Upscaling Seaweed Aquaculture:
Using a Balanced Scorecard to Facilitate Project Financing

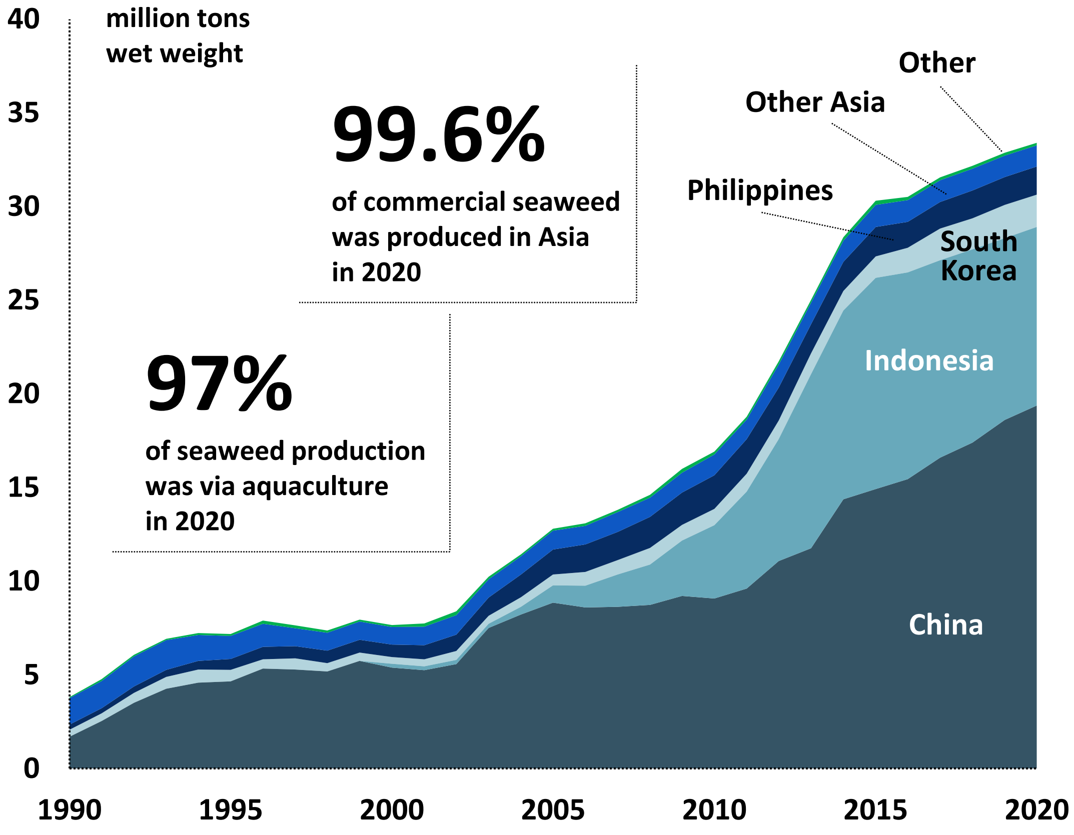
Innovative financial solutions for nature

April 2024

The seaweed farming industry

With wild seaweed resources reaching their limits for sustainable harvesting, future growth is dependent on aquaculture

