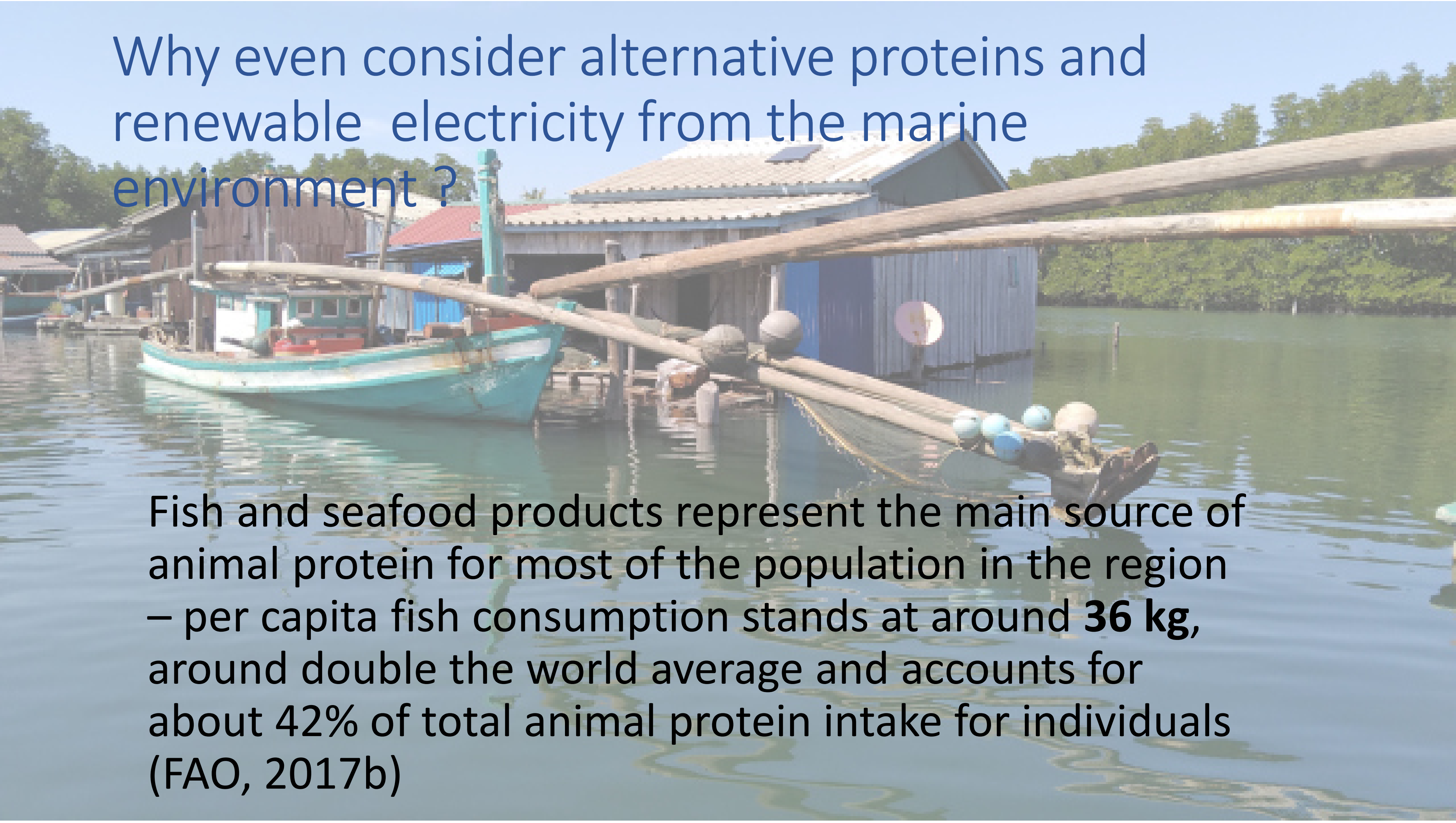
Alternative Proteins Powered by Marine Renewable Energy

- Explaining the energy needs and supply chain considerations for alternative protein



Why even consider alternative proteins and renewable electricity from the marine environment ?

Fish and seafood products represent the main source of animal protein for most of the population in the region – per capita fish consumption stands at around **36 kg**, around double the world average and accounts for about 42% of total animal protein intake for individuals (FAO, 2017b)

Regional importance of fish

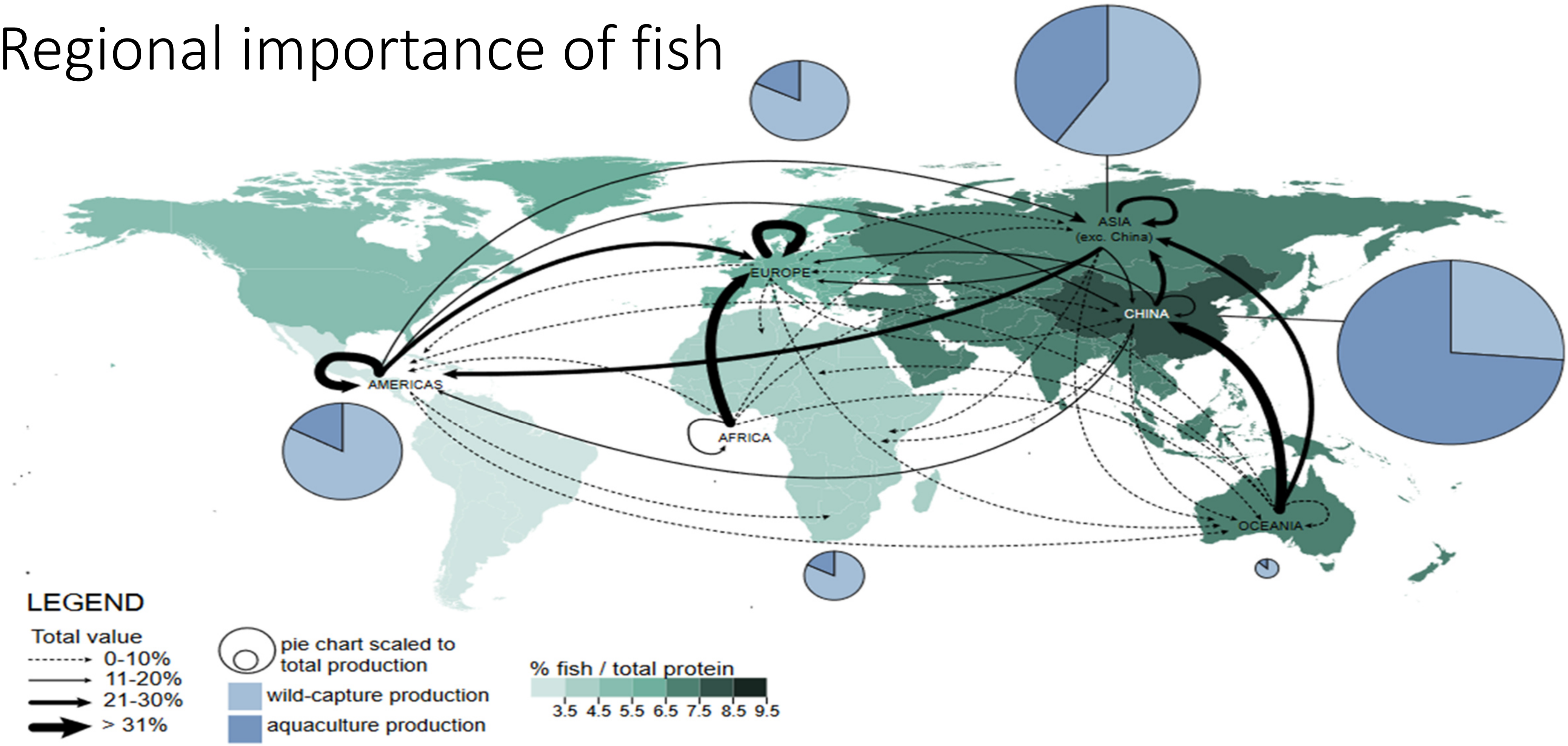


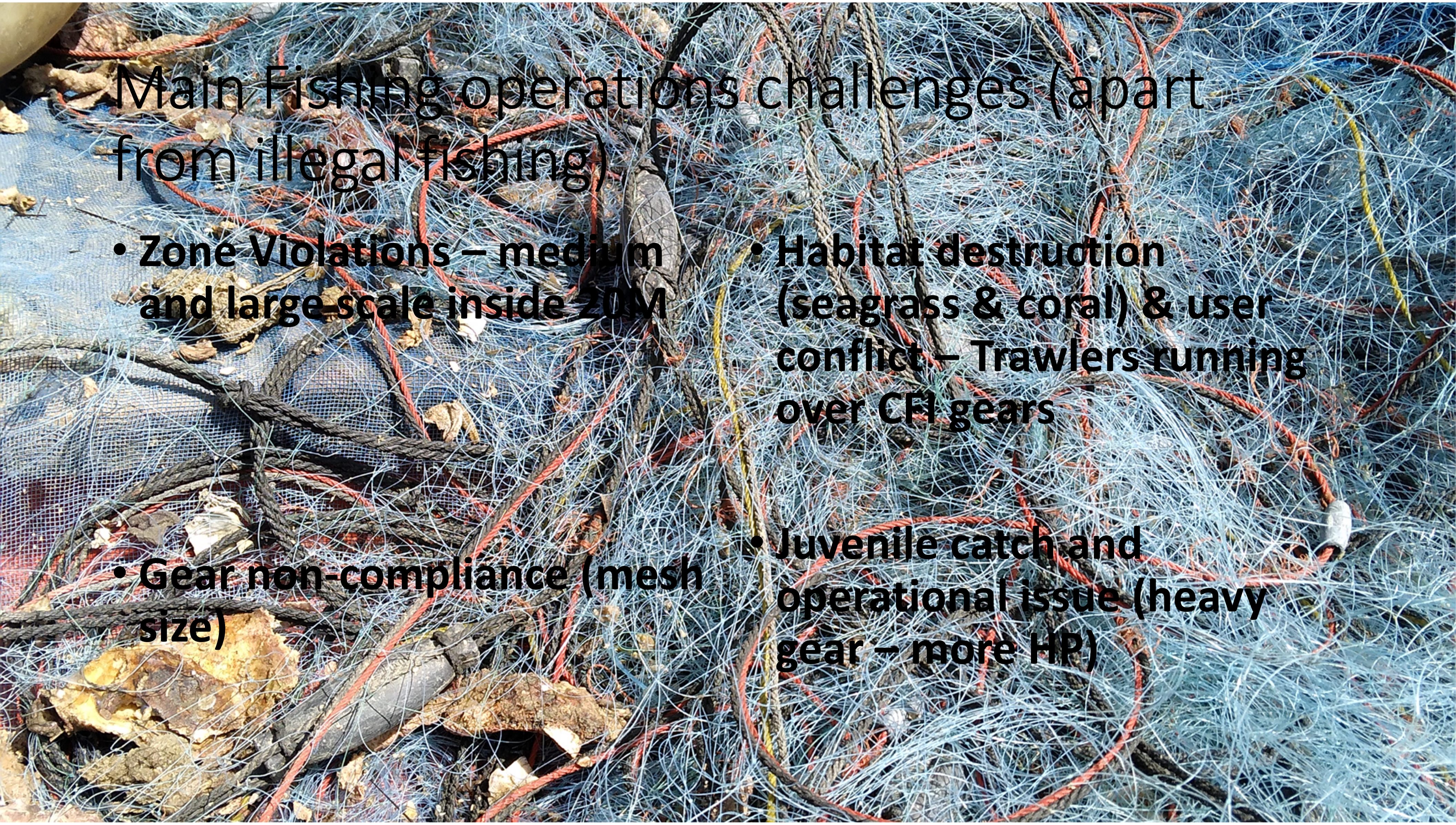
Figure 1. Aquaculture and Wild-Capture Fishery Production in Global Regions and Value of Seafood Flows
Production volume from global regions (pie charts) demonstrating the value of export flows (lines with arrows represent the percentage of the total value exported from each region), and the contribution of fish to human protein consumption (percentage of fish in total protein represented by each region's color). Data sources: aquaculture and wild-capture fishery production;[9,23] export flows;[23] and human consumption of protein from fish.[23,24]

