Food and Agriculture Organization of the United Nations

IN BRIEF

INTEGRATING BLUE FOODS INTO NATIONAL CLIMATE STRATEGIES

AQUACULTURE

Aquatic foods and climate policy

Aquatic foods are increasingly in the spotlight. Playing a critical role in global food and nutritional security, and supporting hundreds of millions of livelihoods in developing countries, aquatic foods and their supply chains are becoming a key focus for policymakers – and there is a growing awareness of their importance in national climate strategies too.

Foods from aquatic sources – both wild-caught and farmed – generally have a significantly lower carbon footprint than terrestrial animal-source foods, and targeted investments in sustainable aquatic foods can support low-emission development strategies. But climate change is also posing severe challenges to the sector, driving shifts in species distribution and abundance in capture fisheries, and affecting production capacity in the aquaculture industry. Vulnerable groups who rely on aquatic foods – such as small-scale fishers, women in post harvest and trade, and communities in the Global South – face the largest impacts.

Historically, aquatic foods have been overlooked in climate discussions, and underfunded in mitigation and adaptation financing. Today, though, as understanding and momentum are growing, it is essential that policymakers fully integrate aquatic foods into nationally determined contributions (NDCs) and other climate processes, to foster resilience in this vital sector, specifically in support of adaptation of vulnerable communities and reduction of the sector's greenhouse gases (GHG) wherever relevant.

As countries are submitting their updated NDCs, it is time to step up action on aquatic foods. Key policy options for aquaculture are discussed below.

Aquaculture production

Aquaculture is a cornerstone of aquatic food production. It has considerable growth potential as a sector, and has a central role to play in feeding the growing global population. In 2022 for the first time aquaculture surpassed capture fisheries in aquatic animal production, producing 51 percent of the global total, and this percentage is projected to continue increasing. Global policy in support of the sustainable development of aquaculture has translated into the adoption of the Guidelines for Sustainable Aquaculture by the FAO Committee on Fisheries in 2024, further reinforcing international commitment to responsible growth of the sector.

Aquaculture mostly relies on accessible and affordable species such as tilapia, African catfish and pangasius. Globally, of some 730 farmed species, 17 staple species make up around 60 percent of total production. In 2023, the sector accounted for 60 percent of global aquatic foods output including aquatic animals and algae. Nearly two-thirds (63 percent) of the aquaculture production of aquatic animals takes place inland, and just over a third (37 percent) is in marine and coastal areas.

Sector growth is primarily being driven by Asian countries, especially China which in 2023 produced 56 percent of the world's output of aquatic animals.

As the sector continues to grow, its total GHG emissions are increasing. In 2017, it was estimated to be responsible for about 0.5 percent of global GHG emissions, mostly from feed production, aquatic nitrous oxide emissions from nitrification and denitrification processes, and energy use.

Different farmed species and farming systems produce widely different levels of GHG emissions, which means there is considerable potential to improve practices and shift to more sustainable systems in the face of climate change. This will require strategic planning, investment and resilience-building measures, to reduce both emissions and the sector's vulnerability to climate impacts.

There are four key areas in which policymakers can work to prioritize measures. First, improve aquaculture feed and feeding management to reduce GHG emissions. Second, transition aquaculture energy inputs to renewables and reduce energy use. Third, promote expansion of low-input, integrated and/or non-fed aquaculture systems. Fourth and finally, support climate-adaptive technologies and practices to increase aquaculture's resilience to climate change.

AQUACULTURE IN NUMBERS

Global production

2023

136 million tonnes, worth **USD 365.7 billion** at farm-gate value.

98.4 MILLION TONNES OF AQUATIC ANIMALS

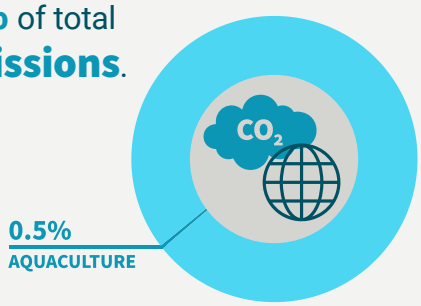
37.6 MILLION TONNES OF ALGAE

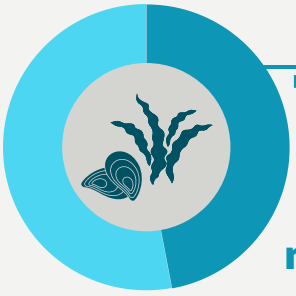
The sector currently supplies **52% of all global aquatic animal** production.