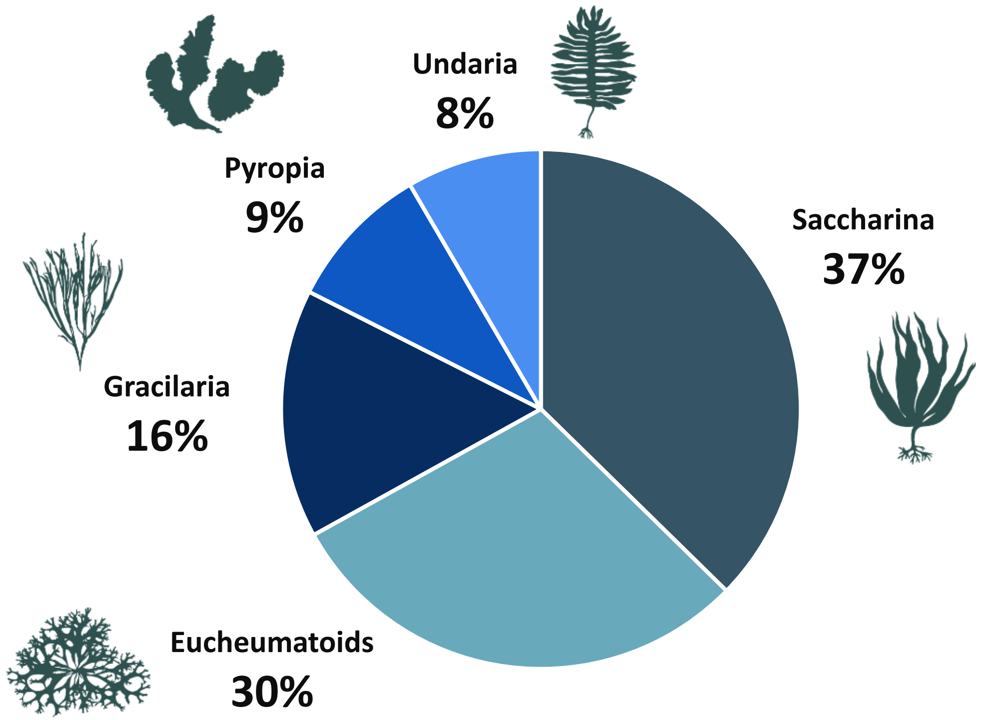
Global commercial seaweed production volumes



Sources: FAO Fisheries and Aquaculture; Hatch Innovation Services; Seneca Impact Advisors

Global seaweed production volumes by major species in 2020

Only ~0.1% of more than 12,000 seaweed species are commercially farmed



Assessing the viability of new seaweed projects

A balanced scorecard based on the following factors:

Project viability = Climate +/− Environmental +/− Socioeconomic +/− Financial

Project viability

There has been increasing recognition by the public and private sectors of seaweed aquaculture's potential positive impacts on climate, nature and livelihoods.

Yet, the industry still faces significant challenges in scientific and technological advancements, downstream processing costs, market adoption, and legal and regulatory uncertainties.

Against this backdrop, obtaining project financing has often proved strenuous. A robust framework to evaluate business cases may provide a useful starting point for discussion.

Climate

While the carbon storage capacity of farmed seaweed biomass is limited to the cultivation period, long-term sequestration may be achieved as dissolved and particulate organic carbon reaches oceanic carbon sinks. Such potential may be highly scale- and location-dependent.

Post-harvest, commercial use pathways determine the processed product's lifecycle climate impacts. Applications range from biofuels, biofertilizers and livestock feed, to food ingredients and supplements and bioplastics, such as those used in packaging and construction.

Environmental

Seaweed farms may promote biodiversity, and the positive impacts are most pronounced when they supersede less complex habitats. They may also improve water quality by absorbing pollutants in coastal waters, and dampen surface waves during storm surges.

However, a seaweed farm's environmental impacts are location-specific. Seaweed cultivation may inadvertently lead to habitat competition, a spillover of pathogens and invasive species, genetic pollution, oxygen depletion, megafauna entanglement, and other adverse impacts.

Socioeconomic

Seaweed farming requires no arable land, freshwater or fertilizers, and is therefore a viable source of income for many coastal communities. Seaweed's nutritional value also enhances global food security, while promoting more vibrant and gender-equal communities.

That said, the industry's economics may favor downstream processors at the expense of independent farmers. Some seaweed-based products may pose health hazards in their processing and consumption due to improper storage or insufficient quality control. Spatial use conflicts may also be a concern.

Financial

Technology and scalability are two common drivers of the financial viability of seaweed commercialization projects.

(1) Technology drives the development of emerging applications. Product quality and safety and costs of adoption are key factors that determine a project's risk-reward profile.

(2) Scalability enables project owners to recover the substantial research and development costs that may be incurred in the commercialization process. The potential to upscale is critical to making seaweed a long-term nature-based solution.