Facts and figures

- The global food system causes 34 percent of global greenhouse gas emissions, and half of this is attributable to today's system of protein production.
- Food loss and food waste is estimated to be 1.3 billion tons per annum globally, accounting for 30% of all food produced. According to the Food and Agriculture Organization of the United Nations (FAO), food loss is defined as any food lost in the sup-ply chain and food waste is defined as discarded food items fit for human consumption. The share of food waste in municipal solid wastes can be >50% in some larger cities.
- The shipping industry is responsible for around 940 million tonnes of CO_2 annually, which is at least 2.5% of the world's total CO_2 emissions.
- The world's fishing fleets in 2011 burned 40 billion litres of fuel and emitted 179 million tonnes of CO_2 -equivalent (CO_2 -eq) GHGs to the atmosphere, or 2.2 kg CO_2 -eq per kg of landed fish and invertebrates.
- "when combined with renewable energy sources, more energy-intensive technologies such as cultivated meat production are still an improvement over conventional chicken, reducing land use by 63%, air pollution by 29%, and greenhouse gas emissions by 17%." & "cultivated meat produced using renewable energy reduces global warming impacts by 17 percent, 52 percent, and 85 to 92 percent compared to conventional chicken, pork, and beef production, respectively." ->> Similar gains are not expected in the conventional meat industry, where *fossil fuels account for only approximately 20 percent* of carbon emissions throughout the supply chain.

Facts and figures (cont.)

- for instance, one important business model for cultured meats is that they could be produced in urban “breweries”, potentially *collapsing global supply chains* and bringing production closer to demand – thereby reducing the environmental impact of global supply chains such as shipping and trucking (including emissions from refrigeration).
- According to the study, 71% of food emissions in 2015 came from agriculture and “associated land use and land-use change activities” (LULUC).*The rest stemmed from retail, transport, consumption, fuel production, waste management, industrial processes and packaging. The research, published recently in Climate Policy, models different energy-use scenarios for reducing global energy-related CO2 emissions to zero by 2050. It found that simply substituting fossil fuels with renewable energy at current energy usage levels is no longer enough.*
- *To keep global heating below 1.5°C—the level necessary to avoid irreversible damage—total energy consumption itself needs to halve over the next three decades based on 2019 levels. Furthermore, to keep temperature from overshooting a 1.5°C increase by 2050, global CO2 emissions must decline by about half by 2030.*



Main Fishing operations challenges (apart from illegal fishing)

- **Zone Violations – medium and large-scale inside 20M**
- **Gear non-compliance (mesh size)**
- **Habitat destruction (seagrass & coral) & user conflict – Trawlers running over CFI gears**
- **Juvenile catch and operational issue (heavy gear – more HP)**

Perfectly edible “Trash Fish”

Supplying the demand leads to bad practices

Catch for the day

Metrics 1: GHG in KG CO2(eq)/ kg

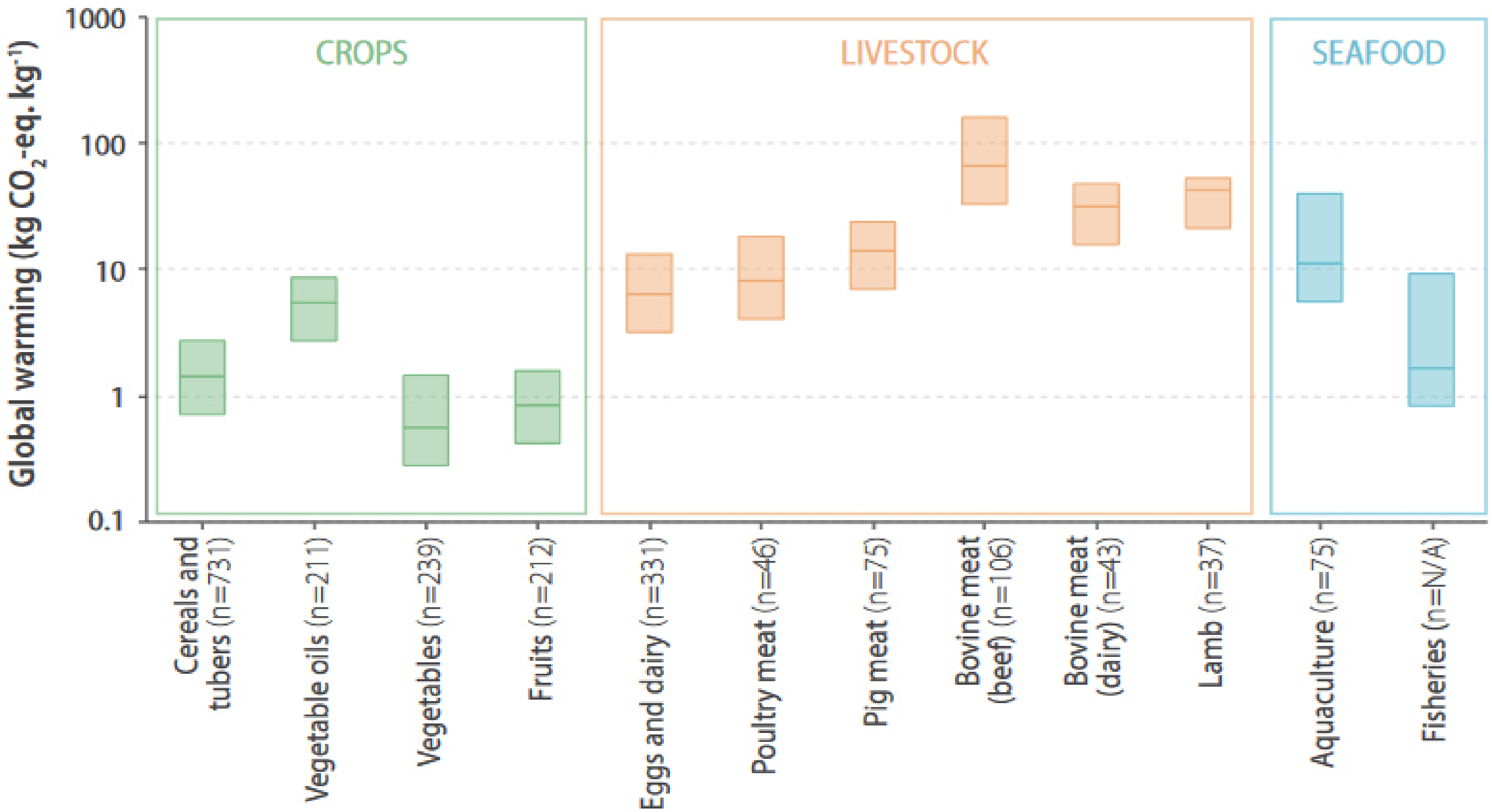


Fig 3. GHG emissions related to a kg of different food commodities from Poore and Nemecek,[27] and Parker et al.[21] Boxes indicate the mean and 10th and 90th percentiles and sample sizes are stated in the labels. Underrepresentation of systems due to missing LCA data is expected to be higher for aquaculture than terrestrial production systems, given the sector's diversity and the more limited number of LCA studies conducted.

Metrics 2: Life cycle energy (GJ/tonne)