GHG emissions

2017*

263 $MtCO_2e$, around **0.5%** of total **global emissions**.





2022

Nearly half of global aquaculture is produced from **non-fed animal and plant species**.

*Latest estimates available.

Source: **FAO.** 2025. *Fishery and Aquaculture Statistics – Yearbook.* Rome. https://doi.org/10.4060/cd6788en;
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POLICY OPTION 1

Improve aquaculture feed and feeding management to reduce greenhouse gas emissions


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Rationale

While some cultivated species groups such as bivalves require no feeding at all, fed aquaculture – of species such as salmon, tilapia and catfish– accounted for about 73 percent of global aquaculture production of animal species in 2022.

As well as being the most expensive input in aquaculture, aquafeed produces far more GHGs than any other part of the sector. Emissions from feed production account for up to 90 percent of aquaculture's carbon footprint, primarily stemming from raw materials, land-use change, fertilizer use, and the energy-intensive processes of transport, processing and distribution.

Optimizing the way in which feeding is managed through the introduction of precision systems offers direct gains, reducing wasted inputs and improving feed conversion ratios (FCRs) in farmed species – this is calculated by dividing the total amount of feed consumed by the total weight gain, with a lower number indicating higher efficiency.

However, emissions vary significantly depending on the species and production system concerned, and there is considerable scope for improving overall sector performance on climate metrics by making changes here. Most obviously, promoting aquaculture of species with lower or no feed demands would contribute to lowering the total carbon footprint of the aquaculture sector; while in fed aquaculture, emissions can be reduced by adapting feed formulas to incorporate lower-emission ingredients.

Concrete measures

- Invest in research, development, and use of low-carbon feed ingredients ensuring they meet nutritional and environmental requirements, and are locally available.
- Incentivize the adoption of precision feeding techniques and efficient species to optimize nutrient intake, reduce feed waste, and improve feed conversion ratios.
- Develop and implement training programmes for farmers on advanced feeding management, precision feeding, and alternative feed ingredients to reduce GHG emissions.
- Establish comprehensive monitoring and reporting systems for key performance indicators, including feed use, to improve feeding management practices and reduce GHG emissions.
- Invest in infrastructure to facilitate the use of fish processing by-products, incentivizing biocircularity.
- Invest in hatchery and distribution infrastructure and establish local and regional distribution networks to ensure small-scale farmers have reliable access to high-quality feeds and seeds.

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CASE STUDY

Co-benefits

- Improved feed conversion ratios and optimized feeding increases efficiencies and reduces costs for farmers, increasing their productivity, profitability and resilience.
- Precision feeding techniques enhance nutrient utilization, leading to healthier fish.

Potential issues

- The use of some crops and wild-caught fish in fish feed may conflict with needs for human consumption: careful management of ingredients is essential.
- Using higher-quality feed ingredients to improve the FCR may increase resultant GHG emissions.

Guidelines for feed use in carp and trout production systems

For farmers in the aquaculture sector, effective feed management is essential to maximize yields, reduce costs and improve economic returns. This FAO-produced tool gives practical advice on how this can be achieved for carp and trout, two key commercial species groups in Central Asia and Eastern Europe. The guidelines provide an introduction to fish nutrition, and discuss the compositions, nutritional values and usage of the different types of feed available – live, supplementary, farm-made and commercial. They also advise on feeding methods, feed storage, and ways in which consumption and efficiency can be optimized.