Sources: *Seaweed Farming: Assessment on the Potential of Sustainable Upscaling for Climate, Communities and the Planet*, UNEP, 2023; Seneca Impact Advisors

Measuring emissions impacts through the value chain

13 CLIMATE ACTION

From farm to end product:

Climate | Environmental | Socioeconomic | Financial

1 Cultivation → 2 Harvesting → 3 Processing → 4 Distribution

Current major use cases:

A Human consumption

B Aquaculture feed

C Hydrocolloids

Gelling, stabilizing and thickening agent used in foods and beverages, cosmetics, pharmaceuticals etc

Source: Seneca Impact Advisors

Environmental impacts may be highly location-dependent

14 LIFE BELOW WATER

Project-specific assessment:

Climate | **Environmental** | Socioeconomic | Financial

Potential *positive* impacts:

Marine biodiversity. Seaweed farming has the potential to enhance biodiversity, especially when farms supersede a less complex habitat (e.g. sandy bottom)

Water quality. Seaweed cultivation may mitigate ocean acidification, deoxygenation, and coastal eutrophication due to the absorption of CO_2, production of oxygen, and removal of nitrogen and phosphorus

Coastal protection. Seaweed farms may dampen coastal waves, providing an adaptation benefit. But the impacts may depend on the farming method, species farmed, and orientation of the farm

Potential *negative* impacts:

Habitat competition. Seaweed farms may compete with wild habitats for sunlight and nutrients

Spillover of pathogens and invasive species. The transfer of non-native species may pose material risks

Genetic pollution. Gene flow from farmed to wild seaweed populations may lead to maladaptation

Organic matter over-disposition. A decrease in biodiversity may result from oxygen depletion etc.

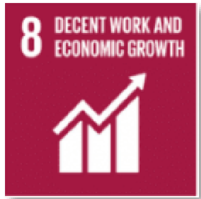
Other risks include marine megafauna (e.g. sea turtles) entanglement, pollution from equipment etc.

Sources: *Seaweed Farming: Assessment on the Potential of Sustainable Upscaling for Climate, Communities and the Planet*, UNEP, 2023; Seneca Impact Advisors

Socioeconomic impacts are often inadequately considered

Project-specific assessment:

Climate | Environmental | **Socioeconomic** | Financial



Potential *positive* impacts:

Seaweed farming has proved to be a **viable income source for coastal communities** in developing countries such as India, Indonesia, Malaysia, the Philippines, Kenya, and Tanzania

Seaweed is a **high-quality food source** that is rich is nutrients (e.g. omega-3, calcium, iodine). Seaweed farms also benefit communities indirectly by providing cash income that **increases food security**

Seaweed farming may contribute to **gender equality** by providing employment opportunities. Other cultural benefits may include **improved education access** and creation of **natural heritage**

Potential *negative* impacts:

Price fluctuations, **falling productivity** caused by crop diseases and pests, and **lack of bargaining power** vis-à-vis monopolistic buyers may contribute to lower income for seaweed farmers

Improper storage of unprocessed seaweed may expose households to **toxic vapors** from hydrogen peroxide and halogenated compounds. **Heavy metals** may be a concern if waters are contaminated