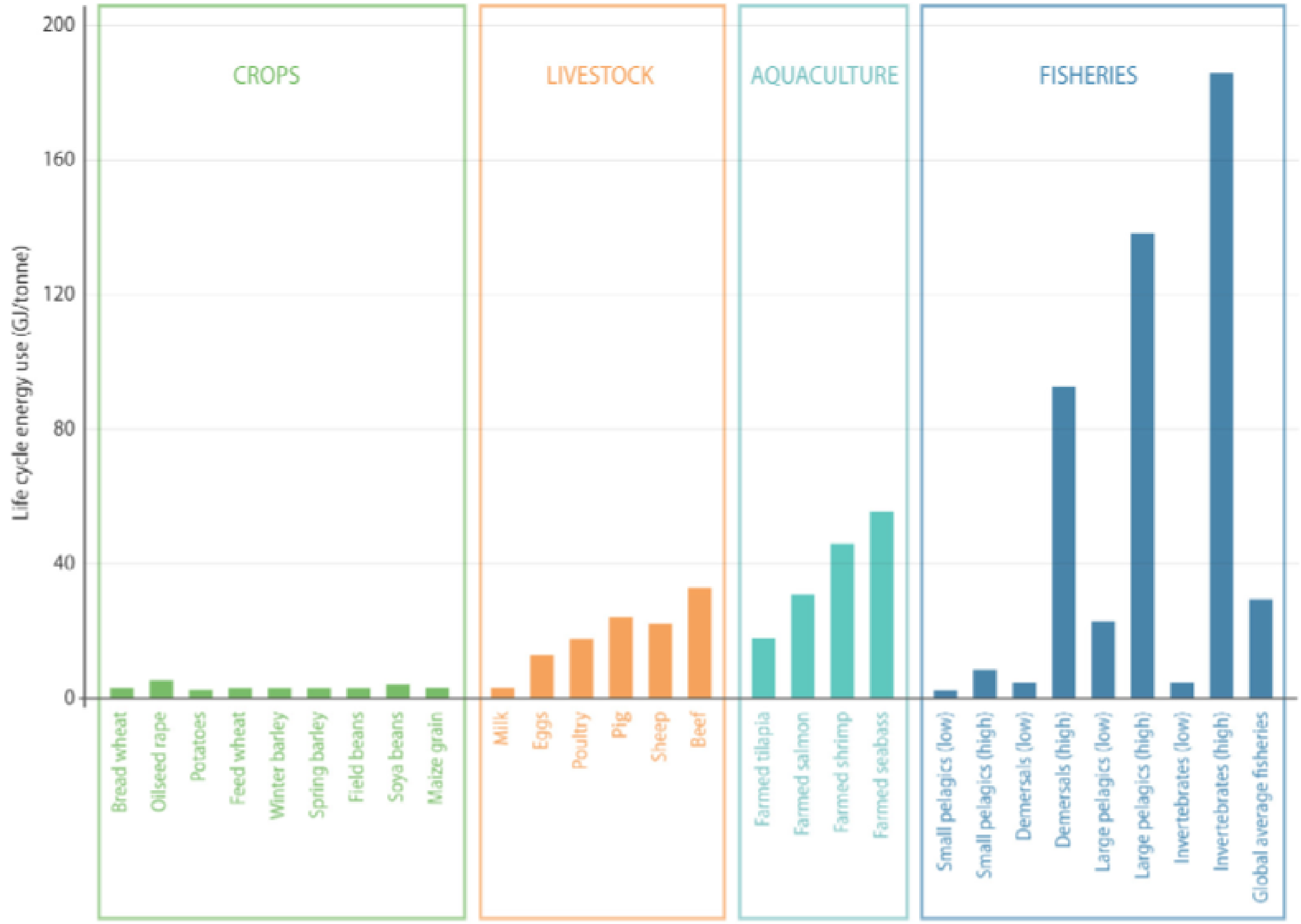
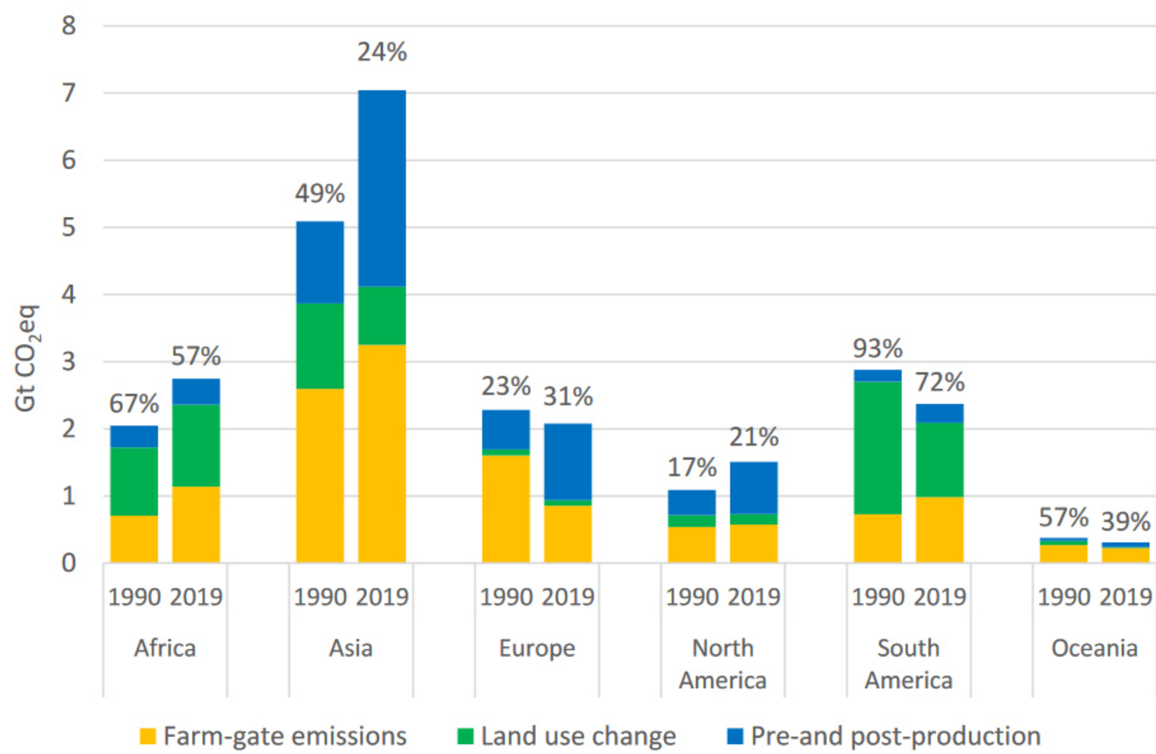


Fig 2. Cradle-to-producer gate life cycle energy use (GJ/tonne). Indicating large variability within capture fisheries and also that energy dependence can be significant in aquaculture. Note: Energy use correlates well with GHG emission except for livestock such as cattle and sheep where methane emission significantly increases GHG.[18]

Food and GHG

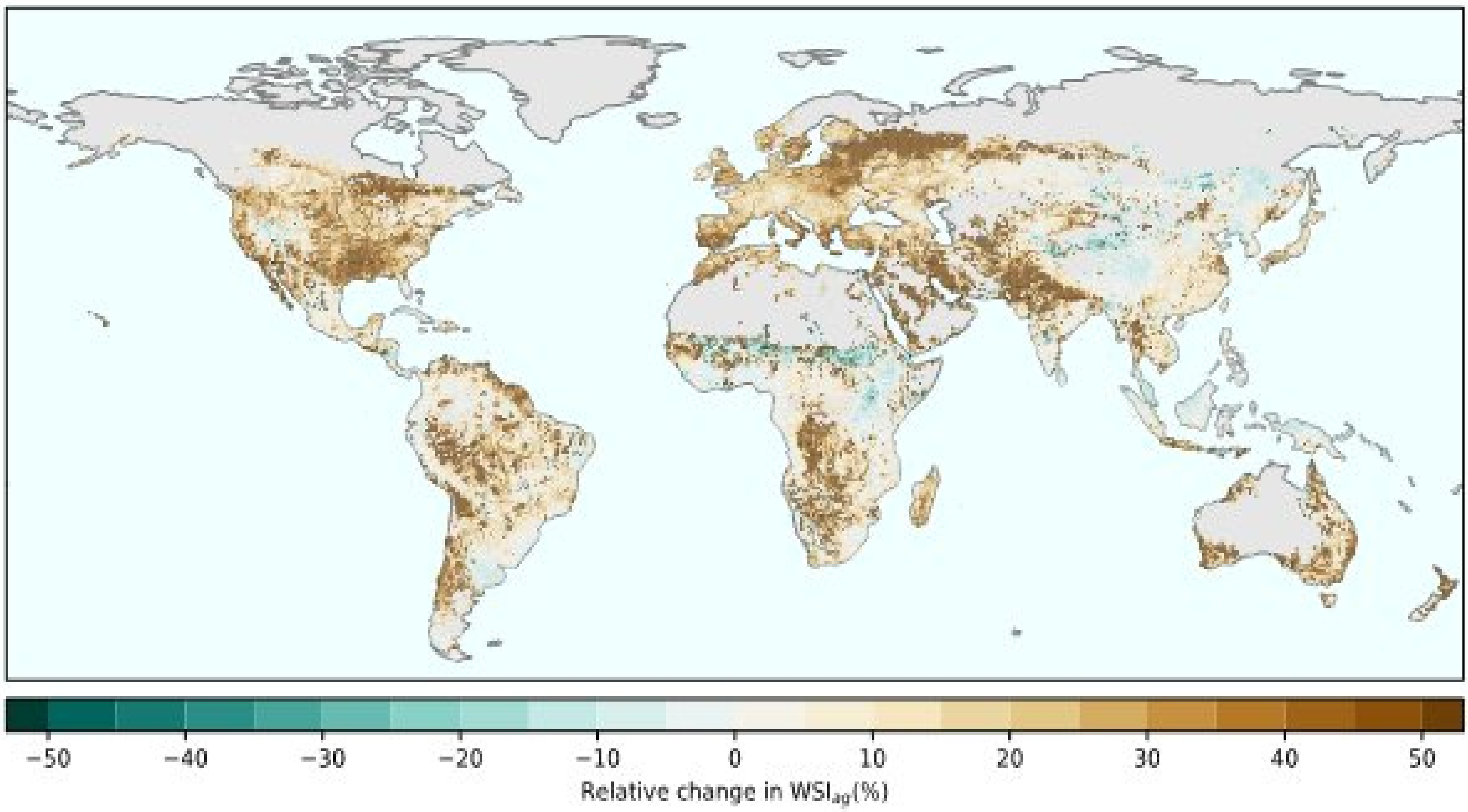
Figure 6: Agri-food systems emissions by region and life-cycle stage



Note: The percentages indicate the share of agri-food systems in the total emissions of the region.

Source: FAO, 2021.

