The EU is the top producer of cruise ships in the world and one of the leading players for high-tech, complex vessels types. Overall, the EU industry received less shipbuilding orders than China, South Korea and Japan in 2021[50].

Due to continuous investments in research and innovation, the EU is also the largest supplier of marine equipment, such as diesel engines, turbines, propellers and blades, followed by Korea, China and Japan.[51]

For the purpose of this report, *Shipbuilding and repair* includes the following sub-sectors:

1. ***Shipbuilding***: building of ships and floating structures; building of pleasure and sporting boats; repair and maintenance of ships and boats.
2. ***Equipment and machinery***: manufacture of cordage, rope, twine and netting; manufacture of textiles other than apparel; manufacture of sport goods; manufacture of engines and turbines (except aircraft), and manufacture of instruments for measuring, testing and navigation.

Size of the EU Shipbuilding and repair sector in 2020

The sector generated a GVA of €14.5 billion in 2020, a decrease of 8% compared to the 2019 peak. Gross profit, at €3.1 billion decreased by 10% on the previous year. The profit margin was estimated at 6%, stable compared to 2019. The turnover reported for 2020 was €55.7 billion, recording a 4%-decrease on the previous year.

In 2020, around 305 500 persons were directly employed in the sector (2%-increase on 2019). Total wages and salaries amounted to €12.1 billion, in line with the previous year, and the annual average wage was estimated at €39 000, down 3% compared to 2019.

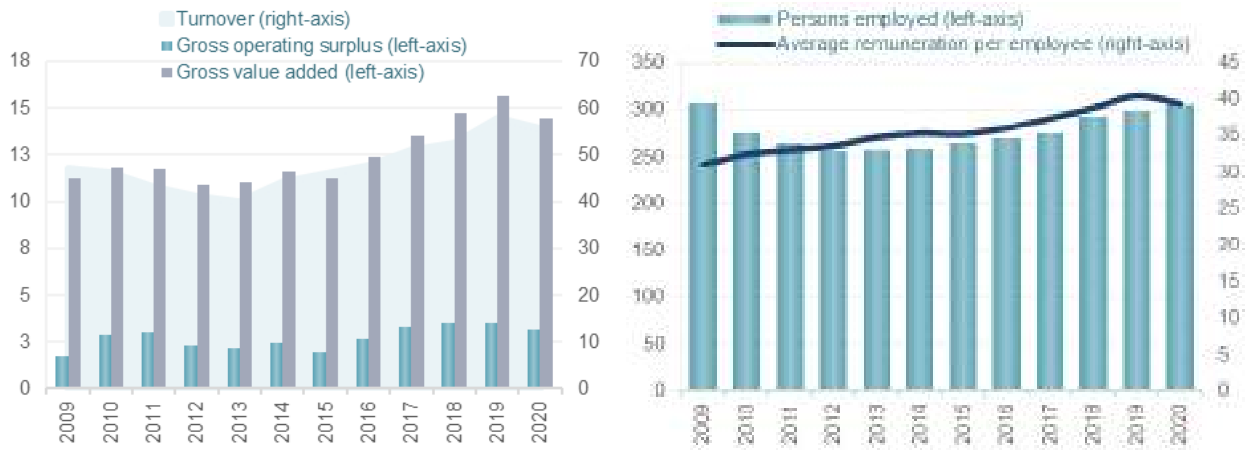
Results by sub-sector and Member State

Germany led employment within *Shipbuilding and repair*, contributing with 16% of the jobs, followed by France (15%) and Italy (14%). In terms of GVA, Germany records 22% of the Members States' GVA, followed by France (20%) and Italy (17%).

Employment: *Shipbuilding* employed about 259 370 persons, accounting for 85% of the jobs, while *Equipment and machinery* employed 46 100 persons (15%).

Gross value added: In 2020, *Shipbuilding* generated €11.7 billion in GVA, about 81% of the sector's GVA, whilst *Equipment and machinery* produced €2.8 billion (19%).

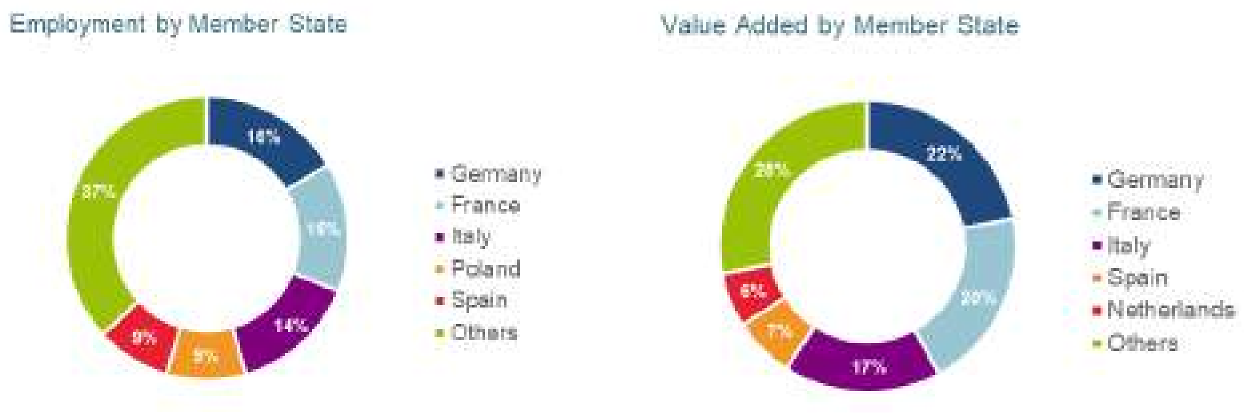
Figure 2.10 Size of the EU *Shipbuilding and repair* sector, 2009-2020. Turnover, GVA ad gross operating surplus in € billion. Persons employed (thousand), and average wage (€ thousand)



Source: Eurostat (SBS) and own calculations.

[48] EIT InnoEnergy (2022). A practical guide to decarbonising ports Catalogue of innovative solutions. June 2022.
[49] EIT InnoEnergy (2022). A practical guide to decarbonising ports Catalogue of innovative solutions. June 2022.
[50] Clarkson Research, October 2021 & market news. Accessible at https://www.cargotec.com/493843/globalassets/files/investors/presentations/other-ir-presentations/2022/investor-presentation-march-2022.pdf
[51] OECD Council Working Party on Shipbuilding (WP6), 2022. Analysis of the marine equipment industry and its challenges. Accessible at https://one.oecd.org/document/C/WP6(2022)15/FINAL/en/pdf.

Figure 2.11 Share of employment and GVA in EU Shipbuilding and repair sector, 2020



Source: Eurostat (SBS) and own calculations

Trends and drivers

Seaborne trade is a major driver for the global industry. Although the first part of 2020 saw a reduction in trade volumes, the global shipbuilding industry operated without major impediments. However, the business model of the EU shipbuilding industry, mainly focusing on the manufacture of passenger ships, such as cruise ships, ferries and yachts, led to severe setbacks during the COVID-19 pandemic. According to the Cruise Lines International Association (CLIA), the passenger volume in Europe declined overall by 82.5% in 2020 and, in some regions, the passenger volume completely halted (e.g., in the Baltic sea basin)[52]. As a consequence, cruise lines recorded heavy losses due to inactivity and were forced to cancel orders for new ships.

The growth of the global economy is an important driver for the industry. General concerns over the global economic outlook are reflected over the demand for new ships. According to the OECD's forecast, 336 million GT are expected to be built over the period 2021-2030, 60% of which will be bulkers, and 20% tankers, with the remaining being containerships and general cargoes[53]. This can be partially explained by the unprovoked invasion of Ukraine and the consequent war, which has affected the price of materials needed to build ships. In particular, steel prices in Europe were almost four times higher in April 2022 than in June 2020. This led to increased production costs that affected the industry.

Environmental regulations play a fundamental role in the evolution of this industry. To reduce carbon intensity of all ships by 40% by 2030 compared to the 2008 baseline, the Marine Environment Protection Committee set several directives that affect directly the *Shipbuilding and repair* sector. Under the MARPOL Annex VI treaty, in addition to the Energy Efficiency Design Index (EEDI) that regulates efficient shipbuilding, the Energy Efficiency Existing Ship Index (EEXI) for ships above 400 GT and the Carbon Intensity Indicator (CII) for ships above 5,000 GT require existing ships to improve the technical performance and reduce the carbon footprint starting January 2023.

Orders for alternative fuels in the maritime sector led to an increase in the production of marine equipment. Most of the orders in EU include battery (combination of pure electric, plug-in and hybrid) and LNG fuel-capable engines; although there is a recent increased focus on alternative fuels contributing to decarbonisation such as methanol, hydrogen and ammonia.

For more information please visit the section on Shipbuilding and Repair within the EU Blue Economy Observatory.

2.6. MARITIME TRANSPORT

The European Union is the world's biggest trading block. Although it is home to just 5% of the world's population, it contributes 14.9% to global GDP (2020). In terms of goods transported in and out of the EU, the majority are shipped using maritime transport. In 2021, 74% of EU total merchandise imports and exports were traded by sea. The top-three EU partner countries are Russia, USA and China.

The EU fleet is large and quite heterogeneous. The ships registered under the flag of an EU Member State represented 16.2% of the total world fleet measured in dead weight tonnage (DWT). The EU Member State-flagged fleet contains nearly 40% of the world's Ro-Pax fleet (vessels that can carry cars and passengers), 33% of all cruise vessels, 29% of passenger ships and 20% of containerships.

Transport of passengers contributed to an appreciable extent to the economy of the sector until 2019, when approximately 400 million passengers embarked and disembarked in EU ports each year. In 2020, due to the COVID-19 pandemic, this figure declined to about 230 million.

Although it is the most energy-efficient mode of transport, *Maritime transport* accounts for about 2 to 3% of global energy-related CO_2 emissions[54] [55]. Given the growth prospects of the sector, it is indispensable that the industry continues to reduce its environmental impact.

For the purpose of this report, *Maritime transport* includes the following sub-sectors:

[52] Cruise Lines International Association, 2021. 2021 Europe Market Report. Accessible at https://cruising.org/-/media/clia-media/research/2022/2021-1r-clia-002-region-overview---europe-and-top-countries.ashx
[53] OECD Council Working Party on Shipbuilding (WP6), 2022. Developments of ship demand, supply, prices and costs. Accessible at https://www.oecd.org/industry/ind/C-WP6(2022)13_DSPC-v2.pdf
[54] IEA (2022), International Shipping, IEA, Paris. https://www.iea.org/reports/international-shipping, License: CC BY 4.0.
[55] Fourth IMO – Greenhouse Gas Study (2020). https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20-%20Full%20report%20and%20annexes.pdf

1. ***Passenger transport***: sea and coastal passenger water transport and inland passenger water transport;
2. ***Freight transport***: sea and coastal freight water transport and inland freight water transport;
3. ***Services for transport***: renting and leasing of water transport equipment.

Size of the EU Maritime transport sector in 2020

The sector generated a GVA of €29.5 billion in 2020, a decline of 14% compared to the 2019 peak. Gross profit, at €14.7 billion, decreased by 15% on the previous year. The profit margin was estimated at 10%, slightly below the 11% recorded in 2019. The turnover reported for 2020 was €147.4 billion, a 10%-decrease on the previous year.

In 2020, around 371 000 persons were directly employed in the sector, 8% less than in 2019. Total wages and salaries amounted to €14.9 billion (6%-decrease from 2019) and the annual average wage was estimated at €40 000, up 2% compared to 2019.

Results by sub-sector and Member State

Germany was the top employer in the *Maritime transport* industry, contributing with 34% of total jobs, followed by Italy (17%) and France (10%). In terms of GVA, Germany records 34% of the Members States' GVA, followed by Denmark (26%) and Italy (9%).

Employment: *Services for transport* employed about 181 700 persons, accounting for 49% of the jobs, while *Passenger transport* employed 97 000 persons (26%) and *Freight transport* 92 900 person (24%).