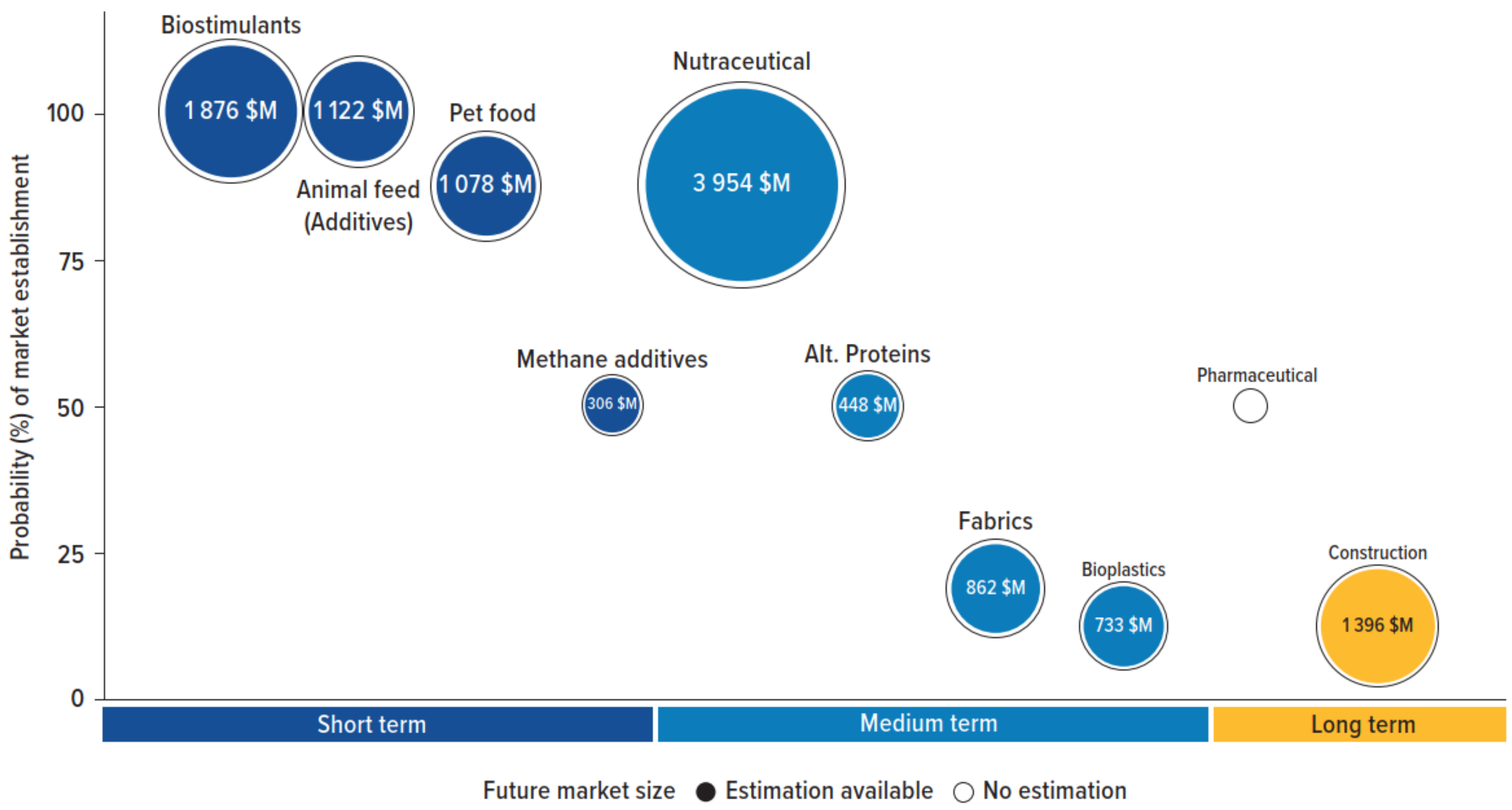
Spatial use conflicts are an important risk factor, and local resistance to seaweed farming due to potential adverse **impacts on tourism**, **recreational space**, and **natural landscape** may offset potential benefits

Sources: *Seaweed Farming: Assessment on the Potential of Sustainable Upscaling for Climate, Communities and the Planet*, UNEP, 2023; Seneca Impact Advisors

Seaweed's emerging applications

2030 market potential estimates by a World Bank study

Climate | Environmental | Socioeconomic | **Financial**



Sources: *Global Seaweed: New and Emerging Markets Report*, World Bank, 2023; Seneca Impact Advisors

KEY FINDINGS OF THE STUDY

1. **Biostimulants**, **animal feed**, **pet foods**, and **methane-reducing additives** are the most promising short-term markets
2. **Nutritional supplements**, **alternative proteins**, **bioplastics**, and **fabrics** offer medium-term opportunities
3. **Pharmaceutical** and **construction** represent longer-term, more uncertain growth areas
4. Farmed **seaweed availability**, **pricing** and **regulations** are key hurdles
5. **"Sustainability premiums"** will drive growth

Our baseline ranking of common seaweed applications

The table below focuses on potential *post-harvest* impacts for the *typical* project