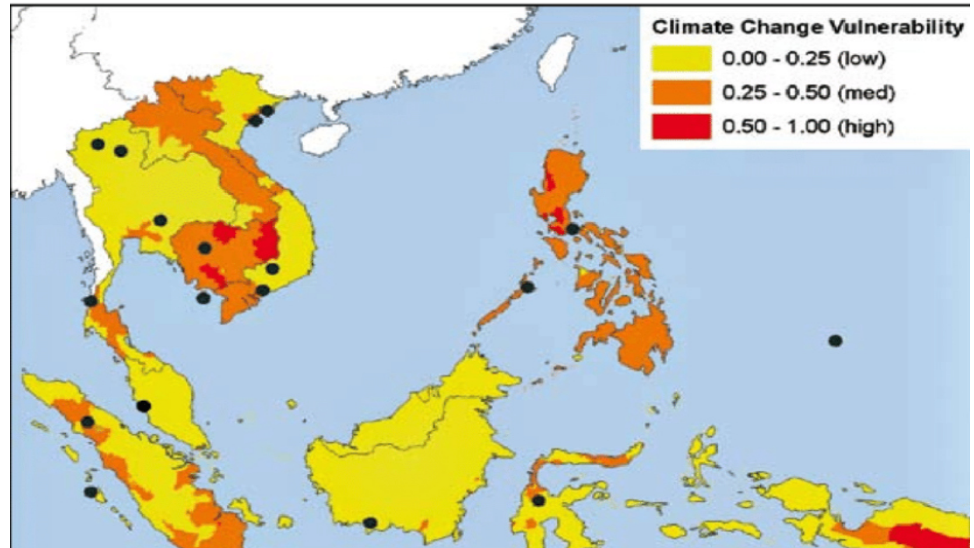
Green and blue water changes predicted based on current climate predictions

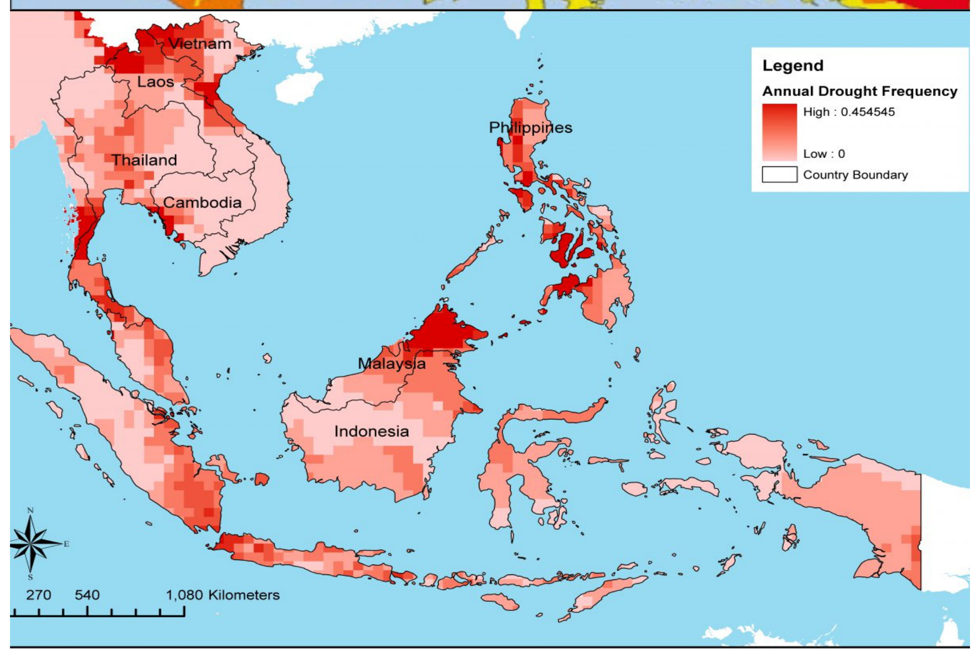


Regional vulnerability

There is no Planet B – every saved captured or unused CO_2 molecule helps

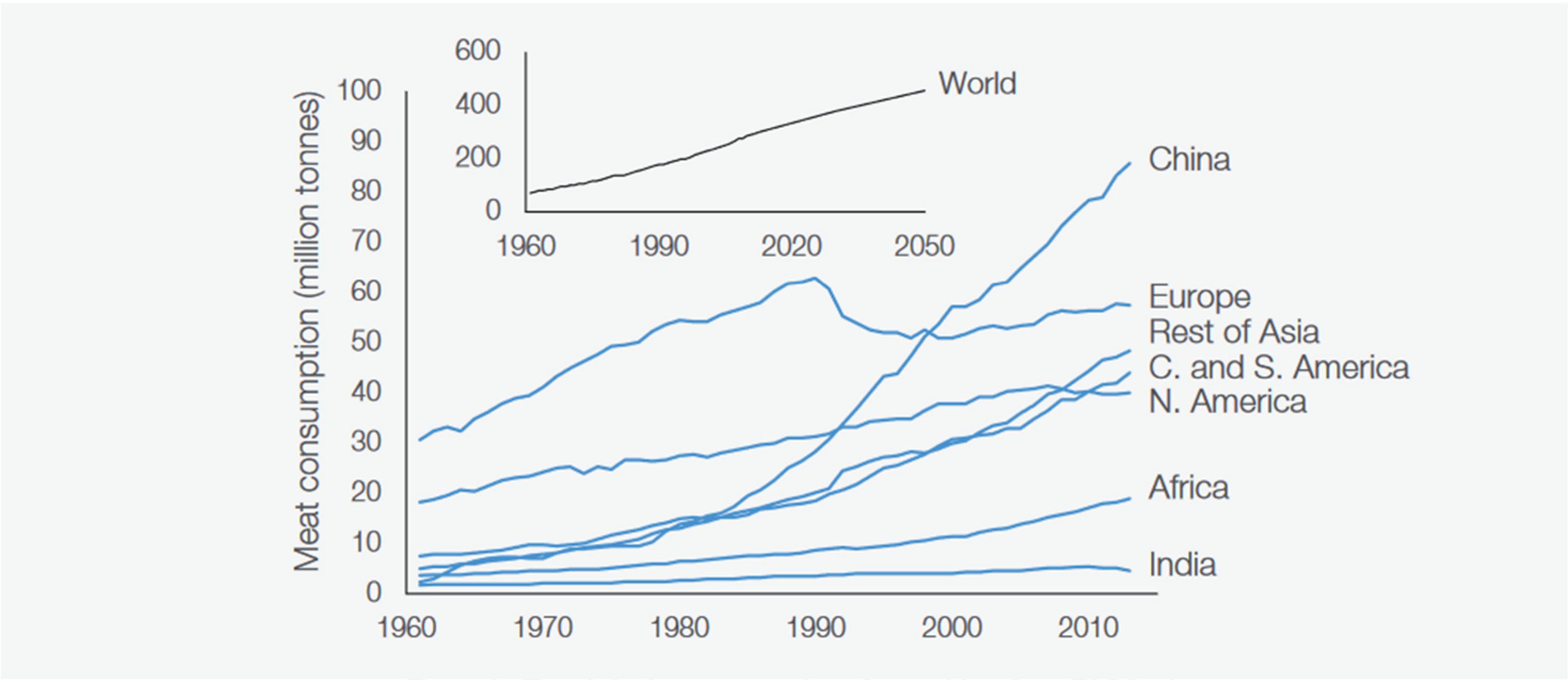
"With ongoing global warming, today's children in South and Southeast Asia will witness increased losses in coastal settlements and infrastructure due to flooding caused by unavoidable sea-level rise, with very high losses in East Asian cities," said the Intergovernmental Panel on Climate Change (IPCC) report.





Not everyone eats meat

Figure 1: Trends in the consumption of meat (data from FAOStat); regional data to date and global data to date and projections to 2050[98]



The demand for more fish

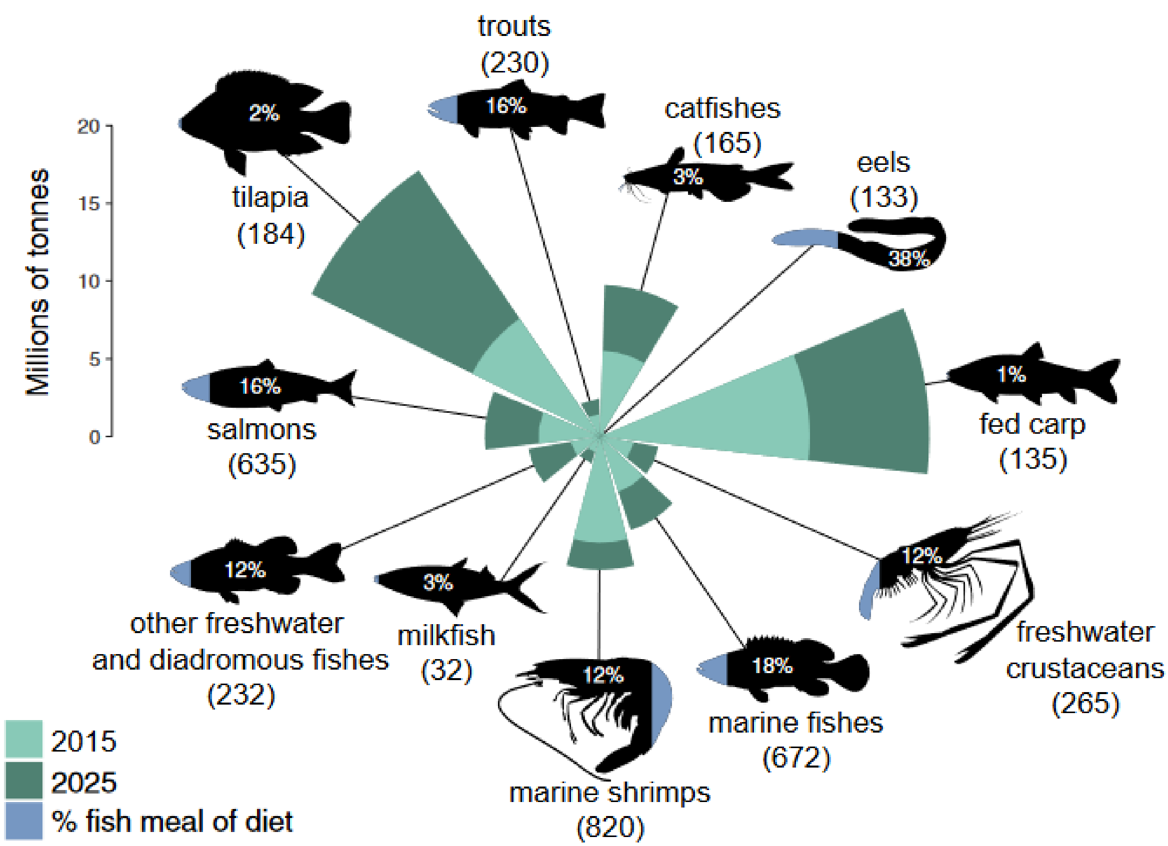


Figure 2. Projected Demand for Fish Meal in Fed-Aquaculture Diets

The estimated aquafeed volume demand (millions of tons) of the major fed-aquaculture species groups in 2015 and 2025, and the use of fish meal in the diet of each group in 2015 (represented by the blue portion of each animal). The values (percentage) inside each species group symbol are the estimated fish meal inclusion in 2015. The values in brackets beside each species group symbol are the estimated volume of fish meal included in the diets in 2015 (thousands of tons). Data sources: fish meal proportion in diets in 2015;[25] estimated aquafeed volume demand.[11]

increase separation and traceability. Alternatively, instead of using food wastes directly, there are additional options including bioconversion and biotransformation. Bioconversion uses the food waste as a nutrient source for insects and/or algae, which can subsequently be used as a feed resource;[42,46] while biotransformation uses food waste as a