Gross value added: In 2020, *Freight transport* generated €15.9 billion in GVA, about 54% of the sector's GVA, followed by *Services* with €11 billion (37%) and then *Passenger transport* with €2.6 billion (9%).

Figure 2.12 Size of the EU *Maritime transport* sector, 2009-2020. Turnover, GVA ad gross operating surplus in € billion, persons employed (thousand), and average wage (€ thousand)

Source: Eurostat (SBS) and own calculation

Figure 2.13 Share of employment and GVA in EU *Maritime transport* sector, 2020

Source: Eurostat (SBS) and own calculations

Trends and drivers

Maritime transport is largely dependent on trade patterns, technological advancement and environmental regulations. Economic shocks such as COVID-19 and rising international trade disputes add to the volatility of international trade and cargo volumes in ports[56]. Like most sectors of the economy, *Maritime transport* has been hit by the COVID-19 pandemic. The United Nations Conference on Trade and Development (UNCTAD) reported that the volume of imports and exports in Europe in 2020 diminished by 7.3% and 7.8% respectively compared to the previous year[57]. However, in 2021 there was a sound rebound (8.3% and 7.9% respectively on the previous year) due to the gradual reopening of economies. The importance of maritime logistics for trade purposes became very evident in 2022, due to the Russian unprovoked invasion of Ukraine. With a reduced maritime connectivity and higher shipping costs, inflation rose, so as shortages of food[57]. This has opened new trade scenarios for countries that try to substitute a supplier (e.g., Ukraine) that is unable to meet the demand.

Due to the pandemic, other economic activities of the sector suffered more than freight transport. *Passenger transport* was suspended in Europe in March 2020, as many Member States implemented travel restrictions and lockdown measures to curb the spread of the virus, with harsh consequences on their economy.

Technological advancement, such as artificial intelligence, digitalisation and automation can drive the growth of the sector. An example of technological advancement is Maritime Autonomous Surface Ships (MASS), which have the potential to increase safety and productivity as well as to contribute towards the sustainability goals for *Maritime transport*[58]. Despite progress in recent years, Maritime transport continues to exert pressures on the environment, with greenhouse gas emissions projected to increase to 90-130% of 2008 emissions by 2050 for a range of plausible long-term economic and energy scenarios, according to the International Maritime Organisation (IMO). Environmental regulations and strategies, such as the Sustainable and Smart Mobility Strategy[59] and the FuelEU Maritime proposal[60], push for more sustainable alternatives within the sector. Several other proposals under the Fit for 55 Legislative Package (July 2021), amongst which the proposal for an extension of the European Emission Trading System (ETS) to include *Maritime transport*, aim to address the climate impact of the sector, so to contribute to the net greenhouse gas emissions reduction target of at least 55% by 2030, compared to 1990 levels.

Underwater noise from shipping is also increasingly recognised as a significant and pervasive pollutant, affecting marine ecosystems on a global scale. Under the marine strategy framework directive, Member States have the responsibility to implement appropriate measures, for example by reducing ship-generated noise, or setting spatial restrictions for human activity.

For more information, please visit the section on Maritime Transport within the EU Blue Economy Observatory.

2.7. COASTAL TOURISM

EU coastal areas are amongst the most preferred tourist destinations for European and international travellers, making coastal and maritime tourism the biggest, growing sector of the EU Blue Economy in terms of GVA and employment[61]. More than half of EU bed capacity is concentrated in regions with a sea border[62]. For the economy of many non-landlocked EU Member States – especially in Southern Europe – tourism generates a significant portion of their total national revenue. At the same time, coastal regions are those with the highest seasonality, i.e., with tourism demand concentrated in a limited number of months, usually July and August[63]. For the purpose of this report, the *Coastal tourism* sector comprises recreational activities taking place in proximity of the sea (e.g. beach-based tourism, coastal walks, wildlife watching) as well as those taking place in the maritime area, including nautical sports (e.g. sailing, scuba diving, cruising, etc.). The socio-economic statistics presented in this section originate from three typologies of activities typically undertaken by tourists as reported by EU Member States, attributed to coastal areas on the basis of a specific computation methodology:

1. ***Accommodation***, i.e. nights spent at tourist accommodation establishments in coastal areas;
2. ***Transport***, reflecting the maritime proportion of sea-borne, road, rail and air passenger travel;
3. ***Other expenditures***, covering specific tourist expenditures in coastal areas (e.g., food & beverage services, cultural and recreational goods, purchase of water-sport equipment and clothing, etc.).

Trends and drivers

The sector was hit hard by the COVID-19 pandemic. In 2020, the GVA generated by the sector amounted to €33.9 billion, down from €81.5 billion registered in 2019, i.e., a year-on-year 58%-contraction. Gross profits, at €3.9 billion, shrunk by more than 85% on 2019 (€27.8 billion). Nonetheless, the sector's turnover resulting from the aggregation of the abovementioned sub-sectors amounted to €108.9 billion (Figure 2.14).

[56] Notteboom, T.E., Haralambides, H.E. Port management and governance in a post-COVID-19 era: quo vadis?. Marit Econ Logist 22, 329–352 (2020). https://doi.org/10.1057/s41278-020-00162-7
[57] United Nations Conference on Trade and Development (UNCTAD). (2022). Review of Maritime Transport 2022: Report by the UNCTAD secretariat. Geneva: United Nations. https://unctad.org/system/files/official-document/rmt2022_en.pdf
[58] Directorate-General for Mobility and Transport (2020). European Commission encourages a maritime future which includes Autonomous and Sustainable Ships and Shipping: https://transport.ec.europa.eu/news/european-commission-encourages-maritime-future-which-includes-autonomous-and-sustainable-ships-and-2020-11-30_en
[59] European Commission (2020). Sustainable and Smart Mobility Strategy – putting European transport on track for the future. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789
[60] COM/2021/562 final - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0562
[61] https://ec.europa.eu/maritimeaffairs/policy/coastal_tourism_en
[62] European Commission. Coastal and maritime tourism. https://ec.europa.eu/growth/sectors/tourism/offer/maritime-coastal_en.
[63] Eurostat (2022). Tourism statistics - seasonality at regional level. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Tourism_statistics_-_seasonality_at_regional_level#The_regions_with_the_highest_seasonality_are_coastal_regions

Figure 2.14 Size of the EU Coastal tourism sector, 2009-2020. Turnover, GVA ad gross operating surplus in € billion, persons employed (thousand), and average wage (€ thousand)

Source: Eurostat (SBS) and own calculations

Coastal tourism was hit by the 2008-09 crisis, and started recovering in 2012, reaching in 2018-2019 higher levels than those registered before the crisis. However, the COVID-19 outbreak and subsequent public health interventions leading to travel restrictions imposed resulted in a massive impact in the sector. Economic performance indicators worsened in 2020 to levels below 2012.

Results by sub-sector and Member State

Spain led the *Coastal tourism* sector in terms of employment contributing with 20% of jobs, followed by Italy with 13%, Greece with 11% and France and Germany both with 10%. In terms of GVA, France led with 20%, followed by Spain with 16%, and Italy and Germany with 13% both.

Figure 2.15 Share of employment and GVA in the EU Coastal tourism sector, 2020

Source: Eurostat (SBS) and own calculations

Employment: the *Accommodation* sub-sector employed almost 863 000 persons, accounting for slightly more than 50% of the jobs; while slightly less than 618 000d persons (36) were employed in *Other services* (e.g. restaurants), and about 237 000 persons (14%) were employed in *Transport*.

Gross value added: In 2020, the *Accommodation* sub-sector generated €13.7 billion in GVA, about 40% of the sector's GVA, while *Other services* generated €11.4 million (34%) and *Transport* €11.4 million (34%).

Trends and drivers

Three out of four enterprises in tourism industries in the EU operated in accommodation (15%) or food and beverage serving activities (61%) in 2019. In 2019, more than half (55%) of the enterprises in the tourism industries in the EU were located in Italy, France, Spain and Germany[64]. Because of the Covid-19 pandemic, in 2020 virtually all Member States had implemented containment measures and restrictions on non-essential travel, closed their borders and reinstated internal border controls within the Schengen area, often accompanied by requirements for cross-border travellers to stay in quarantine. This meant that millions of

[64] Eurostat (March 2022). Tourism industries - economic analysis. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Tourism_industries_-_economic_analysis

European citizens were suddenly unable to travel[65]. In the course of March 2020, tourism came to a grinding halt and its turnover did not fully recover until 2022. After the decline experienced due to the COVID-19 pandemic, the total number of nights spent in EU tourist accommodation reached 2.73 billion in 2022. This marks a 5%-difference compared with the number of nights spent in 2019 (2.88 billion nights). Compared with 2021 (1.83 billion nights), nights spent were up by 49% in 2022. In the course of 2022, tourism figures in all months were higher than the corresponding months in 2021, with the fourth quarter of 2022 recording 472 million nights. This was a decline of only 2% compared with the pre-pandemic fourth quarter of 2019 (483 million nights)[66].

[65] Eurostat (May 2020). Tourism in the EU. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Tourism_in_the_EU_-_what_a_normal_summer_season_looks_like_-_before_Covid-19
[66] Eurostat (March 2023). EU tourism nights recover to 95% of 2019 level. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20230315-1

CHAPTER 3

EMERGING SECTORS – OCEAN ENERGY & BLUE BIOTECHNOLOGY

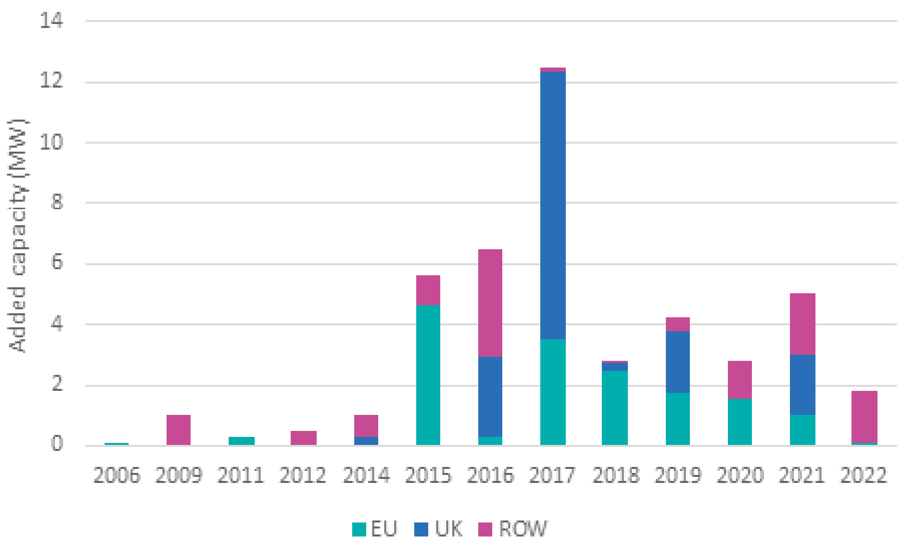
3.1. EMERGING MARINE RENEWABLES

This chapter deals with the emerging sector of *Ocean renewable energies*. Given that offshore wind energy production from bottom-fixed structures is already commercially exploited in the EU, this technology is considered as an established sector and therefore not included in this chapter. Following the effective scale-up of conventional offshore wind, the technologies of floating offshore wind, ocean energy (wave and tidal), floating solar photovoltaic are emerging as valid options to contribute to the EU goals of reaching 60 GW of offshore renewable energy capacity by 2030 and 300 GW by 2050[67]. Specifically for ocean energy (e.g., tidal and wave), sub-targets were set for at least 1 GW by 2030 and 40 GW by 2050. To compare the different technologies, we use the indicators of Technology Readiness Level (TRL)[68], capacity, load factor and Levelised Cost of Energy (LCOE).