POLICY OPTION 2

Transition aquaculture energy inputs to renewables and reduce energy use


© FAO/Alexander Joe

Rationale

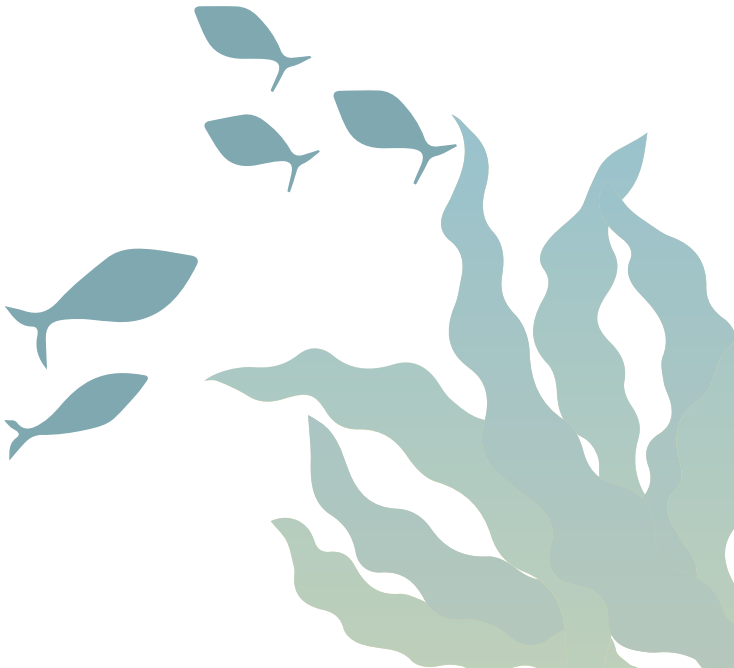
After feed, energy use is another major source of GHG emissions in the aquaculture sector. While energy demands vary between farms depending on the species and methods in question, feed processing, storage, transportation, water exchange and treatment, handling systems and farm equipment all have energy needs. As the sector continues to grow, it is essential that energy use is optimized as far as possible in order to minimize GHG emissions and maximize overall efficiency.

Where this energy comes from is all-important. Transitioning from fossil fuels to renewable sources – solar, wind, bioenergy, hydro and geothermal – can substantially reduce the carbon footprint of an aquaculture operation. For example, switching from diesel oil to natural gas for farmed salmon has been found to cut nitrous oxide emissions by 85 percent and CO_2 emissions by 20 percent.

Making the transition will require upfront investment that could be prohibitive, particularly for operators in developing countries, but this challenge can be eased through government measures such as low-interest loans to support the adoption of energy-efficient technologies and renewable energy sources.

Concrete measures

- Provide targeted incentives and subsidies to help farms, feed production, and transportation upgrade to energy-efficient equipment and renewable energy systems, such as efficient pumps, temperature control systems, solar panels, and electric vehicles.
- Establish and enforce energy efficiency standards for aquaculture operations to optimize and reduce energy use.
- Facilitate subsidized energy audits to help farms identify opportunities for energy savings and transition to renewable energy.
- Implement demand response programmes that incentivize energy-intensive equipment use during off-peak hours.
- Create trainings and platforms for farmers, researchers, and industry experts to share technology and knowledge on energy management and emissions reduction.
- Include aquaculture in national climate policies and energy priorities, connecting it to other sectors for comprehensive support of energy transitions.
- Promote public–private partnerships to drive renewable energy adoption in aquaculture.



CASE STUDY

© FAO

Co-benefits

- Reducing fossil fuel use lessens the risk of pollution from spills and leakage, directly improving water quality and ecosystem health.
- Transitioning to renewable energy sources can lead to substantial long-term savings on bills, improving financial stability. Excess renewable energy can be sold back to the grid to provide additional revenue.

Potential issues

- Upfront investment needs can be a financial burden for smaller companies.
- New systems often require specialist knowledge to operate and maintain, which may pose challenges for farms with limited technical expertise.

Fisheries and Aquaculture Clean Technology Adoption Program (FACTAP)

Canada's Fisheries and Aquaculture Clean Technology Adoption Program (FACTAP), which was active from 2017 to 2024, was established to support the fisheries and aquaculture sector to integrate clean technology in day-to-day operations. During this time FACTAP provided over CAD 35 million to more than 200 projects to test and implement technologies – from hydraulic generators to composting systems – to improve environmental performance, and the impact of its work continues today. Knowledge and best practices generated through the programme are widely shared, so operators can identify which new approaches could help increase the efficiency and reduce the footprint of their own enterprises.