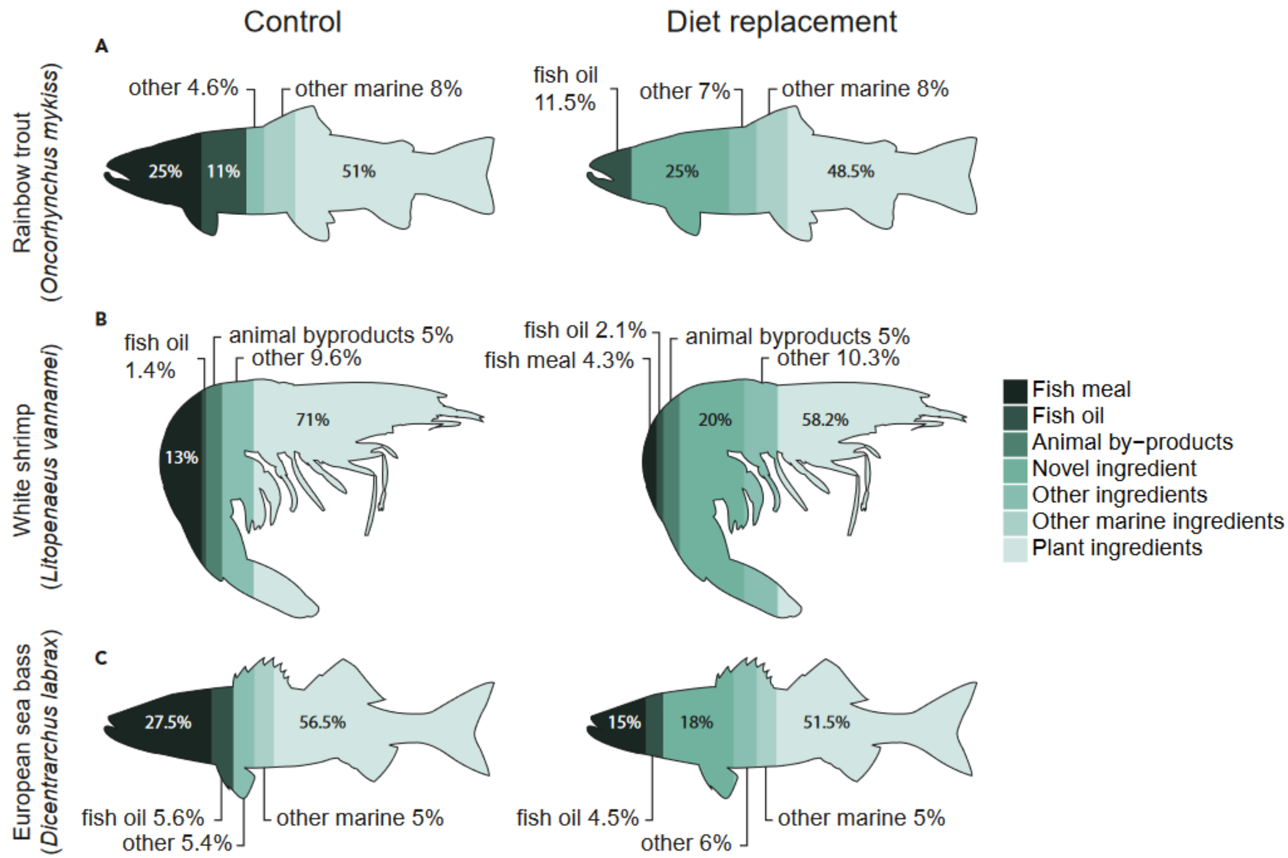
Case Studies of Fish Meal Replacement in the Diets for Fed-Aquaculture Species

The complete or partial replacement of fish meal using alternative protein sources demonstrated equivalent or higher growth in the animals than the control fish meal diets. Shading represents the proportion of dietary ingredients.

(A) Rainbow trout (Oncorhynchus mykiss) were fed a control diet with 25% fish meal or an experimental diet with 25% yellow mealworm protein meal.

(B) Pacific white shrimp (Litopenaeus vannamei) were fed a control diet with 13% fish meal or an experimental diet with 20% microbial biomass and 4.3% fishmeal.

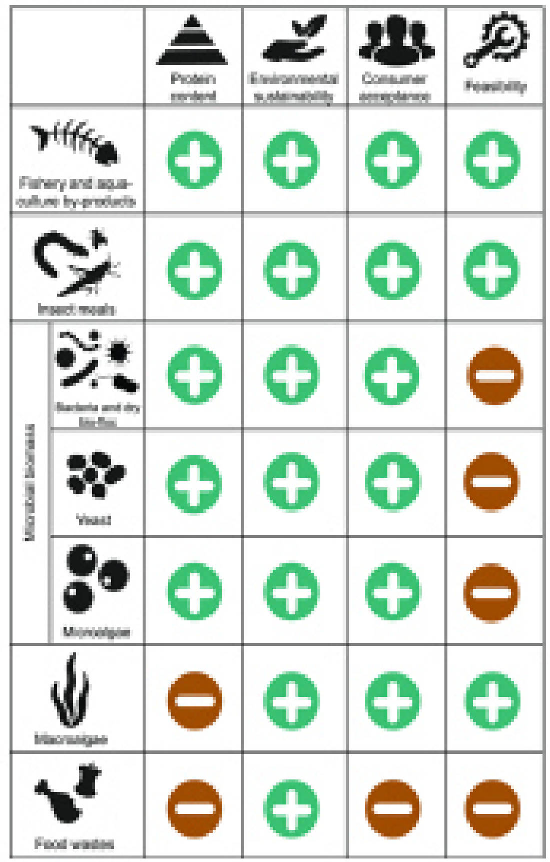
(C) European sea bass (Dicentrarchus labrax) were fed a control diet with 27.5% fish meal or an experimental diet with 18% freeze-dried microalgae and 15% fish meal.



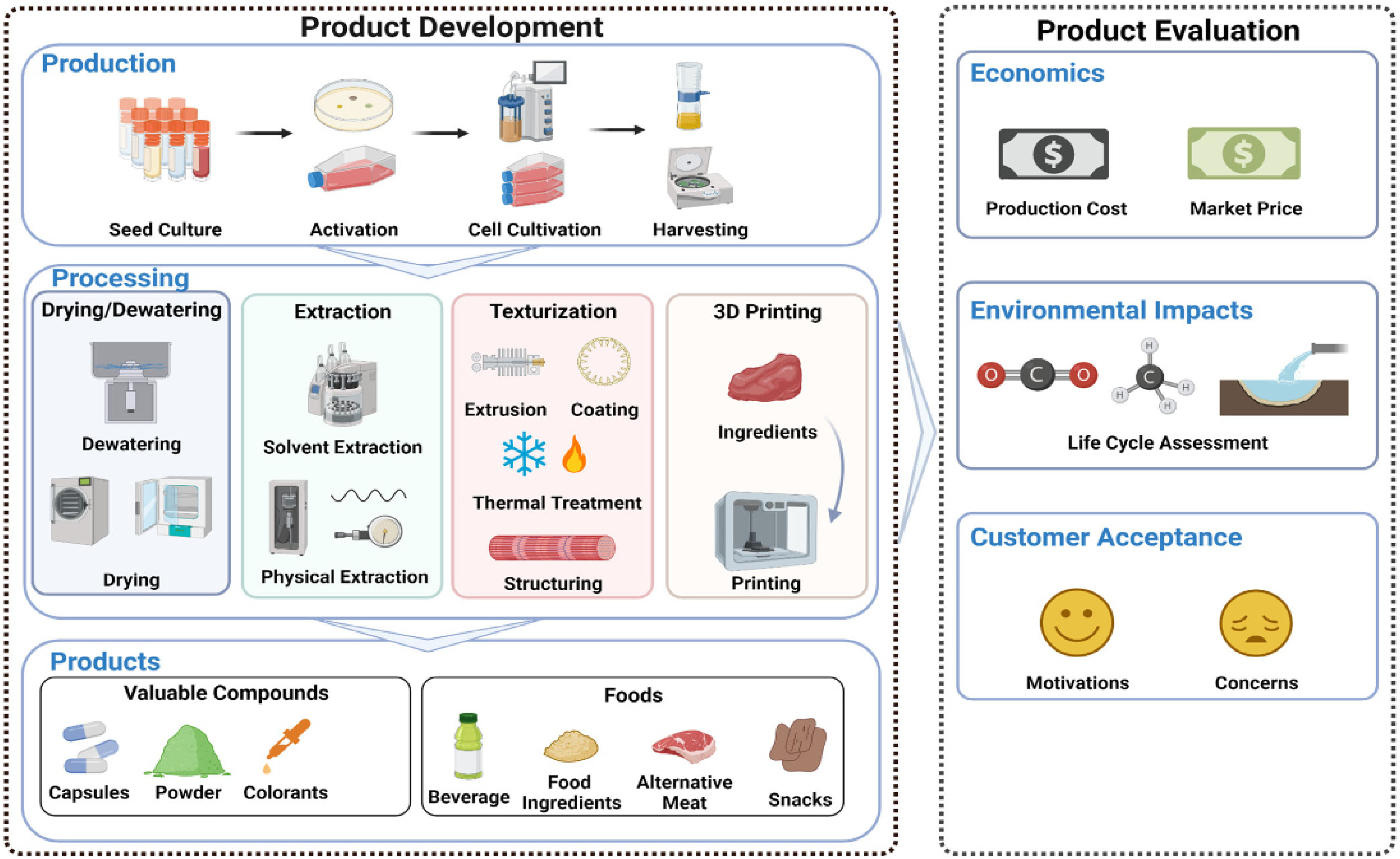
What are alternative proteins ?

Generally implies Vegetable proteins

Other alternative proteins



Do you want to make the “Beef” or sell the equipment?



Is *anyone* using renewable energy?

Good Food Institute

17 percent less CO_2 emissions than conventional chicken. Even more emissions savings

	Chicken		Pork		Beef	
Greenhouse gas emissions (in CO2-eq)	**Plant-based chicken**	**Cultivated chicken**	**Plant-based pork**	**Cultivated pork**	**Plant-based beef**	**Cultivated beef**
	86% Less than conventional chicken	**17%** Less than conventional chicken	**92%** Less than conventional pork	**52%** Less than conventional pork	**99%** Less than conventional beef from beef cattle	**92%** Less than conventional beef from beef cattle

Note: Cultivated meat emissions savings are based on cultivated meat production powered by renewable energy. For GHG comparison to conventional beef production, cultivated meat's global warming benefits are best viewed as short-term, as beef's impacts are driven primarily by methane. Plant-based quantities are for a wheat-based product.