Ocean energy

Tidal energy is the first of the emerging ocean energy technologies to have been implemented at a large scale, with barrages in France (1966) and Korea (2011) reaching together 494 MW of installed capacity[69]. While being commercially viable because of their use of technologies similar to the hydropower sector, the deployment of such facilities has been limited by the availability of locations fit for purpose and by the significant local environmental impacts. New technologies exploiting tidal energy have been developed, including horizontal axis turbine (TRL 9), tidal kite (TRL 8), enclosed tips (TRL 7), vertical axis turbine (TRL 7) and oscillating hydrofoil (TRL 6)[70]. The most advanced wave energy technologies are point absorber and oscillating water column (TRL 9), followed by attenuator, overtopping (TRL 8), OWSC and rotating mass (TRL 7)[71]. In addition to tidal and wave energy, other technologies aim to exploit ocean energy. Ocean thermal energy conversion (OTEC) exploits the temperature difference between deep cold water (at 800 to 1 000 m depth)[72] and surface warm water. The technology has been already demonstrated by developers in Japan and the USA (TRL 8)[73]. Salinity gradient power (or osmotic power) uses salt content differences between freshwater and saltwater. In European sea basins, testing facilities hosting both individual devices and arrays are located in Scotland, the UK, Spain and France. Two main processes to make use of this potential energy are being tested and applied: Pressure Retarded Osmosis (PRO) and Reversed Electro Dialyses (RED). PRO technology is having its first commercial unit in 2021, while RED is used for a demonstration plant on a test rig in the Netherlands (TRL 7).

Figure 3.1: Annual capacity installation of tidal stream and wave energy plants in the EU, UK and rest of the world



Source: JRC database, 2023

[67] COM (2020) 741.
[68] TRL scale can be found in: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415- annex-g-trl_en.pdf
[69] European Commission (2022) EU blue economy report.
[70] JRC (2022) Ocean energy in the European Union.
[71] Ibid.
[72] Ibid.
[73] OES | USING SEA WATER FOR HEATING, COOLING AND POWER PRODUCTION (ocean-energy-systems.org).

Figure 3.1 presents the annual installed capacity for the EU, the UK and the rest of the world (ROW) for tidal stream and wave energy projects. In 2022, there were a few such installations in the EU, accounting for a total of 55 kW of tidal energy and 33.5 kW of wave energy devices. Cumulatively, global capacity in 2022 for tidal energy reached 41.2 MW, of which 30.2 MW in European sea basins, while wave energy installations reached 24.9 MW globally, of which 12.7 MW in European sea basins[74]. Europe has been traditionally leading the *Ocean energy* sector, however in the past few years there has been a decrease in the installation rate of devices. After a period of setback in investments, a new wave of projects is emerging. Among those, the EU project EnFAIT[75] led by Nova Innovation recently added 2 turbines to its test tidal array in Shetland islands (UK) with the first turbine already in the water since 2016, reaching 600 kW[76 77]. The Meygen tidal energy site was commissioned in 2016; some of the turbines have been out of the water for maintenance and have been retrofitted to decrease the cost for future operation and maintenance and are now being redeployed in 2022/early 2023. EuropeWave is exploring different concepts of wave energy technologies to be tested in the Basque country and in Scotland[78]. The load factor remains low for both tidal and wave energy, reaching 20% to 25% according to recent studies[79 80]. According to the JRC[81], LCOE ranges from 110 to 480 €/MWh for tidal energy, and 160 to 750 €/MWh for wave energy. These relatively high costs and the diversity of the available technological options are challenging for both developers to mobilise funding in R&D and for equipment manufacturers to get enough demand to get involved. The EU is also leading in filing patents on international markets, while it only receives a small number of patent applications, already making the EU a significant exporter of ocean energy technologies.

Floating wind energy

Floating wind energy is a growing sector progressing steadily toward commercial viability. Floating wind is becoming particularly attractive for Member States whose deep-water seas (over 50 m) have so far limited the development of conventional fixed bottom offshore wind energy. Several projects are already operational, and many are planned for the next few years. Technological differences between projects are mainly linked with the floating structure. The majority of the current projects use semi-submersible floater technologies, other projects use spar-buoy, barge, tension-leg platforms and semi-spar floater technologies. Semi-submersible and spar-buoy technologies already reach TRL 8-9, while Floatgen pilot project in France upgraded the concrete barge technology to TRL 7-8[82]. Tension-leg platform is tested with a prototype (TRL 6) launched off the coast of Canary Islands by the X1 Wind project[83].

Current floating wind energy projects in the EU account for 40 MW of installed capacity. One of the first floating wind projects in the EU was the Floatgen[84] project in France (2 MW capacity, with an electricity production of 25 GWh since 2018) coordinated by Ideol and operational in 2018, and Winfloat[85] in Portugal – whose initial 2 MW capacity has been scaled-up to 25 MW – commissioned in 2011. Following its first project (Hywind Scotland[86]), with the Hywind Tampen[87] project Equinor plans to deliver in Norway the world's largest floating farm, with a capacity of 60 MW and a potential additional capacity to reach up to 88 MW. These projects proved high performances in terms of load factor, with Hywind Scotland[88] reaching 57.1% over 12 months in 2020-2021[89] and Floatgen [90] 59.2% over 3 months in 2022-2023 [91], both outperforming conventional offshore wind [92]. A recent study estimates a LCOE ranging from 95 to 160 €/MWh for floating wind in Europe[93], comparable to the LCOE of 67 to 140 €/MW for conventional offshore wind[94]. Floating wind was the second most funded wind technology in the period 2009-2020 by the EU programs FP7 and H2020. 7 research projects were funded under FP7 and 21 under H2020. With the technological uptake of floating wind, the EU tends to both increase its funding and reduce the number of funded projects. Floating wind is also expanding worldwide, with an installed capacity expected to reach more than 14 GW by 2030[95], and the share of EU-based capacity expected to decrease from 71% in 2021-2025 to 44% in 2026-2030, creating new market opportunities for EU developers.

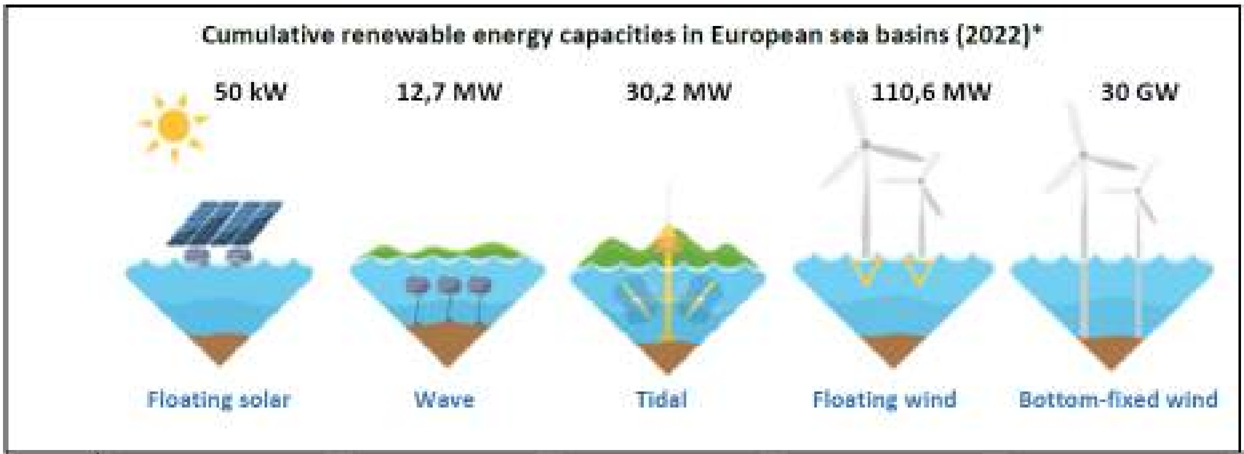
Floating solar photovoltaic energy

Floating solar photovoltaic energy (FPV) consists of a floating structure on which traditional solar panels are installed. The technology has been for now mostly deployed on lakes and hydro-power reservoirs, with a worldwide installed capacity of 1.3 GW in 2018 already expected to reach 13 GW in 2022. The state of the art of FPV power at sea is still at an R&D and demonstration

[74] Ocean energy Europe, Ocean Energy - Key trends and statistics 2022.
[75] https://setis.ec.europa.eu/ocean-energy-european-union_en
[76] Nova Innovation, "Europe Case Study - Shetland Tidal Array". Access: https://www.novainnovation.com/markets/scotland-shetland-tidal-array/
[77] reNews, "Shetland Tidal Array becomes world leader", January 2023. Access: https://renews.biz/83490/nova-innovation-adds-two-more-turbines-to-tidal-array/
[78] EuropeWave project, "Five wave energy projects to continue to next phase of EuropeWave", September 2022. Access: https://www.europewave.eu/news/europewave-phase2-announcement
[79] IRENA, Tidal energy technology brief, June 2014. Access: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/Tidal_Energy_V4_WEB.pdf
[80] Coles et al. A review of the UK and British Channel Islands practical tidal stream energy resource, November 2021. Access: https://royalsocietypublishing.org/doi/10.1098/rspa.2021.0469
[81] Ocean energy in the European Union, 2022.
[82] FORESEA project, "FORESEA Success Stories", June 2019. Access: https://www.nweurope.eu/media/9768/success-story-2020.pdf
[83] XIWind project, "X1 Wind's X30 floating wind prototype delivers first kWh", March 2023. Access: https://www.x1wind.com/news/x1-winds-x30-floating-wind-prototype-delivers-first-kwh/
[84] https://floatgen.eu/
[85] https://cordis.europa.eu/project/id/296050
[86] https://www.equinor.com/energy/hywind-scotland
[87] https://www.equinor.com/energy/hywind-tampen
[88] https://www.equinor.com/energy/hywind-scotland
[89] Equinor, "Hywind Scotland remains the UK's best performing offshore wind farm", March 2021. Access: https://www.equinor.com/news/archive/20210323-hywind-scotland-uk-best-performing-offshore-wind-farm
[90] https://floatgen.eu/
[91][91] BW Ideol, "Floatgen achieves continuous capacity factor of nearly 60%", February 2023. Access: https://www.bw-ideol.com/en/floatgen-achieves-continuous-capacity-factor-nearly-60
[92] IEA, "Average annual capacity factors by technology", 2018. Access: https://www.iea.org/data-and-statistics/charts/average-annual-capacity-factors-by-technology-2018
[93] Martinez et al. Mapping of the levelised cost of energy for floating offshore wind in the European Atlantic, February 2022. Access: https://www.sciencedirect.com/science/article/abs/pii/S1364032121011564
[94] https://eur-lex.europa.eu/resource.html?uri=cellar:bdd70525-3658-11ec-8daf-01aa75ed71a1.0001.02/DOC_2&format=PDF
[95] JRC analysis based on 4C Offshore.

phase, with a growing interest in the past 5 years and several projects. Developing FPV at sea faces many technical challenges, including the survivability[96] of the structure, algae development, salt deposits and pollution. Current floating solar photovoltaic capacity in the EU reaches 50 kW. The early stage of development of offshore FPV makes it difficult to evaluate its load factor. It can expect to match the levels of onshore PV, ranging from 10% to 20%[97]. The first EU FPV project was North Sea 1[98] in the Netherlands (17 kW capacity) installed by Oceans of Energy in 2019, which proved the ability of the structure to withstand waves up to 10 m high and was later scaled-up to 50 kW. The Oceans of Energy project reached an LCOE of 120 to 150 €/MWh[99], in line with the potential predicted by different studies[100]. While FVP remains significantly more expensive than onshore PV, whose LCOE fell under 50 €/MWh, it is already competitive among other ocean renewable energy technologies. A significant project of 250 kW of capacity is planned by Fred Olsen and Ocean Sun in the Canary Islands. A growing number of projects also plan to combine FPV with other ocean renewable energy sources (EU-SCORES project) or activities such as aquaculture (HelioRec), desalination (Ocean Sun) and unmanned survey vessels (Van Oord).