POLICY OPTION 3

Promote expansion of low-input, integrated and/or non-fed aquaculture systems

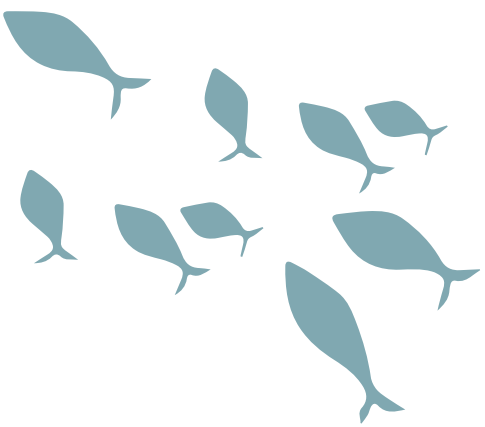
Rationale

About 47 percent of global aquaculture production came from non-fed animal and plant species in 2022. Given that feed is the largest source of GHG emissions in the aquaculture production process, algae, bivalves and filter-feeding finfish generally have a smaller footprint than cultivated aquatic species that require feeding, and generate far lower GHG emissions than land systems. In order to grow, seaweeds photosynthesize and absorb naturally occurring nutrients from the water around them; while bivalve farming is among the most sustainable forms of farming on the planet, thanks to the way bivalves use their gills to capture food particles from the water that passes through openings in their shells, and the high amount of protein and micronutrients they contain.

Integrated agriculture/aquaculture systems, for example raising low-trophic fish species in rice paddies, or fertilizing fish with organic manure from livestock or poultry, enable overall outputs to be maximized from limited resources, and feed costs to be reduced. This increases production efficiency and hence decreases energy use.

Concrete measures

- Promote the development and proper management of low-trophic, low-input systems, such as filter-feeding finfish, seaweeds, and bivalves, that provide nutrition with minimal environmental impact.
- Offer financial incentives and technical assistance to develop functional and beneficial integrated multispecies aquaculture, tailored to national and regional characteristics, such as cage fish farming combined with seaweed and bivalve cultivation.
- Invest in the necessary infrastructure, such as water management systems, processing facilities, and transportation networks, to support and scale low-input aquaculture practices.
- Support the development of supply chains and improve market access for non-fed aquaculture products through certification programmes and promotional campaigns to raise consumer awareness and demand.
- Implement capacity-building programmes for aquaculture operators, providing them with the skills and knowledge needed to adopt and maintain sustainable, low-input, non-fed and integrated farming practices.
- Support data collection and spatial assessments, including life-cycle assessments and ecological evaluations, to guide the expansion of low-input, non-fed and integrated aquaculture systems with minimal environmental impact.



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Co-benefits

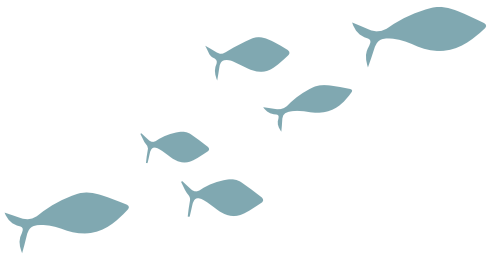
- Low-input and non-fed operations have smaller environmental footprints, reducing nutrient pollution and habitat destruction, and lessening impacts on biodiversity. Some can even benefit ecosystems, as when bivalves filter out impurities from the water column.
- Integrated farming systems combining multiple species are less vulnerable to disruption, increasing supply chain resilience for aquatic foods.

Potential issues

- Advanced management practices are required for complex integrated and multi-species systems, and knowledge gaps remain regarding market development, infrastructure and how to scale up operations.
- Financial incentives and support may not be equally accessible, putting smaller operators at a disadvantage.
- Considerably more investment is needed to develop the full potential of farmed algae as a core product.

Philippine Seaweed Industry Roadmap 2022–2026

Farmed seaweed is an important commodity in the Philippines, the world's third-largest producer. It accounts for 60 percent of total aquaculture production and supports the livelihoods of more than a million people, most of them small farmers. In 2022, the Department of Agriculture launched a five-year strategic development roadmap to position the country as the global leader in seaweed and carrageenan. It has also partnered with several organizations to support seaweed farmers' associations, which offer their members training in cultivation, disease prevention, and processing.



POLICY OPTION 4

Support climate-adaptive technologies and practices to increase aquaculture's resilience to climate change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Rationale

While aquaculture can contribute to addressing climate-related challenges in capture fisheries, such as stock depletion, climate change is also driving a range of trends which threaten the productivity, sustainability and profitability of the aquaculture sector itself. Higher water temperatures and lower oxygen levels, ocean acidification and changes in salinity, increased pests and diseases, harmful algal blooms (HAB), droughts and floods can all have a negative impact on aquaculture systems, while extreme weather events pose increasing risks to infrastructure and other assets.