Source: GFI & CE Delft lifecycle assessment 2021, Table 5.

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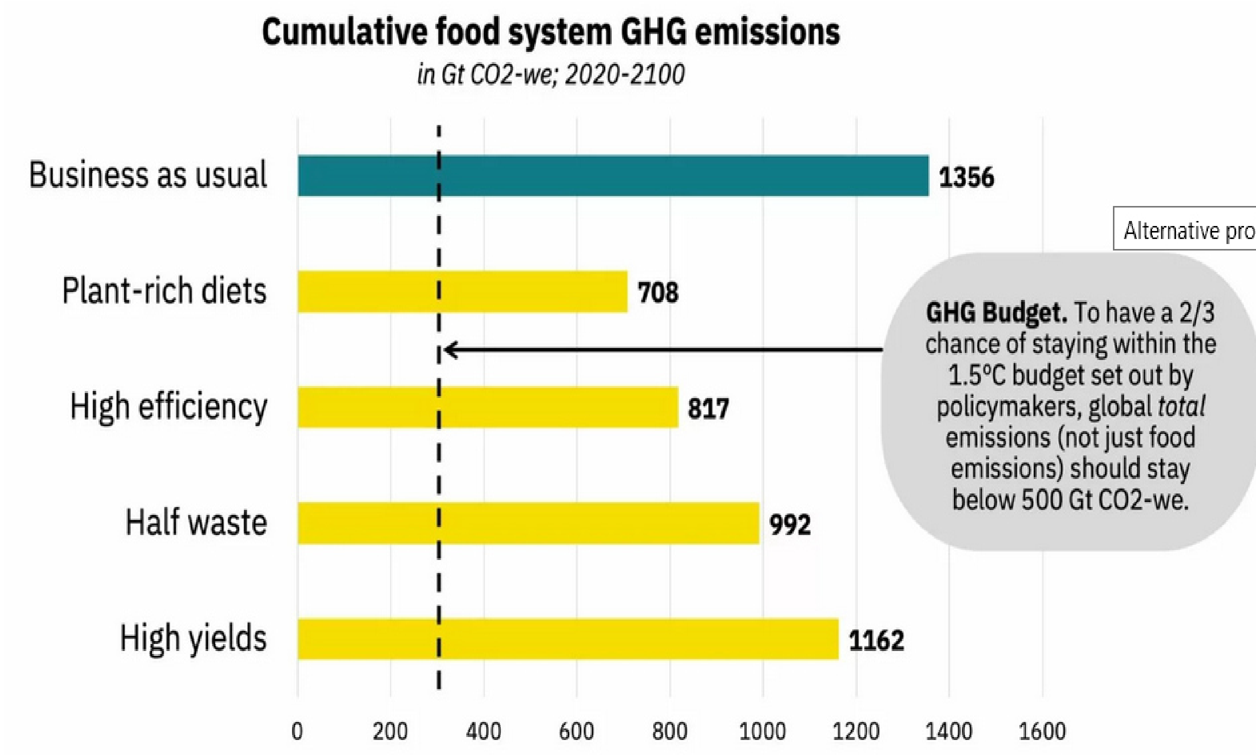
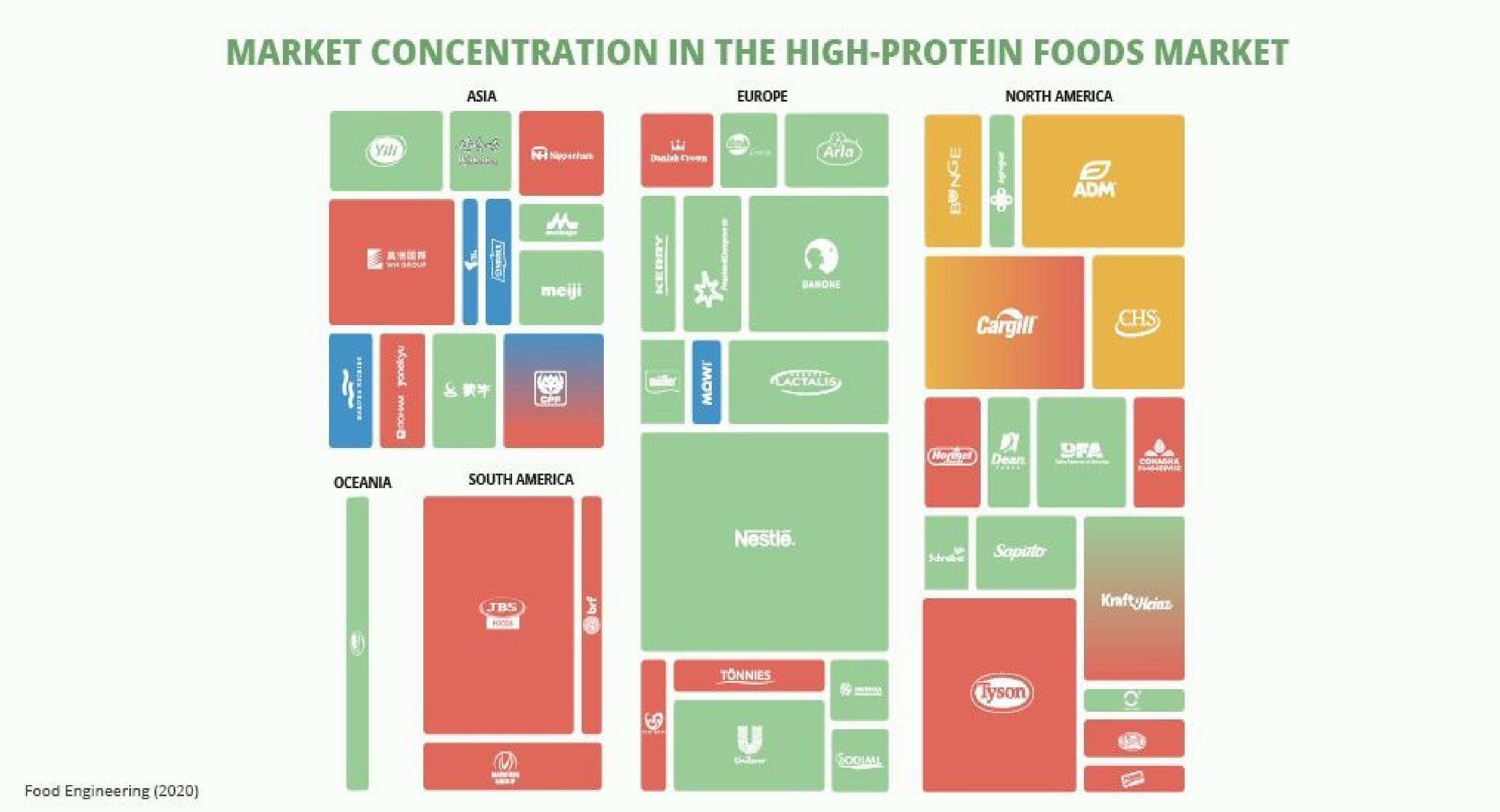
Business unusual



Source: Michael A. Clark, et al. Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. Science. 2020.

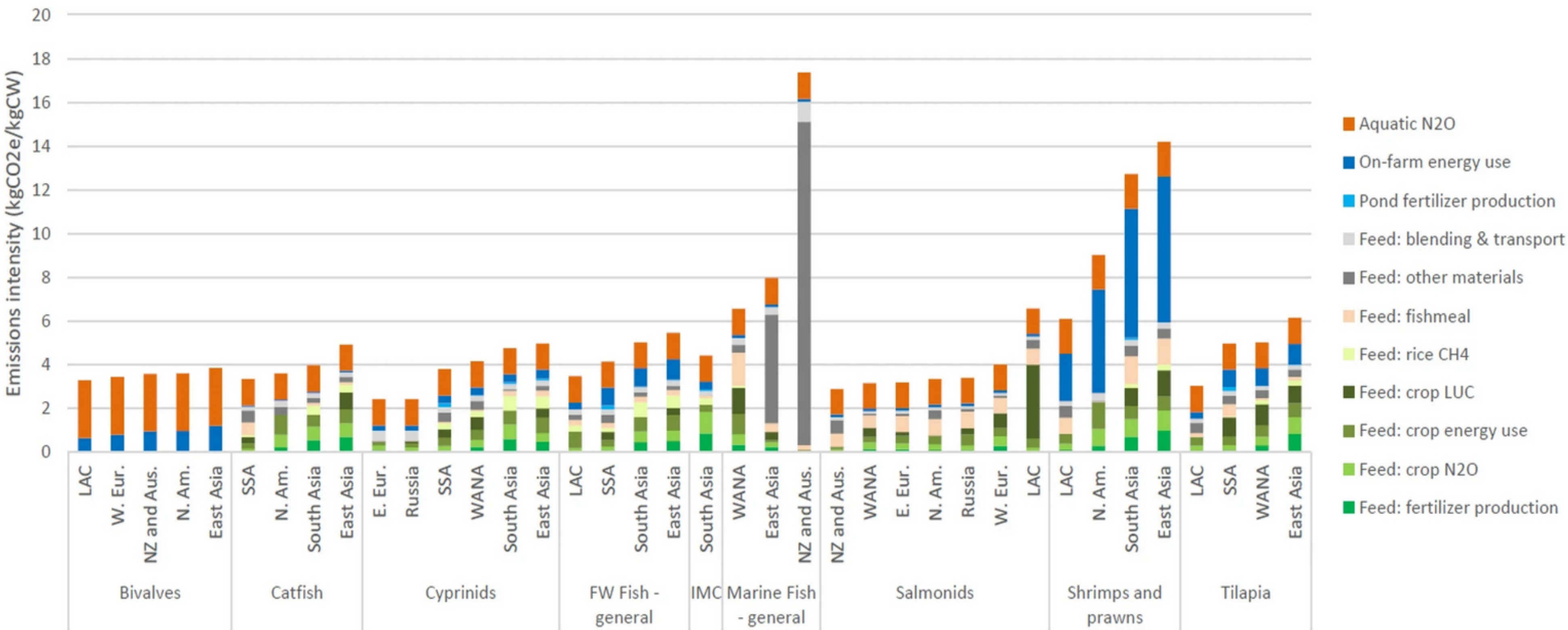
Where are investments made and where are opportunities ?