Figure 3.2 Offshore renewable energy technologies main characteristics



	Floating solar	Wave	Tidal	Floating wind	Bottom-fixed wind
Load factor					
LCOE	120-150 €/MWh	110-480 €/MWh	160-750 €/MWh	95-160 €/MWh	67-140 €/MWh
Ext.					Bottom-fixed offshore wind
TRL 9		Point absorber OWC	Horizontal axis turbine	Semi-submersible Spar-buoy	
TRL 8		Attenuator Overtopping	Tidal kite	Barge	
TRL 7	Floating solar photovoltaic	OWSC Rotating mass	Enclosed tips Vertical axis turbine		
TRL 6			Oscillating hydrofoil	Tension-leg platform Semi-spar	

**Data include cumulative installed capacity in the EU27 and the UK for emerging technologies (based on JRC data for tidal, wave energy and for floating wind, and on the only known floating photovoltaic project in Europe: Oceans of Energy's North Sea farm). Data for bottom-fixed wind is from WindEurope's 2022 Statistics of current installed capacity in Europe.*

Offshore renewables and Blue Economy

Hybrid approaches that incorporate more than one renewable energy source are also starting to be deployed at a small scale. Incorporating ocean energy devices into offshore wind, floating offshore wind and floating PV technologies will help lower the cost of ocean energy technologies through sharing facilities, while maximising and stabilising the energy output.

Beyond electricity production, these technologies also have the potential to contribute to the goal to deploy 40 GW of hydrogen

[96] Capability of the device to be able to stay operational for long times and survive bad weather
[97] IEA, "Average annual capacity factors by technology", 2018. Access: https://www.iea.org/data-and-statistics/charts/average-annual-capacity-factors-by-technology-2018
[98] https://oceansofenergy.blue/north-sea-1/
[99] EU-SCORES project, "Co-location of offshore wind, wave and offshore solar energy could lead to unprecedented LCOE reduction", November 2022. Access: https://euscores.eu/co-location-of-offshore-wind-wave-and-offshore-solar-energy-could-lead-to-unprecedented-lcoe-reduction/#:~:text=Oceans%20of%20Energy%20indicates%20an,EUR%20per%20MWh%20by%202030
[100] Ghigo et al. Design and Analysis of a Floating Photovoltaic System for Offshore Installation: The Case Study of Lampedusa, November 2022. Access: https://www.mdpi.com/1996-1073/15/23/8804

electrolysis capacity connected to renewable sources by 2030[101]. Hydrogen production offers interesting synergies with established and emerging ocean renewable energies. It answers to challenges of grid stability and variability faced by the precited technologies, by allowing the storage of excess electricity production. On the other hand, the deployment of offshore renewable energies answers the limits of space met by renewable energies onshore. The production of hydrogen directly at sea makes it also easier to organise its large-scale transport and distribution from production site at a relatively low cost.

Offshore renewables can be used to directly power sectors of the Blue Economy such as aquaculture or seawater desalination. Launched in 2020, the ERSEO projects aims to meet the needs of oyster farms in Ria d'Etel (France) thanks to a 20 kW device[102]. Another interesting use of offshore renewable power is desalination. Among the few current projects is WINDdesal, led by the German company Synlift[103]. More recently, Gaia, a prototype of offshore desalination plant coupled with wave energy, was launched in the Canary Islands[104].On a more systemic level, MUSICA project plans to couple wind, solar photovoltaic and wave energy to power aquaculture and desalination activities in the island of Chios (Greece). The use of offshore renewables to support the energy transition of small islands is also tested in the Phares project combining tidal, solar photovoltaic and offshore wind energy in Ouessant (France).

For more information, please visit the section on Ocean Energy within the EU Blue Economy Observatory.

3.2. BLUE BIOTECHNOLOGY: A FOCUS ON ALGAE

The exploitation of marine biological resources is analysed in this report in the *Marine living resources* (section 3.1) and the *Blue biotechnology* (this section 4.2) sectors.

The *Marine living resources* sector encompasses the harvesting of renewable biological resources (primary sector), their transformation into food and feed products (processing) and their distribution along the supply chain.

The *Blue biotechnology* sector considers the non-traditionally commercially exploited groups of marine organisms and their biomass applications. Thus, it encompasses any economic activity associated with the use of renewable aquatic biological biomass, e.g., food additives, animal feeds, pharmaceuticals, cosmetics, energy, etc. Algae (macro- and micro-), bacteria, fungi and invertebrates are among the important marine resources included in the *Blue biotechnology* sector.

This biomass is used for a variety of commercial applications including food and food supplements, feed, cosmetics, fertilisers and plant biostimulants, and innovative commercial uses such as biomaterials, bioremediation or biofuels. These groups of organisms and derived compounds are important resources in relation to a number of EU priorities such as carbon neutrality, innovative, healthy and sustainable food systems and sustainable and circular bioeconomy. Hundreds of new compounds from the marine realm are being discovered every year demonstrating the innovative nature and potential of the sector, while new technologies are being researched to increase the quality and reliability of these compounds.

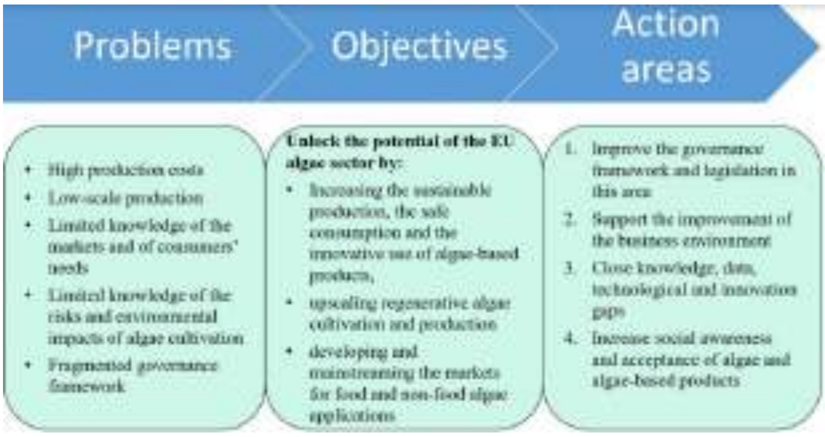
In this year's edition of the Blue Economy report, this section is focusing mostly on algae production.

Exploitation of conventional marine biological resources is covered in this report in the *Marine living resources* section (2.1), concerning the harvesting of renewable biological resources (primary sector), their transformation into food and feed products (processing) and their distribution along the supply chain. This section on the EU *Blue biotechnology* covers non-traditional exploitation of marine organisms and their biomass applications. Algae (macro- and micro-), bacteria, fungi, invertebrates and fish wastes are source of raw materials for *Blue biotechnology*, contributing to a wide range of new opportunities in human and animal health, food, food supplements, animal feeds, inputs to the chemicals industry, cosmetics, fertilisers and plant biostimulants, biomaterials, bioremediation and bioenergy. This summary focuses on the potential increase of algae production, as indicated in the EU's Algae Initiative, published on 15 November 2022. The initiative recognises the problems the algae sector faces and outlines the objectives and specific actions to unlock algae potential in the EU (see Figure 3.3 below)[105].

The EU Algae Initiative and other EU policy positions, such as the 2021 Strategic guidelines for a more sustainable and competitive EU aquaculture[106] and the new approach for a Sustainable Blue Economy in the EU[107] published in May 2021 recognise that marine bioresources can and should be very important contributors to healthy environments on land as well as in the oceans, carbon neutrality, innovative, healthy and sustainable food systems, and a sustainable and circular bioeconomy. There is a drive towards low trophic species (micro and macro-algae, filter feeders like molluscs), organic aquaculture and integrated multi-trophic aquaculture (IMTA), to generate high-value proteins, bioactive materials and environmental benefits.

[101] COM/2020/301.
[102] Guinard Energies, "Installation de l'hydrolienne Guinard Energies en Ria d'Etel", February 2019. Access: https://www.guinard-energies.bzh/wp-content/uploads/GE19_CP_Installation_P154-1.pdf
[103] Offshore Engineer, "Unique Floating Wind Turbine Set for Middle East Debut", February 2021. Access: https://www.oedigital.com/news/485362-unique-floating-wind-turbine-set-for-middle-east-debut
[104] Ocean Oasis, "Launch of pilot buoy 'Gaia'", November 2022. Access: https://www.oceanoasis.co/launch-of-pilot-buoy-gaia/
[105] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on Towards a Strong and Sustainable EU Algae Sector COM/2022/592 final & the accompanying Staff Working Document SWD (2022) 361 final.
[106] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030 COM/2021/236 final. – https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:236:FIN
[107] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on a new approach for a sustainable Blue Economy in the Transforming the EU's Blue Economy for a Sustainable Future. COM/2021/240 final

Figure 3.3 The EU Algae Initiative: Unlocking the potential of the EU algae sector



Source: EU Algae Initiative COMM (2022) 592 final

There is a high potential for algae to bring benefits to the EU, in particular to alleviate environmental pressures from conventional agriculture, aquaculture, and fisheries, including mitigation of nutrient run-offs into surface and coastal waters, management of harmful algal blooms and the circularity of wastes as inputs. The practicability of microalgae cultivation on non-arable land and the potentially large areas available for seaweed cultivation in territorial waters and in the open sea make both components of the algae sector currently as the most notable sectors of the EU *Blue biotechnology*. However, despite around 30% of algae-related companies located in Europe, the EU (including EEA countries) still has less than 1% of the global algae production[108]. According to the FAO, in 2020 Asia accounted for 34 916 thousand tonnes of biomass (live weight), that is 99.4% of global algae production, whereas the EU-27 totalled 0.5 thousand tonnes[109]. The growth potential of algae production could counter-balance this relative decline.

The European Commission's Knowledge Centre for Bioeconomy[110] can be used via search-function to find and collate reports (e.g., Biomass Study[111]) and data on macroalgae, microalgae and on traditional fisheries and aquaculture, provides some information on fisheries and aquaculture biomass, in the context of the Blue Economy. For algae enterprises, the website Phyconomy provides an open database which is updated continuously, providing a panorama of international commercial activity[112].

An important complementarity action to the EU Algae Initiative was the establishment of a collaborative European Algae Stakeholder Platform (EU4Algae), co-funded by EC DG MARE and the EU's Climate, Infrastructure and Environment Agency CINEA and taking place from February 2022 to February 2025.

EU4Algae[113] is the major platform for driving forward the aims of the EU Algae Initiative. EU4Algae will underpin, facilitate and accelerate the scale-up of "a regenerative, resilient, fair and climate friendly algae industry in Europe", through collaboration between all types of European algae stakeholders. The platform aims to become a single information hub on algae funding calls, projects, business-related information, intelligence and best practices and has already produced a strategy document for comment. Another aim is to broaden the range of commercially-useful algae species in the EU. EU4Algae has already established 7 working groups with active on-line workshops: WG1 Macroalgae Production; WG2 Microalgae Production; WG3 Algae for Food; WG4 Algae for Feed; WG5 Ecosystem Services/Bioremediation; WG6 Materials/Chemicals/Bioactives and Algae Biorefining; & WG7 Youth and Entrepreneurship – to become prime movers in making the necessary changes in the European environment for algae activities. Mid-April 2023 there were 730 registered members in EU4Algae.