It is vital that countries make proactive and strategic interventions in the face of these climate threats. Targeted technological solutions to address individual stressors and systemic vulnerabilities are essential. More broadly, a holistic approach to increase the adaptive capacity of the sector through actions in the short, medium and long term will improve its overall resilience as the impacts of climate change accelerate. Technical research, data collection and training programmes are required on a scale that reflects the severity of the challenges to come. FAO's Guidelines for Sustainable Aquaculture explores strategies for addressing climate change in its section 5.6.

Concrete measures

- Identify the main hazards faced by the aquaculture system to guide adaptation actions, including reducing risk and exposure. Aqua-Adapt is a tool designed to help identify the main climate change risks facing aquaculture and support users in identifying possible solutions to address them.
- Strengthen capacity for climate-informed decision-making by identifying and predicting key climate change hazards, such as extreme weather events and water quality issues, and supporting aquaculture farmers with early warning systems, data collection, and regional knowledge-sharing on climate risks and management practices.
- Invest in genetic enhancement programmes to develop farmed types (e.g. strains and varieties) more resilient to changing conditions such as temperature and salinity, with a focus on locally adapted species.
- Incorporate climate risk assessments into aquaculture spatial planning, considering climate impacts in site selection, farm layout, and stocking and harvesting schedules.
- Identify and implement climate-resilient infrastructure, such as climate-controlled facilities, advanced water management systems, and protective barriers against flooding and storms.
- Support R&D initiatives to explore cost-effective new technologies, including energy-efficient systems, integrated farming approaches, closed recirculating aquaculture systems, feed alternatives, and climate-resilient breeding programmes.
- Encourage climate-resilient management practices, such as adaptive stock density and water management, biosecurity protocols to prevent disease, and advanced monitoring techniques such as sensors, automated control systems, and water treatment technologies.
- Subsidize adoption of climate-smart aquaculture practices and systems by women to improve income and employment gains and reduce inequality.

Co-benefits

- Using technical innovation to increase climate resilience also drives increased efficiency and productivity, boosting overall yields and profitability.
- Advanced technologies and improved infrastructures can reduce GHG emissions from the sector, mitigating its contribution to climate change.

Potential issues

- Substantial upfront investment is often required to implement technological and infrastructure improvements, which can be a particular challenge for small-scale farmers.
- Ensuring farmers have the necessary expertise to use climate-resilient technologies and management practices requires wide-reaching technical assistance and training programmes.
- Some technologies – e.g. recirculating systems – may lead to increased GHG emissions unless they are powered by renewable energy sources.

Brazilian Climate Change Plan 2025-2035 proposal

The Brazilian Climate Change Plan 2025-2035 proposal will outline adaptation and mitigation strategies for various sectors, including a dedicated strategy for agriculture, livestock, fisheries, and aquaculture. Aligned with the FAO Guidelines for Sustainable Aquaculture and the NDC-Fish guidelines, the aquaculture strategy promotes climate resilience through sustainable, low-emission practices. Key adaptation actions include developing water-efficient aquaculture technologies, promoting climate-resilient aquaculture practices, and supporting small-scale and family aquaculture farmers. Mitigation actions focus on promoting low-GHG emission models, expanding bioinputs such as macroalgae, creating a national GHG inventory for aquaculture, establishing a Low-GHG Emission Aquaculture Sector Plan, and strengthening technical assistance and rural extension for climate mitigation.

Existing NDC examples

- Belize has set an adaptation target to develop an Aquaculture Management Plan or Strategy by 2030, to improve the value chain of aquaculture products, and establish sustainable aquaculture practices and guidelines for designated areas.
- Canada aims to improve the measurement, verification and reporting of GHG emissions and carbon sinks in agriculture and aquaculture, to create enabling conditions for scaling-up investment in climate-smart practices.
- Kenya has prioritized the promotion and expansion of nature-based enterprises, including seaweed farming, as a key adaptation intervention area for 2031–2035.

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Scan to read the full report

This briefing is based on information contained in *Integrating blue foods into national climate strategies*, a joint report from Stanford Center for Ocean Solutions, WorldFish, FAO, Beijer Institute of Ecological Economics, CARE, and Environmental Defense Fund, on how nations can use aquatic foods to enhance their nationally determined contributions and strengthen climate action.