Food Engineering (2020)

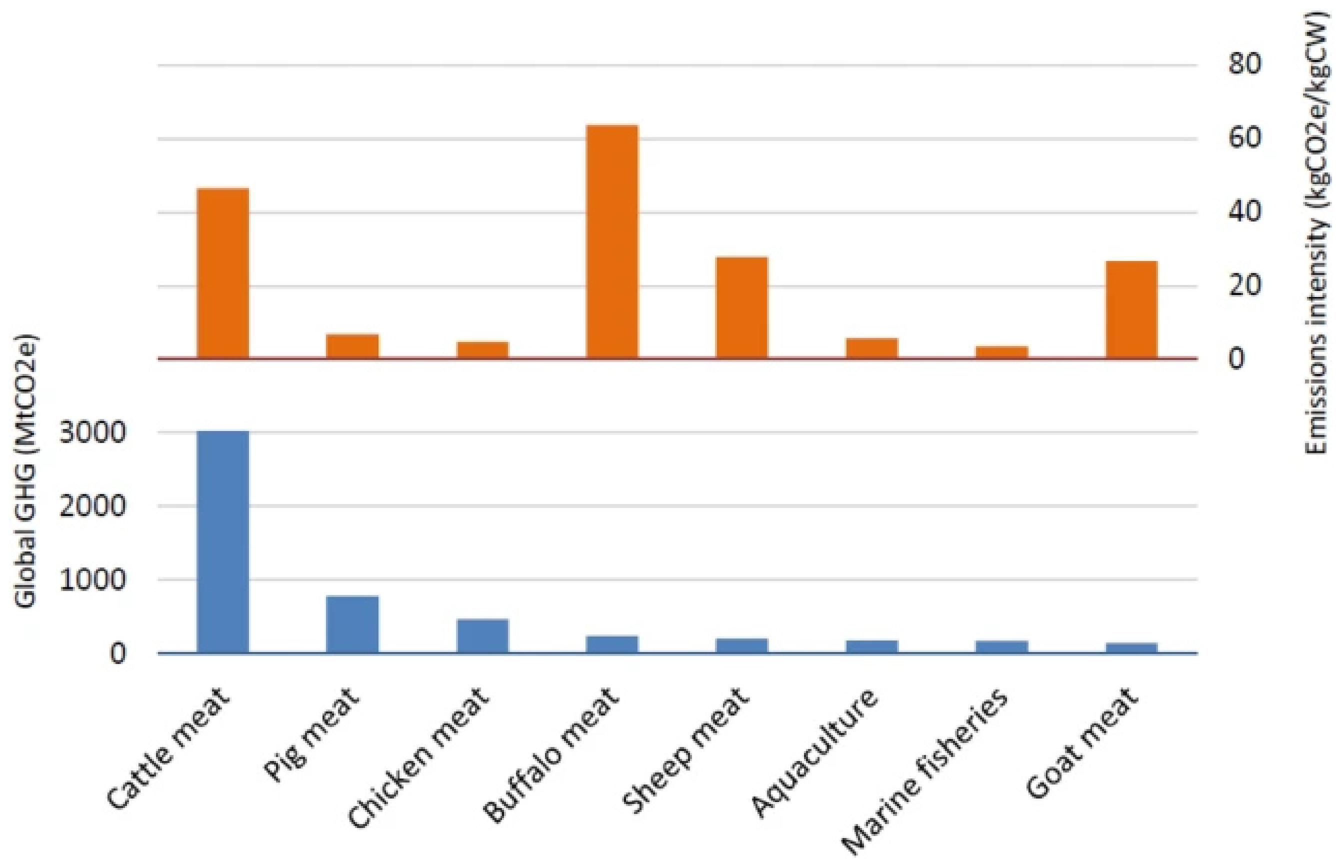
Making a difference – How and where? [cw-carcass weight]

From: Quantifying greenhouse gas emissions from global aquaculture



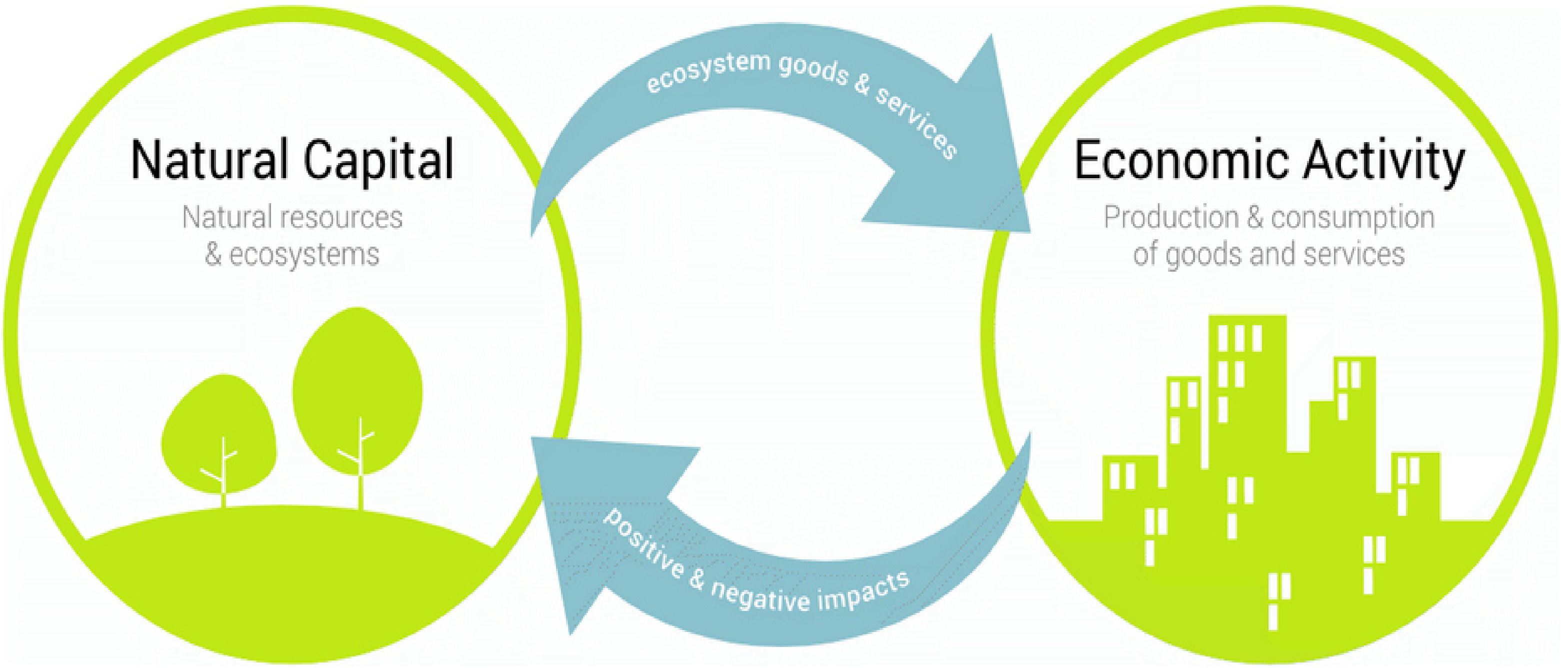
Emissions intensity of the main aquaculture groups, 2017. *Source* calculated in this study. *IMC* Indian Major Carps, *E. Eur*, Eastern Europe, *LAC* Latin America and the Caribbean, *N. Am.* North America, *NZ and Aus.* New Zealand and Australia, *SSA* Sub-Saharan Africa, *W. Eur.* Western Europe, *WANA* West Asia and North Africa.

The global emissions from aquaculture are lower than livestock because (a) there is a greater amount of livestock production (in 2010 fish and shellfish accounted for 6% of global protein intake, compared to 18% of protein from meat and (b) overall livestock has a higher emissions intensity than aquaculture.



4 Reasons why conserving biodiversity is more important to your business bottom line than you think

https://www.linkedin.com/pulse/4-reasons-why-conserving-biodiversity-more-important-your-jadot-phd/?trackingId=uep5rvRslsSy3sQKquKOrw%3D%3D

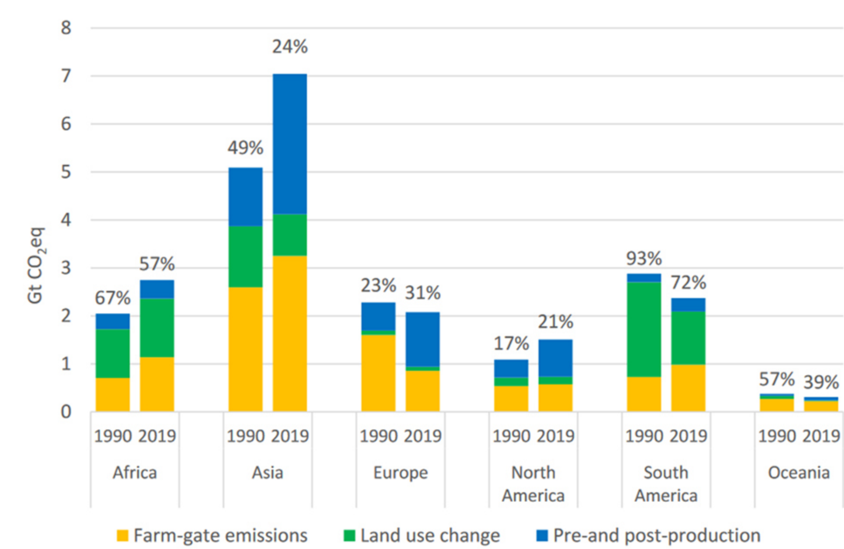


Mitigating risk – Oceans ⟷ Fish(eries)

- The oceans absorb a third of humanity's carbon dioxide emissions and 90 percent of the excess heat generated by increased greenhouse gas emissions; **it's the largest carbon sink on the planet**
- Fish play a far more important role as contributors of nutrients to marine ecosystems than previously thought. In a pair of articles, they show that fish contribute more nutrients to their local ecosystems than any other source -- enough to cause changes in the growth rates of the organisms at the base of the food web.
- Two-thirds of the world's fish stocks are either fished at their limit or over fished. The UN Food and Agriculture Organization (FAO) has estimated that 70 percent of the fish population is fully used, overused or in crisis.

A role for renewable marine energy and alternative protein?