3.2.1. The algae sector in the EU: market dynamics

Foundation data for amounts of harvested and farmed seaweed and value of farmed seaweeds can be obtained from FAO publications[114] [115], supplemented by detailed European studies[116] (used in STECF publications[117]). Global output for 2019 was about 34.7 million tonnes of farmed seaweed and 1.1 million tonnes of wild-harvested seaweed. For farmed seaweeds, the top 7 countries account for more than 99% and are all in Asia, with China and Indonesia producing 87% of the total global production. In 2019, the EU produced only about 260 tonnes of farmed seaweed aquaculture (worth about €4 million), mostly in France, Spain, Ireland and Portugal. There were 5 tonnes of microalgae produced (worth about €25 000) in France and Bulgaria, and almost 350 tonnes of spirulina (worth €8.5 million), mainly in France and Greece. The number of companies producing algae in Europe increased by 150% in the period 2010-2020, totalling 225 companies – 67% seaweed and 33% microalgae – with almost

[108] EU JCR KCB Brief on algae biomass production 2019 doi:10.2760/402819
[109] https://www.fao.org/3/cc0461en/online/sofia/2022/aquaculture-production.html see Table 7
[110] https://knowledge4policy.ec.europa.eu/bioeconomy
[111] See https://publications.jrc.ec.europa.eu/repository/handle/JRC132358 for the latest report, published 2023.
[112] https://phyconomy.net/database/, accessed 28.3.2023.
[113] https://maritime-forum.ec.europa.eu/en/frontpage/1727.
[114] FAO (2021) Fishery and Aquaculture Statistics 2019 Yearbook Rome: Food and Agricultural Organisation of the United Nations ISBN 978-92-5-135410-0 – tables pp 14 & 36.
[115] FAO (2023) FishStatJ – Software for Fishery and Aquaculture Statistical Time Series Rome: Food and Agricultural Organisation of the United Nations.
[116] Araújo R. et al. (2021) Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy, Front. Mar. Sci. https://doi.org/10.3389/fmars.2020.626389 and Vázquez Calderón F & Sánchez López J (2022). An overview of the algae industry in Europe, Guillen Garcia, J. and Avraamides, M. editor(s), Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-54516-3, doi:10.2760/813113, JRC130107.
[117] Scientific, Technical and Economic Committee for Fisheries (STECF) – The EU Aquaculture Sector – Economic report 2020 (STECF-20-12). Publications Office of the European Union, Luxembourg, 2021, EUR 28359 EN.

the same number of Spirulina producers. EU country information can be found via the bioeconomy dashboard[118], but is incomplete. Overall, the ratio of at-sea to on-land activities is 75:25. Data aggregated by Phyconomy suggests there are almost 450 companies in the entire seaweed value chain – thus also including downstream activities other than just production – but many of these lack production data[119]. The 6 biggest companies worldwide, producing 100 000 to 1 000 000 tonnes per year, include one European (French) company, three Chinese, one Chilean and one Brazilian companies[120].

For seaweed wild harvesting, almost 90% of global production originates from the top 8 countries (Chile, China, Norway, Japan, France, Indonesia, Peru and Ireland). France and Ireland contribute 7.5% of the total (FAO data). Harvesting from wild stocks is still the primary production method for macroalgae in the EU, producing more than 84 000 tonnes of seaweeds in France, Ireland and Spain, with hand-harvesting still used by 85% of producers. Though not in the EU, Norway and Iceland contributed a further 180 000 tonnes. Mechanical harvesting is regarded as environmentally-risky, resulting in restrictive permits that allow only a fraction of natural seaweed forests to be harvested. Better environmental risk assessments, with reliable data on least-damaging harvesting systems, and use of newer robotic and remote-sensing technologies, may allow more relaxed permits.

Economics of production still need to be achieved for seaweeds – the target cost is probably €100 per tonne for commodity production, but current cost of farmed seaweeds is more like €500-€1 000 per tonne. Over 60% of the seaweed companies in Europe generate somewhat traditional products: food (36%), food-related (15%) including food supplements, nutraceuticals and hydrocolloid production, and feed (10%); cosmetics and well-being products account for 17% and other applications such as fertilisers and biostimulants less than 11% of the total share[121].

Data for microalgae production and industry economics are much more difficult to obtain and aggregate. EABA notes that global production of microalgae biomass is about 130 000 tonnes dry weight per annum worth about €2.6 billion, more than 75% from China; European output is less than 0.5% of global production and some countries have virtually no industrial production of microalgae. 16 European countries produce microalgae, with Germany, France and Spain dominating, 15 countries produce Spirulina, with France hosting 65% of the mapped production units. Microalgae are easiest to cultivate in closed reactors on land, mainly photobioreactors (PBR – over 70%), while 83% of Spirulina companies use open ponds. New technologies are under development for microalgae, to reduce costs, improve light-capturing efficiency and streamline processing and extraction of useful components.

The available STECF data on the algae sector in Europe are in the context of turnover, cost structure and employment in the overall aquaculture industry[122]. Only France (macroalgae, microalgae and Spirulina), Spain (macroalgae, microalgae and Spirulina) and Portugal (macroalgae), the main producing countries, reported data.

Their total production value in 2018 was €10.7 million, in line with the €12.5 million in FAO's report for the whole EU. STECF[123] reported 156 algae aquaculture companies in France, Spain and Portugal, 87% of them micro-enterprises (fewer than 5 employees), with 509 persons, 399 full time equivalents. The data show that the algae aquaculture sector was profitable in 2015, with a GVA margin and an EBIT margin of 54% and 23%, respectively, but the economic performance fell to 32% GVA margin and -0.03% EBIT margin in 2018.

The European algae sector remains modest in size today and many companies are microenterprises, but the conditions are favourable to grow it into a strong sustainable and regenerative sector within the EU *Blue Biotechnology*, based on increasing innovation, rising market demand and general political support. Technological advancements and increased investment are however needed.

3.2.2. Socio-economic drivers to accelerate the blue biotechnology

EU Algae Initiative actions

To implement the EU Algae Initiative, the Commission will take amongst others, the following actions:

- integrate the algae sectors knowledge into the EU Aquaculture Assistance Mechanism;
- investigate the feasibility of creating a centralised data-source for all algae-related economic data;
- commission a number of fact-finding studies including:
  - identifying the appropriate and feasible opportunities to use seaweeds in the EU as carbon sinks and in climate change mitigation;
  - identify valid and safe alternatives to the use of nutrients and CO_2 from various sources for microalgae cultivation and organic certification;
  - establishing the exact scale and nature of wild seaweed harvesting and beached seaweed collection in the EU and monitoring schemes in place.

Investment

Investment is growing in algae and related *Blue biotechnology* activities[124]. In 2022, 41 deals were recorded at a value of €109 million, with about 28% in Europe, which recorded the highest proportion of start-ups. Investment in 2020-2021 included €30 million for a company developing and marketing seaweed ingredients for pharmaceuticals and nutraceuticals and €16.7 million for a seaweed-to-biofuels company. Processing and product-oriented companies seem more attractive than production companies. Investment patterns are a guide to value-chain trends, suggesting that seaweed-based plastics are likely to expand greatly in the near future, with more than 35 investments to date[125], though methane-reduction in livestock also seems an

[118] https://knowledge4policy.ec.europa.eu/visualisation/bioeconomy-different-countries_en#algae_prod_plants
[119] https://phyconomy.net/articles/2022-seaweed-review/, which also gives an overview of progress and challenges.
[120] https://phyconomy.net/database/
[121] STECF-20-12, based on Araújo et al. (2021).
[122] STECF-20-12, based on Araújo et al. (2021).
[123] STECF-20-12, based on Araújo et al. (2021).
[124] https://phyconomy.net
[125] Further information is given in chapter 1 of EUMOFA (2023) Blue Bioeconomy Report 2022.

attractive target for investors. Phyconomy's database provides an inventory of investing organisations and investments[126].

Improved market data

Mapping blue biotechnology activities is made difficult by the lack of effective and accurate NACE (economic activity) codes covering the wide range of industrial applications involved. The sole code referring to biotechnology is a catch-all, 72.11 - Research and experimental development on biotechnology[127]. Similarly, classes 03.11 & 03.12, marine and freshwater fishing and 03.21 & 03.22, marine and freshwater aquaculture, are very broad, to the point that it is not possible to tease out the proportion of the algae sector. Reports by FAO and the EU's STECF (based on JRC studies) provide most of the publicly-accessible data on algae production, wild-harvesting and sector employment, but the information is incomplete, often aggregated so not useful for examining specific sectors, and not consistently repeated year-on-year.

Production and processing costs mitigation

Any tools, systems, technologies and innovations that can slash production and / or processing costs will benefit all sectors of blue biomass valorisation. The cost of kelp-farming has been estimated at about €8 500 - €17 000 per dry matter tonne in Europe, versus €2 000 - €4 000 in Canada, Chile and Alaska[128], far higher than the target costs for bioenergy, foods or chemicals. Significant advances in starting culture costs, automation, robotics, remote sensing and decision-making process, energy management, extraction techniques and solvents and sequential processing will all cumulatively help in this.

For more information, please visit the section on Blue Biotechnology within the EU Blue Economy Observatory.

[126] https://airtable.com/shrGYaj6CikiaXEhH/tblUVYzt7c25xtoZP/viw45l8NPmN96Xjr2. To be noted that Phyconomy tracks all types of investment – e.g. angel investing, venture capital, equity, etc. – in the public domain. Not all equity investments disclose the amount of investment, some investments are not announced at all, and investments with debt or own means are not included. So the amount reported most certainly underestimates the total amount invested.

[127] https://nacev2.com/en/activity/research-and-experimental-development-on-biotechnology

[128] Coleman S, St Gelais AT et al. (2022) Identifying Scaling Pathways and Research Priorities for Kelp Aquaculture Nurseries Using a Techno-Economic Modeling Approach Front Mar Sci 9: 894461 DOI: 10.3389/fmars.2022.894461, used in Phyconomy 2022 report.

CHAPTER 4

ENERGY TRANSITION IN THE EU BLUE ECONOMY, CLIMATE CHANGE AND COASTAL IMPACTS

The European Green Deal (EGD)[129] calls for a transition towards a modern, resource-efficient and competitive economy where net greenhouse gas (GHG) emissions are gradually phased out by 2050 and the EU's natural capital is protected. In the trajectory towards EU climate neutrality, the Commission aims to reduce net GHG emissions by at least 55% by 2030[130]. This long-term strategy sets out a comprehensive package of measures ranging from ambitious GHG emission reductions, to cutting-edge research and innovation for the development of low carbon technologies, to the preservation of Europe's natural environment[131].

In this context, a sustainable Blue Economy offers many solutions to achieve the EGD objectives. However, this requires some of the current activities, technologies and processes to reduce their carbon footprint, while climate neutral activities and technologies need to play a central role in the EU Blue Economy.

For more information, please visit the section on Energy Transition within the EU Blue Economy Observatory.

4.1. ENERGY TRANSITION IN THE EU MARITIME TRANSPORT

The EGD calls for a 90% reduction in GHG from all modes of transport, which are responsible for almost a quarter of Europe's GHG, and this includes several important sectors of the EU Blue Economy, such as *Maritime transport*.

Maritime transport (shipping) is the most carbon-efficient mode of transport, with the lowest carbon dioxide (CO_2) emissions per distance and weight carried. Indeed, it produces less exhaust gas emissions – including nitrogen oxides, hydrocarbons, carbon monoxide and sulphur dioxide – for each tonne transported per kilometre than air or road transport[132].

Table 4.1 CO_2 emissions range per tonne-kilometre for freight. In g CO_2/km

Transport mode	Transport mean	CO_2 emission range
Maritime transport	container ship coastal,	20-45
	container ship ocean	5-25
	bulk carrier ocean	1-5
	bulk tanker ocean	2-7
Road	Heavy-duty vehicles (big truck)	70-90
Railway	diesel freight train	25-60
	electric freight train	5-25
Civil aviation	short haul cargo aircraft	1200-2900
	long haul cargo aircraft	350-950

Source: Intergovernmental Panel on Climate Change, 2014[133]

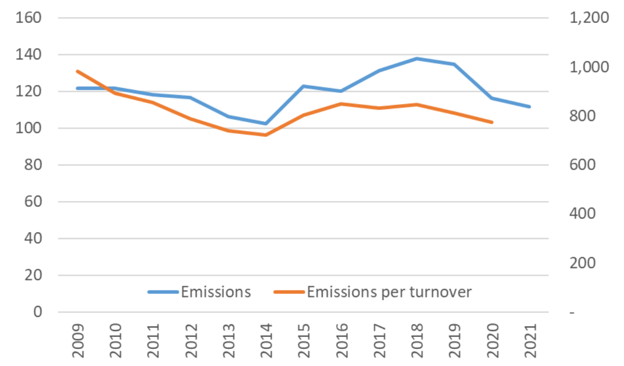
However, shipping contributes to GHG emissions because of the great volumes involved, representing around 13% of the overall EU GHG from the transport sector[134]. *Maritime transport* carried out 74% of the goods traded to and from the EU in 2021[135]. Ships registered under the flag of an EU Member State represent 16.2% of the total world fleet measured in dead weight tonnage (DWT)[136]. EU passenger ships can carry up to 1.3 million passengers, representing 40% of the world's passenger transport capacity.

Because of its efficiency, the share of *Maritime transport* compared to other transport modes continues to increase, as well as the total volume transported. Hence, the *Maritime transport* sector is not decreasing its emissions at the desired pace. Given the importance of maritime transport and the prospects of increased maritime transport, it is indispensable that the industry increases efforts to reduce its environmental impact[137].

As can be seen from Figure 4.1, GHG emissions from the EU *Maritime transport* sector (blue line) declined until 2014, and since then had an increasing trend until 2018, falling again thereafter. GHG emissions from the EU *Maritime transport* sector decreased 5% between 2009 and 2020. Instead, GHG emissions divided by turnover, as a proxy of business activity, went up marginally until 2016 and have been slightly decreasing since then, for a 21% drop during the same period. This shows that GHG emissions of the EU *Maritime transport* sector did increase but to a lesser extent than the surge in turnover (i.e., business activity).

[129] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on the European Green Deal. COM (2019) 640.
[130] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people (COM/2020/562).
[131] https://ec.europa.eu/clima/policies/eu-climate-action_en
[132][132] Swedish Network for Transport and the Environment.
[133] Sims R., et al., 2014: Transport. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[134] https://ec.europa.eu/clima/policies/transport/shipping_en
[135] Eurostat, International trade in goods by mode of transport. https://ec.europa.eu/eurostat/statistics-explained/images/6/6a/Globalisation_chapter_2.4_Dec_2022.xlsx
[136] European Maritime Safety Agency. The EU Maritime Profile - Section 2: the maritime cluster in the EU - EMSA - European Maritime Safety Agency (europa.eu).
[137] EMTER 2021.

Figure 4.1 GHG emissions by the EU Maritime transport sector, 2009-2021. Emissions in million tonnes (left axis) and emissions per turnover in tonnes per million euro (right axis)



Source: Own elaboration from Eurostat data

Due to the expected growth of the world economy and associated transport demand from world trade, GHG emissions from shipping might grow if measures were not implemented, making it paramount for the industry to continue to improve energy efficiency of ships and to shift to alternative fuels.

Maritime transport is going to face huge decarbonisation challenges in the next decades, due to current lack of market-ready zero-emission technologies, long development timeframes and life cycles of vessels. The 2020 Communication on a Sustainable and Smart Mobility Strategy[138] aims to bring the first zero emission vessels to the market by 2030. It incentivises the deployment of renewable and low-carbon fuels (using hydrogen, for example) and the feeding of onshore power supply with renewable energy. Technologies to produce zero-emission fuels and vessels are to a large extent available but in most instances not market ready[139]. The early years of this transition are challenged by the existence of several alternative fuel options and a wide gap, in terms of cost, with the fossil fuels used today[140]. Hence, the smooth deployment of these energy-efficient technologies will depend to a large extent on several factors, such as costs, availability, maturity, reliability and level of environmental sustainability[141].

The FuelEU Maritime initiative[142] as well as the Commission proposals for a regulation on Alternative Fuels Infrastructure[143], a Renewable Energy Directive[144] and the extension of the Emission Trading System to shipping[145], all part of the EU's Fit for 55 package, will contribute to increasing the availability and uptake of alternative and clean maritime fuels and to developing market-ready zero-emission technologies.

The successful reduction of emissions from the Maritime transport sector requires not only appropriate regulatory and non-regulatory incentives, R&I and an investment-friendly environment for the sector, but also other technical considerations. Innovative engineering solutions, for example, are needed to consider how ships are fuelled, designed and built, as well as how they interact with ports[146], while keeping the EU *Maritime transport* sector competitive.

4.2. ENERGY TRANSITION IN THE EU FISHING FLEET

The process of decarbonisation also implies the necessary energy transition in the EU fishing fleet. Despite some progress on reducing emissions from shipping and fishing vessels, this reduction may not be considered enough in relation to the goals of the Paris Agreement.

On 21 February 2023, the Commission presented a Communication on the Energy Transition of the EU fisheries and aquaculture sector to support it in becoming more economically resilient to high energy prices and at the same time reduce its carbon footprint[147]. The main objectives of the measures are to promote the use of cleaner energy sources and reduce dependency on fossil fuels as well as to lower the sector's impact on marine ecosystems. The communication was included in the Fisheries and Aquaculture package, which included four communications[148].

The EU fishing fleet consumed 1.9 billion litres of fuel to land 5 million tonnes of fish valued 5.8 billion at the first sale in 2020. This fuel consumption leads to the emission of roughly 5.2 million tonnes of CO_2. Between 2009 and 2020, fuel consumption and therefore CO_2 emissions decreased by 18%, while fish landings in weight decreased by 6%, despite increasing by 2% in value. Fuel use and efficiency for the fisheries sector can be defined as follows:

- **CO_2 emissions per kg of fish** is defined as emissions of CO_2 from the fuel consumed per quantity of fish landed, expressed as kg per kg;
- **Fuel efficiency** is defined as the ratio between fuel costs and income from landings, expressed as a percentage;
- **Fuel use per income generated** is defined as the ratio between the quantity of fuel consumed and the value of landings, expressed as litres per euro.

The EU fleet has become more fuel efficient over the years, yet has shown lower efficiency more recently, mainly due to rising fuel prices. Fuel efficiency is largely a result of fuel prices. Fuel price increases lead to higher fuel costs, worsening the efficiency. The lower the percentage the more fuel efficient the vessel (i.e., less income is used to cover fuel costs). Fuel costs as a proportion of income were estimated at 13% in 2020, reaching the 2016 level, the lowest historical level, and worsened after 2021.

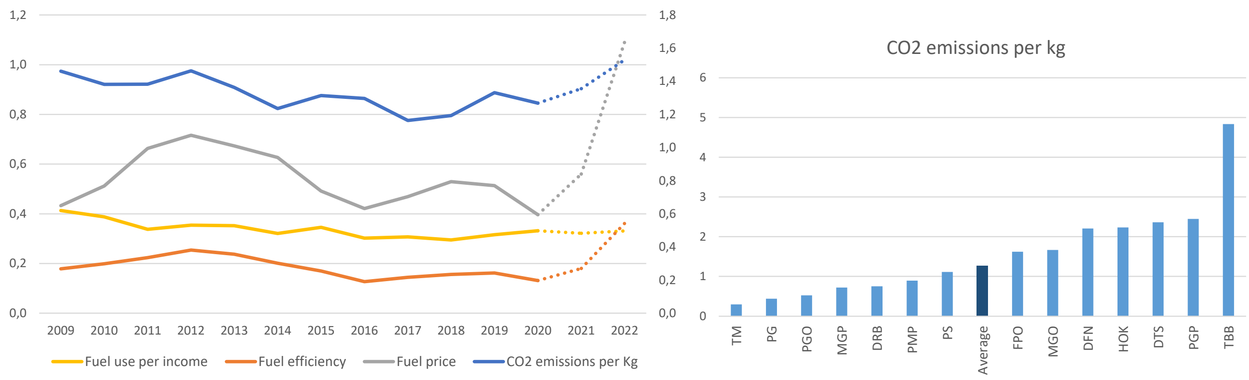
[138] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on Sustainable and Smart Mobility Strategy – putting European transport on track for the future COM (2020) 789.
[139] Innovation Needs for Decarbonisation of Shipping, Mission Innovation, Danish Maritime Authority, 2021, http://mission-innovation.net/missions/shipping/
[140] Industry Transition Strategy, Maersk Mc-Kinnely Moller Center for Zero Carbon Shipping, 2021, https://cms.zerocarbonshipping.com/media/uploads/documents/MMMCZCS_Industry-Transition-Strategy_Oct_2021.pdf
[141] European Commission. (2021). 2020 Annual Report on CO_2 Emissions from Maritime Transport. {SWD (2021) 228 final}.
[142] COM (2021) 562 final.
[143] COM (2021) 559 final.
[144] COM (2021) 557 final.
[145] COM (2021) 551 final.
[146] COMMISSION STAFF WORKING DOCUMENT (2020). Full-length report. Accompanying the document Report from the Commission 2019 Annual Report on CO_2 Emissions from Maritime Transport. {C(2020) 3184 final}.
[147] COM (2023) 100 final
[148] https://ec.europa.eu/commission/presscorner/detail/en/IP_23_828

CO_2 emissions per kg of fish show a decreasing trend over time, a 13%-decrease between 2009 and 2020. This could be partly explained by the better status of some key fish stocks, as well as the aim of the sector to reduce fuel consumption. The estimated increases for 2021 and 2022 should be taken with caution since these are based on forecasts. In 2020, the EU fishing fleet directly emitted 1.27 kg of CO_2 to land a kg of fish. These emissions vary significantly by fishing method and species targeted, with pelagic trawling to catch small pelagics being the one with the lowest emissions. Typically, seafood has on average a lower carbon footprint than animal production on land.

It has recently been estimated that globally on average 3.7 kg CO_2 eq. are emitted per kg of edible fish when accounting for the whole life cycle (including distribution, processing and commercialisation)[149]. This study confirms that small pelagics have the lowest emissions, which are lower than chicken, pork and beef. Groundfish have a similar impact to chicken (the least impactful of the animal products), large pelagics have a higher impact than chicken but lower than pork, and shrimps have a higher impact than pork but lower than beef.

Similarly, for the EU, estimations point to emissions of 4.6 kg CO_2 eq. per kg of cod and 9.0 kg CO_2 eq. per kg of shrimp for the whole life cycle, with the majority of emissions generated during the production process (i.e., fishing activity)[150].

Figure 4.2 Left) Evolution of Fuel intensity (l/kg), Fuel efficiency (%), Fuel use per income (l/€) and Fuel price for 2009-21; Right) CO_2 emissions per kg of fish by fishing method for 2020[151]



Source: Own elaboration from STECF data[152]. Please note that 2021 and 2022 data are STECF forecast

4.3. ENERGY TRANSITION IN THE AQUACULTURE SECTOR

The life cycle analysis of greenhouse gas emissions from aquaculture products considers several stages: 1) production, processing and transport of the feed; 2) rearing of finfish, shellfish and crustaceans and 3) processing and transport of the final product. Available studies[153] provide heterogeneous data regarding GHG emissions related to the different types of seafood and agri-food products, due to the methodologies used and the scope of each study. However, these studies generally provide a comparable ranking between the different types of products: lower impact for shellfish compared to finfish (due to the absence of feed) and lower impact of most finfish compared to meat products – even though some finfish may range at the same level of pork and chicken products in some studies – one of the highest impacts in terms of GHG being for beef meat. The figure overleaf provides a comparison between the emissions of the main types of farming in Ireland; shellfish production emits less than 1 kg of CO_2 eq. / kg of product, while salmon and other finfish emit between 3.9 and 4.5 kg of CO_2 eq. / kg of product. References for meat products are higher: 7.2 kg of CO_2 eq. / kg of product for pig meat, 6.1 kg of CO_2 eq. / kg of product for poultry meat and 21 kg of CO_2 eq. / kg of product for beef meat[154].