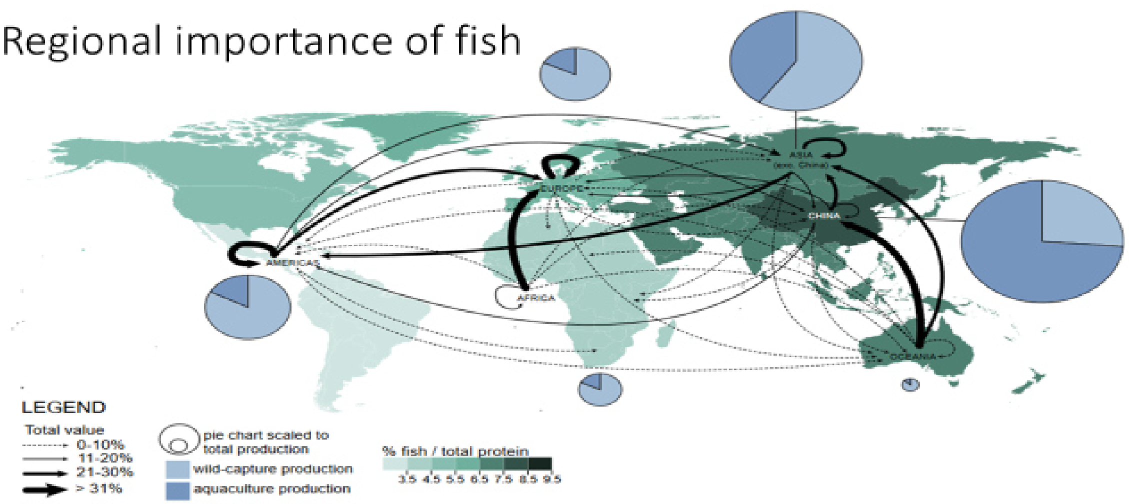
Figure 6: Agri-food systems emissions by region and life-cycle stage



Note: The percentages indicate the share of agri-food systems in the total emissions of the region.

Source: FAO, 2021.

Regional importance of fish



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Impact points

Alternative feeds

- Black soldier fly larvae – protein and fats
- Crickets – Protein and fats
- Mollusk

Alternative Proteins	**Electricity requirements**
Mycelium "fish"	LOW
Plant based "fish"	LOW
Hybrid "fish" – mollusk-plant – insect protein	LOW
Cell culture	HIGH (to Very High)

Marine renewable energy

- floatovoltic solar panel arrays
- Wind powered aeration
- Wind turbines
- Demersal tide turbines

Alternative feeds and/or foods

- Black soldier fly larvae & Crickets - protein and fats – total or partial replacement of fish in diet for mariculture fish
- Can be a standalone protein and fat source for human consumption

- Fed –
- food waste converter, or organic (non-food waste) if for human consumption
- Low spatial requirements
- Suitable for volume renewable energy

- Mollusk - total or partial replacement of fish in diet for mariculture fish
- Protein replacement in Pet food
- Standalone "seafood

- Unfed – so no feed requirement
- Carbon sequestration (shell)
- Coastal habitat protection

Alternative Proteins as alternative to fish

- Mycelium “fish”
- Plant protein based “fish”
- Hybrid “fish” – mollusk-plant – insect protein
- Cell culture

Low spatial footprint

Urban/peri-urban friendly

Collapsing the supply chain

Marine renewable energy compatible if in appropriate location

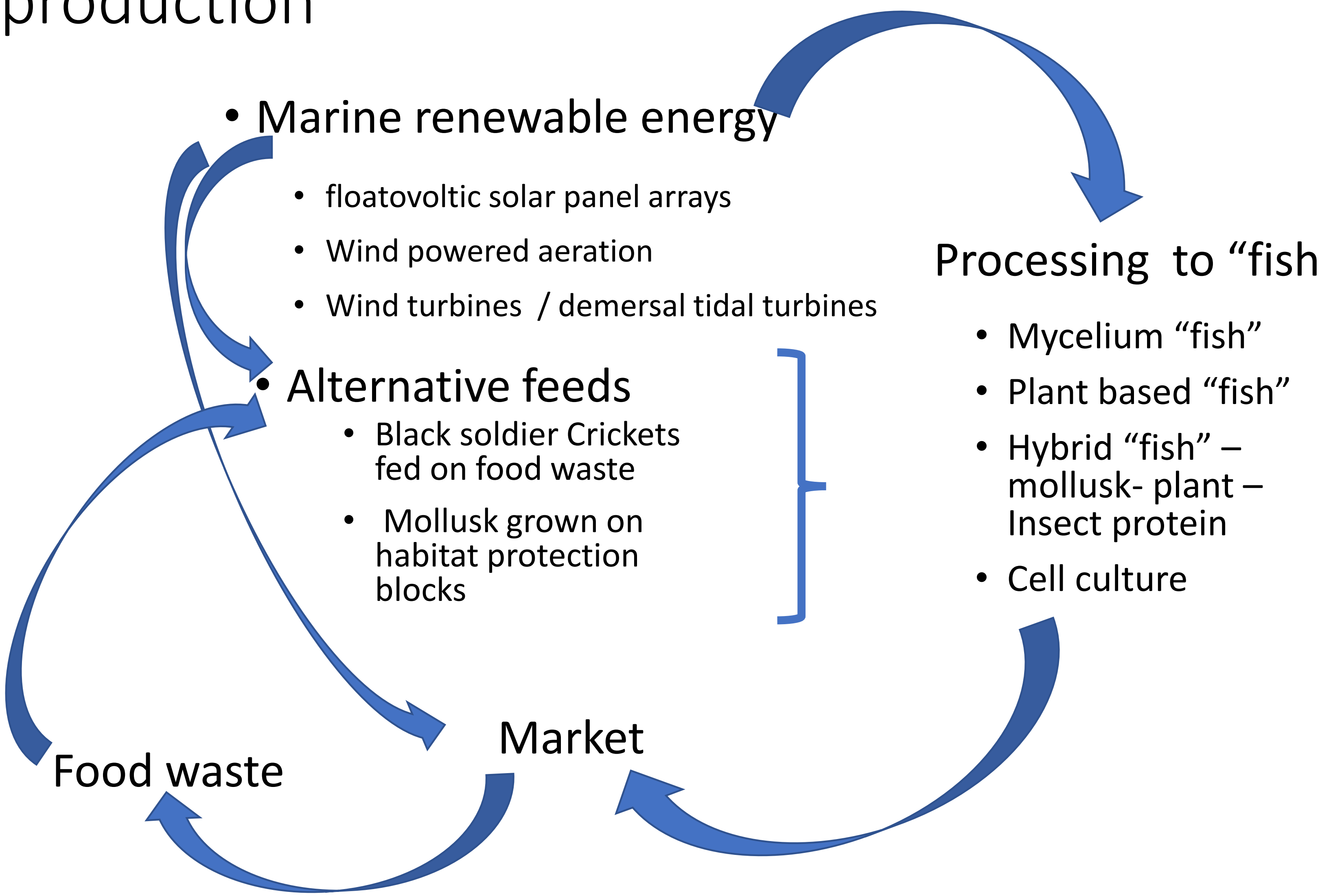
Marine Renewable Energy

Fossil fuel generated electricity costs up to 17 cents per kilowatt-hour, and solar energy is between 3 and 6 cents. https://www.renewableenergymagazine.com/jane-marsh/how-aquaculture-is-taking-advantage-of-renewable-20210629

a floatovoltic solar and/or wind panels

- Can shade and cool down area
- Impervious to sea level rise
- Short transmission lengths
- Direct on site use and potential surplus
- Ecological leverage if anchored on Habitat enhancement blocks (from Cambodia)

Circular production



Life cycle Assessment midpoints, but…

"However, in the case of cultivated meat, most of the energy consumption was estimated to be used for cultivation with only 6% being attributed to frying by the consumer. In contrast, for soymeal, the energy used for frying represented almost 60%of the total energy use in the whole life cycle."

Food category	Energy demand (MJ)	Global warming (kg $Co_{2,eq}$)	Water consumption (m^3)	Aquatic eutrophication (g $PO_{4,eq}$)
In vitro animal cell	33	2.2	0.5	—
	106	7.5	—	7.9
	373	24.6	—	—
Beef	79	30.5	—	214.0
	—	30.6	0.9	15.1
	—	40.1	0.3	39.1
	233	61.5	0.8	—
Filamentous fungi	—	2.8	0.3	4.7
	77	6.2	—	—
Insect	40	3.0	—	—
Microalgae	217	14.7	0.3	—
	1,516	96.1	3.9	—
	4,181	245.1	3.3	—
	2,200	300.0	18.1	—
Plant cell culture	—	45	1.7	52.1
	—	88	3.4	101.2
Plant—conventional	5.4	0.7	0.04	—
	37	2.7	—	—
	—	3.5	0.11	1.3
	49	4.0	—	—
	92	6.0	0.03	—
Pork	16	4.1	—	26.2
	—	7.2	0.04	1.9

Alternative Feedstock	Electricity requirement production	Suitable for RMP	Alternative Protein type	Electricity requirement Processing	Suitable for RMP
Black soldier fly larvae –> protein and fats (circular) As feedstock or standalone product depend on food source (food waste or non-food waste)	low	Yes, but location dependent	Protein shake Hybrid "fish" – mollusk-plant – insect protein	low	Yes, but location dependent
Crickets –> Protein and fats (circular) As feedstock or standalone product - usually food stock is non-food waste, post processing scraps	low	Yes, but location dependent	Hybrid "fish" – mollusk-plant – insect protein Feedstock for livestock/fish	low	Yes, but location dependent
Fungal -> Protein (circular) Needs to be processed - can grow on agri/forestry/brewing waste	Medium	Yes, but location dependent	Mycelium "beef/pork/chicken/ fish" protein	high	Yes, but location dependent
Micro-Algae -> Protein Needs to be processed – various environments	VERY HIGH	Yes, but location dependent	Hybrid "fish" plant – micro-algae protein	HIGH	Yes, but location dependent
Mollusk -> Protein Non-fed aquaculture, can be integrated into marine rehabilitation	Very low	Yes (ocean cultivation)	Hybrid "fish" – mollusk-plant – insect protein Seafood Petfood alternative protein	low	Yes, but location dependent

Sustainable marine electricity generation – Best impact for alternative protein value chain

- The closest to the "production" aspects
- The most integrated in circular value chains
- The lowest cost sustainable marine electricity generation
- The least transmission distance
- Incorporated with the highest "value add" potential products

→ Integrating all the above criteria will provide the best sustainably powered products with the lowest carbon footprint

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