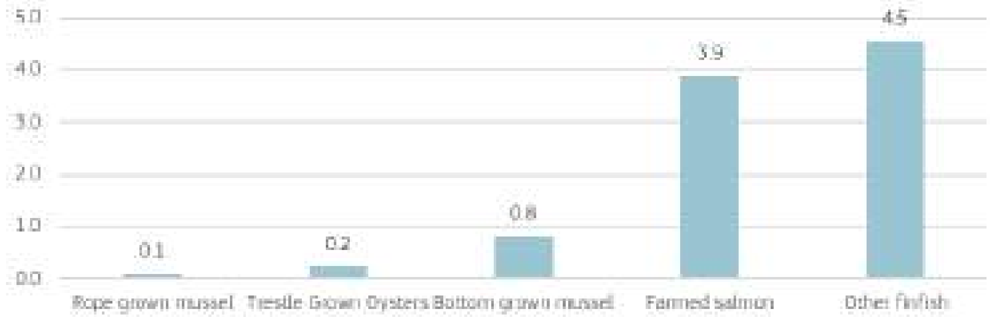
With regard to energy consumption on site, a FAO study (MacLeod *et al.*, 2019) analysed the type of energy used in each farming system at global level, based on nine studies published between 2008 and 2017. It shows that the quantity of energy is significantly higher for shrimps and prawns (18 581 MJ/tonne live weight (LW)) compared to other types of farming, due to the energy used for water aeration and pumping. It is below 3 500 MJ/tonne LW for other types of farming, the lowest use of energy being for cyprinids and catfish, with energy used being below 1 000 MJ/tonne LW. Electricity accounts for about 75% of

[149] Bianchi, M., Hallström, E., Parker, R. W., Mifflin, K., Tyedmers, P., & Ziegler, F. (2022). Assessing seafood nutritional diversity together with climate impacts informs more comprehensive dietary advice. Communications Earth & Environment, 3(1), 188.
[150] Sala, E., Mayorga, J., Bradley, D., Cabral, R. B., Atwood, T. B., Auber, A., Cheung, W., Costello, C., Ferretti, F., Friedlander, A.M., Gaines, S.D. ... & Lubchenco, J. (2021). Protecting the global ocean for biodiversity, food and climate. Nature, 592(7854), 397-402.
[151] DFN = Drift and/or fixed netters; DRB = Dredgers; DTS = Demersal trawlers and/or demersal seiners; FPO = Vessels using pots and/or traps; HOK = Vessels using hooks; MGO = Vessel using other active gears; MGP = Vessels using polyvalent active gears only; PG = Vessels using passive gears only for vessels < 12m; PGO = Vessels using other passive gears; PGP = Vessels using polyvalent passive gears only; PMP = Vessels using active and passive gears; PS = Purse seiners; TM = Pelagic trawlers; and TBB = Beam trawlers.
[152] STECF (Scientific, Technical and Economic Committee for Fisheries). The 2022 Annual Economic Report on the EU Fishing Fleet; Publications Office of the European Union: Luxembourg, 2022.
[153] For instance:
MacLeod, M., Hasan, M.R., Robb, D.H.F. & Mamun-Ur-Rashid, M. 2019. Quantifying and mitigating greenhouse gas emissions from global aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 626. Rome, FAO - https://www.fao.org/3/ca7130en/CA7130EN.pdf
French database Agribalyse (ADEME): https://agribalyse.ademe.fr/
Carbon Footprint report of the Irish Seafood Sector, BIM, 2023 - https://bim.ie/wp-content/uploads/2023/02/BIM-Carbon-footprint-report-of-the-Irish-Seafood-Sector-1.pdf
[154] Source: Carbon Footprint report of the Irish Seafood Sector, BIM, 2023.

the energy used for shrimps and prawns as well as for freshwater fish; it is 37% for bivalves. Diesel is highly used for bivalves' production (63%), cyprinids (53%) and marine fish & salmonids (47%).

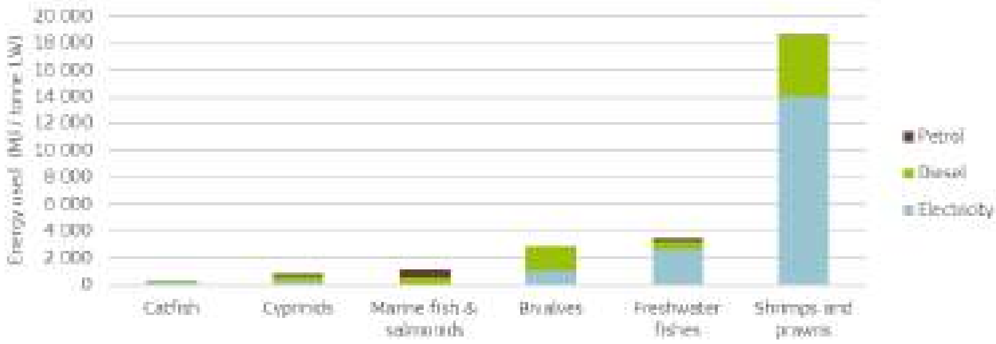
The same FAO study provides emission factors in kg of CO_2 equivalent / tonne of LW by type of species and geographical areas (Western versus Eastern Europe) related to on-farm use of energy. Based on these emission factors and the volume of aquaculture produced in the EU, we assess that the total emissions related to on-farm use of energy were 188.5 thousand tonnes CO_2 equivalent in 2020 (see figure below). Most of the emissions were from the shellfish sector (67% of the emission for 49% of the production), as its emission factor is the highest among the main species farmed at EU level – even though it is significantly lower than for shrimps and prawns. Marine fish and salmonids both accounted for 10% of emissions while they accounted for 41% of production volume. Cyprinids accounted for both 7% of emissions and production volume. Crustaceans accounted for 3% of emissions with 1% of production volume, due to a high emission factor.

Figure 4.3 Average kg CO_2 eq. emitted / kg of product, per species farmed in Ireland



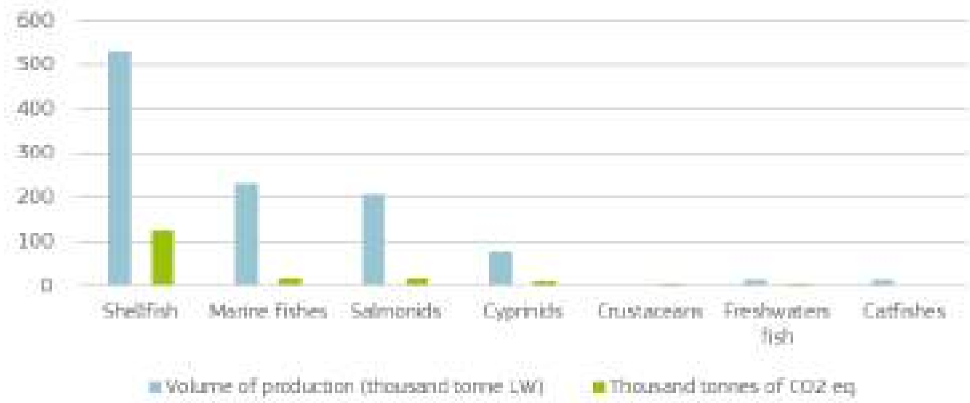
Source: Carbon Footprint report of the Irish Seafood Sector, BIM, 2023

Figure 4.4 Amount of energy used on-farm per type of farming (MJ / tonne LW)



Source: MacLeod et al., FAO, 2019

Figure 4.5 EU production of farmed products (2020) and estimate of the emission for on-farm energy use (CO_2 eq.)



Source: MacLeod et al.; FAO and own calculations

Based on these emission levels, it is possible to figure out solutions to reduce GHG emissions from aquaculture. The main leverages identified are:

- increasing energy efficiency in order to reduce the energy use on-site;
- shifting to renewable energy sources from diesel, which currently accounts for a significant share of the energy

used on-site for several types of farming, such as bivalves, marine fish, salmonids and cyprinids;

- improving the feed conversion ratio (with evolution of the ratio composition and the animal genetics);
- improving the interaction with surrounding habitats, in order to enhance blue carbon sequestration (for bivalves and seaweed mariculture)[155];
- implementing polyculture in order to reduce the GHG releases from bivalve farming and reduce eutrophication around fed finfish farms (with impact of blue carbon habitats). This could be achieved through: i) co-farming of bivalves and seaweed, and ii) co-farming of finfish and seaweed or bivalves[156].

4.4. CLIMATE CHANGE AND COASTAL IMPACT

Coastal zones are home to large human populations and significant socio-economic activities. They also support diverse ecosystems that provide valuable ecosystem services to the European citizens, related to waste treatment, climate and water regulation, food production, and recreation, among others. Within a 10-km coastal zone of the EU-27 countries, almost €400 billion worth of ecosystem services were generated in 2018. One third of the EU population lives within 50 km of the coast. Globally about 120 million people are exposed annually to tropical cyclone hazards, in which since 1980, over 300 000 people have lost their lives. Climate change could have profound impacts on coastal zones due to sea level rise and changes in frequency and/or intensity of storms, which will drive coastal floods and erosion. To that end, the Commission services (JRC) have developed the integrated risk assessment tool LISCoAsT (Large scale Integrated Sea-level and Coastal Assessment Tool). The sections below summarise findings related to the future dynamics of coastal flood impacts, adaptation and ecosystem services, along the EU-27 coastline.

4.4.1. Coastal floods and economic impacts

Damages from coastal flooding in the EU-27 currently amount to €1 billion annually, which is equivalent to around 0.01% of current EU-27 GDP[157]. France is the country currently experiencing most damages (€0.2 billion annually). Around 72 000 people in the EU-27 are exposed to coastal flooding every year. Damages from coastal flooding are projected to rise sharply with global warming for all EU-27 countries with a coastline if current levels of coastal protection are not raised. Annual damages grow to €814 billion and €137 billion by 2100 under a high emissions scenario and a moderate mitigation scenario respectively (

Figure 4.6), when assuming socioeconomic development according to SSP5 and SSP1[158], respectively. The largest absolute damages are projected for Germany, Denmark, France, Italy, and the Netherlands. For some countries the damages represent a considerable proportion of future national GDP, e.g., 4.9% (Cyprus), 3.2% (Greece) and 2.5% (Denmark) by 2100 (high emissions). Although damages from, and exposure to, coastal flooding, are around 90% lower with mitigation compared with high emissions. Further mitigation, according to the 1.5°C warming goal of the Paris agreement, would result in even higher reduction of the 2100 expected annual damage; i.e., 92% to 95%, depending on the socioeconomic scenario considered. However, future losses are still significantly greater than at present and this means appropriate adaptation measures are needed to lessen the effects of future climate change along the EU coastline.

If dykes are raised along EU-27 coastlines, to a level of protection for each section that maximises their economic benefit (avoided flooding) relative to their cost, then EU-27 annual flood damages could be reduced significantly relative to no adaptation (

Figure 4.6). Under the high emissions and moderate mitigation scenarios respectively in 2100, the damages are reduced by 98% (€796 billion/year) and 96% (€131 billion/year). Likewise, 71% (1.6 million/year) and 63% (0.6 million/year) fewer people would be exposed to coastal flooding respectively[159]. The average annual cost of adaptation for the EU-27 over the period 2020-2100 is €1.8 billion/year in the high emissions scenario and €1.1 billion/year in the moderate mitigation scenario. Germany and France have the highest adaptation costs because of higher construction costs and length of coastline where additional protection is required. The average annual cost of additional coastal protection is about two orders lower than the estimated reduction in annual flood losses by the end of the century. This means that investing now in coastal protection will have very large (and growing) benefits in the long term.

[155] Jones, A.R. et al., Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture, 2022 - https://academic.oup.com/bioscience/article/72/2/123/6485038

[156] Ibidem.

[157] Vousdoukas, M. I., Mentaschi, L., Voukouvalas, E., Bianchi, A., Dottori, F., Feyen L., 2018. Climatic and socioeconomic controls of future coastal flood risk in Europe. Nat. Clim. Chang. 8(9), 776-780.

[158] SSPs are based on narratives describing broad socioeconomic trends that could shape future society. SSP1 ('Sustainability') represents a world of sustainability-focused growth and equality, while SSP5 ('Fossil-Fueled Development') represents a world of rapid and unconstrained growth in economic output and energy use (see Van Vuuren, D.P., et al. The representative concentration pathways: an overview. Climatic Change 109, 5-31. doi:10.1007/s10584-011-0148-z (2011)).

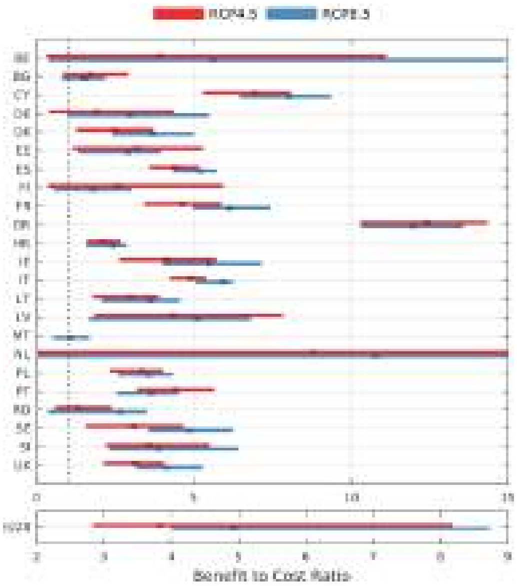
[159] Feyen, L., Ciscar, J.C., Gosling, S., Ibarreta, D., Soria A. (editors), 2020. Climate change impacts and adaptation in Europe. JRC PESETA IV final report. EUR 30180EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-18123-1, doi:10.2760/171121, JRC119178.

Figure 4.6 EU-27 annual damages and population exposed to coastal flooding in present and by 2100 under two emissions scenarios, with and without adaptation respectively. For adaptation, dykes are raised to a level of protection that maximizes their economic benefit. High emissions correspond to RCP8.5 combined with socioeconomic projections from SSP5 (Fossil-Fueled Development). Moderate mitigation corresponds to RCP4.5 combined with SSP1 (Sustainability)

	Today	High emissions		Moderate mitigation	
		No adapt	Adapt	No adapt	Adapt
Damages (€ billion/year)	1.0	814	18	137	6
People exposed (million/year)	0.07	3.1	0.7	1.2	0.4

Overall, benefits at EU-27 level outweigh costs by 3 to 9 times depending on the scenario and uncertainty range considered; with the economic benefits of adaptation increasing under high emissions. The uncertainty in the estimates is driven by several components like climate projections, data and methodological issues. Also, the benefit to cost ratio of elevating dykes varies strongly between coastal segments in Europe. The presence of human development renders investing in dykes economically beneficial, typically, when population density exceeds 500 people per km^2. In urbanised and economically important areas, the benefits of raising dykes tend to be several times the costs, which is the case for 24% and 32% of the European coastline under a moderate mitigation and high emissions scenario, respectively. However, for the rest of Europe's coasts, additional protection against coastal inundation is not needed or economically beneficial[160]. This can be either because natural barriers will sufficiently safeguard against the projected rise in sea level extremes in areas with steep morphology, or because costs of raising dykes outweigh benefits, which can happen in sparsely populated areas and along complex, winding coastlines.

Figure 4.7 Benefits vs Costs at country level. Each colour expresses a scenario (Sustainability–RCP4.5 (red) and fossil fuel-based development–RCP8.5 (blue)), with patches expressing the very likely range and squares the expected BCR per country. The vertical black dotted line expresses BCR =

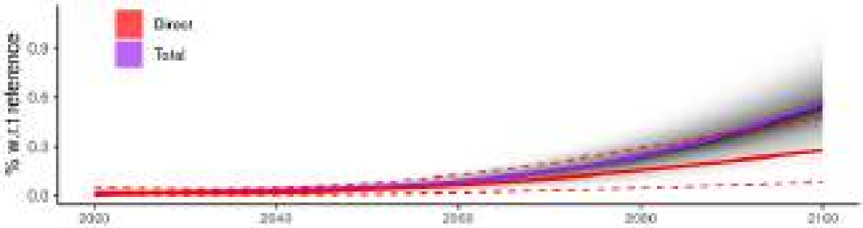


These cost and benefit analyses focusses only on direct damages of coastal flooding and omit other contributions. For example, lost ecosystem services are not included as they require a different modelling framework. Similarly, flood damages of critical infrastructure are only based on land use information[161] and the additional value of such assets is not considered. Finally, long-term economic impacts are also omitted since they also require a different framework. The reason is that damages to residential buildings, firms' physical assets and agriculture production generate long-term economic losses that propagate and compound throughout the century. Such effects are typically not considered when assessing the efficiency of coastal adaptation options, since the response of the economic system to exogenous shocks is highly uncertain. Such uncertainty relates to the economic agents' behaviour and other relevant macroeconomic assumptions, i.e., how consumers finance the repairing of their homes, whether firms decide to build back better after an inundation and possibly compensate the losses with a productivity gain, how long it takes for a firm to reconstruct. Further analysis done on this specific issue has shown that under high emission scenarios, the EU-27 could lose every year between 0.25% and 0.91% of its output by 2100, twice as much as the expected direct

[160] Vousdoukas, M.I., Mentaschi, L., Hinkel, J., Ward, P.J., Mongelli, I., Ciscar, J.-C., Feyen, L., 2020. Economic motivation for raising coastal flood defences in Europe. Nature Communications 11, 2119.
[161] Copernicus Land Monitoring Service. Corine Land Cover, https://land.copernicus.eu/pan-european/corine-land-cover (2020)

damages (Figure 4.8) The welfare losses present a strong regional variation with the South showing the lowest level of resilience and a significant part of the population that could suffer welfare losses of worrying proportions by the end of the century.

Figure 4.8. Coastal flooding impacts as percentage of the GDP for EU-27: the grey to black colour scale represents the concentration of the GDP total coastal flooding impacts around the most likely scenarios. The red lines show the mean (solid line) and the very likely range of the direct impacts (dashed lines)



4.4.2. Coastal erosion and lost ecosystem services

Coastal zone ecosystem services account for 2.8% of the EU-27 GDP in 2018, with the main source of services currently being agricultural areas (34% of total) followed by wetlands (29%) and forests (20%). Sea level rise is expected to accelerate coastal erosion during the 21st century[162]. Already by 2050 approximately 2 000–2 300 km^2 of the coastal zone could erode, depending on the emission scenario (moderate or high emissions). By 2100, erosion is projected to reach 3 800–5 000 km^2 and it would disproportionately affect several valuable habitats. In effect, the loss of 1-1.3% of land and inland waters would result in a 4.3-5.4% decline in the value of ecosystem services, i.e., from €360 to 341–344 billion per year. About 75% of the losses would occur because of the decline in services of wetlands (11–14% of 2018 services), particularly salt marshes. Other land cover types strongly affected are beaches, sands, and dunes (29-35% of 2018 services, many of which related to coastal tourism), as well as coniferous forests, salines, estuaries, inland marshes, and natural grasslands. On the other hand, impacts on agricultural lands would be limited.

Table 4.2 Coastal ecosystem services in EU27 from all land-use classes currently and projected to be lost in the future, by service type

Ecosystem service type	Value in 2018	% lost by 2100	
	billion euro	Moderate emissions	High emissions
Regulating services	**169.8**	**7.3**	**9.0**
Waste treatment	91.3	11.0	13.5
Erosion control	34.7	2.7	3.3
Climate regulation	14.0	0.9	1.2
Soil formation	10.3	0.5	0.7
Water regulation	7.9	5.8	7.2
Disturbance moderation	4.4	12.6	15.4
Other (pollination, air quality etc.)	7.2	3.5	4.4
Provisioning services	**115.7**	**0.9**	**1.2**
Food production	63.4	0.8	1.1
Genetic and medicinal resources	32.3	0.8	1.1
Water supply	12.3	1.4	1.8
Raw materials (incl. ornamental resources)	7.7	1.4	1.8
Cultural services	**40.0**	**1.8**	**2.3**
Recreation	37.2	1.5	1.9
Other (spiritual, aesthetic, etc.)	2.9	6.0	7.4
Habitat services	**34.5**	**4.2**	**5.2**
Nursery service and genetic diversity	34.5	4.2	5.2
Total	**360.1**	**4.3**	**5.4**

Different functions of the ecosystem would be unevenly affected. The most valuable component is regulating services, which include waste treatment, climate and water regulation, disturbance moderation, erosion control, soil formation, pollination and others. Regulating services would also be the most affected, declining by 7–9% by 2100. Smaller impacts are projected for habitat services, such as nursery and genetic diversity (4–5% loss), cultural services, such as recreation (around 2% loss), with provisioning services (e.g., supply of food, water and raw materials) losing only about 1% of current level. One of the principal assumptions of the methodology followed is that static land use is assumed. This is inevitable since land use projections come with high uncertainty and would result not only in a more tedious and computationally expensive analysis, but also in a wide range of estimates.

Although many of the processes that generate coastal erosion are beyond human control[163], ecosystem services can be preserved with adequate mitigation measures and Coastal Areas Spatial Planning.

[162] Paprotny D., Terefenko P., Giza A., Czapliński P., Vousdoukas M.I. Projecting losses of ecosystem services due to coastal erosion in Europe with remote sensing data. Science of the Total Environment 760, 144310, doi:10.1016/j.scitotenv.2020.144310 (2020).
[163] Mentaschi, L., Vousdoukas, M. I., Pekel, J.-F., Voukouvalas, E. & Feyen, L. Global long-term observations of coastal erosion and accretion. Scientific Reports 8, 12876, doi:10.1038/s41598-018-30904-w (2018).

However, such actions come with many challenges. For example, measures for coastal protection were for many years dominated by hard solutions such as seawalls, breakwaters, groins and dykes; which even though effective, tend to result in further erosion and thus downgrade coastal ecosystem services. This implies that the coastal protection benefits highlighted in the previous section can have negative results on ecosystem services. Nature-based solutions can be an alternative protection pathway to that end. These involve a variety of soft site-specific human interventions that can protect the coast without altering the coastal environment, as much as conventional methods do.

Nevertheless, under rising seas, some kind of hard protective barrier will probably be necessary, so nature-based solutions tend to extend to also hybrid solutions, e.g., artificial reefs or constructed dunes, which combine hard infrastructure and natural approaches. They can harness the strengths and minimise the weaknesses of both approaches. Yet, despite their potential, hybrid protection solutions are still rarely implemented. The reason is the lack of guidelines for when a soft, hybrid or hard coastal defence approach is most appropriate, as well as detailed assessments of lifespans and construction/maintenance costs. This is an ongoing process that involves implementing more pilot projects and monitoring them intensively in order to understand which coastal landscapes could benefit in wider implementation of hybrid or nature-based solutions, as well as the related costs.

Figure 4.9 Historical (2000-2018) and projected (2050 and 2100) coastal ecosystem services per year, in billion of 2018 euros, total for the study area

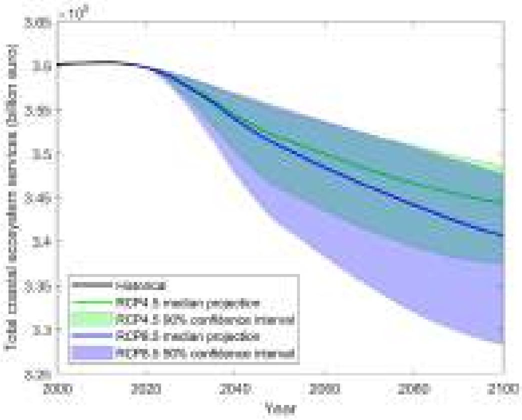


Table 4.3 Historical (2018) and projected (2050 and 2100) land cover/use in the coastal zone, in thousand km2. The values for 2050 and 2100 are the median projections for RCP4.5 and RCP8.5 (first row) and the 90% confidence interval combined for both emissions scenarios (second row). Water excludes the sea and ocean

CLC class	2018	2050	2100
Artificial surfaces	46.7	46.0-46.1 [44.9-46.4]	44.7-45.3 [42.0-45.8]
Agricultural areas	238.1	236.8-237.0 [235.2-237.5]	234.6-235.5 [230.0-236.3]
Forest and semi natural areas	239.8	236.9-237.3 [233.6-238.4]	232.7-234.6 [224.6-236.2]
Wetlands	37.7	37.2 [36.6-37.4]	36.5-36.7 [35.4-36.9]
Water	17.3	17.1-17.2 [16.9-17.2]	16.9-17.0 [16.5-17.1]
Total	**579.7**	**574.0-574.8 [567.2-576.8]**	**565.4-569.1 [548.5-572.4]**

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