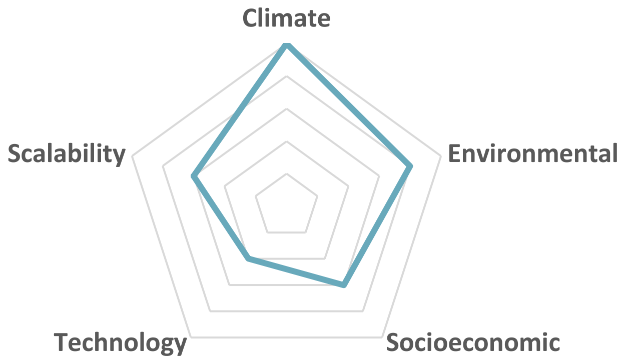
				Financial	
	Climate	Environmental	Socioeconomic	Technology	Scalability
Human consumption					
• Direct food source	●●●●○	●●●●○	●●●●●	●●●●●	●●●●●
• Additives	●●●○○	●●●○○	●●●●○	●●●●○	●●●●○
• Alternative proteins	●●●●○	●●●●○	●●●○○	●●●○○	●●●○○
Feedstock					
• Aquaculture	●●●●○	●●●●○	●●●●○	●●●●○	●●●●○
• Livestock	●●●●○	●●●●○	●●●○○	●●●○○	●●●●○
• Methane reduction	●●●●●	●●●●○	●●●○○	●●○○○	●●●○○
Biostimulants	●●●●○	●●●●●	●●●●○	●●●●○	●●●●○
Cosmetics	●●○○○	●●●○○	●●●○○	●●○○○	●●○○○
Bioplastics	●●●●○	●●●●○	●●●●○	●●○○○	●●○○○
Biofuels	●●●●●	●●●●○	●●●○○	●○○○○	●○○○○
Deep ocean sinking	●●●○○	●●●○○	●●○○○	●○○○○	●○○○○

Source: Seneca Impact Advisors

Application example 1: Feedstock | Methane reduction

Balanced scorecard – *Post-harvest assessment for the typical project*:

Project viability



Climate factors [1]

- The livestock sector accounts for 14.5% of global anthropogenic GHG emissions
- On an experimental scale, adding as little as 2% organic matter of the seaweed *Asparagopsis taxiformis* in livestock feed has been shown to reduce methane production in steers by 99%
- There have been similar lab results for sheep, and dairy and beef cattle

Environmental factors

- Reducing the use of land-based fertilizers (e.g. corn, soybean meal) could preserve land resources, and avoid potential adverse environmental impacts in the process
- However, the overall positive impacts may be limited by the relatively small quantities of seaweed-based feed additives required

Socioeconomic factors [1]

- While no notable adverse effects on food safety and nutritional value have been observed in lab settings, potential exposures to heavy metals in seaweed additives' farming process are a significant concern
- Cattle price inflation from the prohibitive costs of seaweed-based livestock feed additives could offset incremental benefits from the employment opportunities created

Technology factors [1, 2]

- It is estimated that the cost of seaweed farming would have to decrease by 77% for seaweed to be competitive vs corn, the likely alternative to be replaced
- The barriers to entry appear extremely high, as an important intellectual property is held by an Australian company, which has licensing arrangements with a small number of feed additive manufacturers

Scalability factors [3]

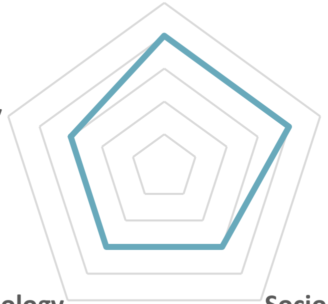
- A World Bank study estimates that this product segment will grow from $47 million in 2022 to over $300 million in 2030, a 57% CAGR
- Seaweed availability is a major bottleneck, as the cultivation of *Asparagopsis* is relatively concentrated and related farming techniques are not widely accessible
- Growth may also be hampered by regulatory hurdles in many jurisdictions

Sources: (1) *Seaweed Farming: Assessment on the Potential of Sustainable Upscaling for Climate, Communities and the Planet*, UNEP, 2023; (2) Seaweed Product Analysis, Environmental Defense Fund, 2023; (3) *Global Seaweed: New and Emerging Markets Report*, World Bank, 2023; Seneca Impact Advisors

Application example 2: Alternative proteins

Balanced scorecard – *Post-harvest assessment for the typical project*:

Project viability



Climate factors [1]

- Proteins extracted from seaweeds could replace more carbon-intensive land-based meat, egg, soy, and milk proteins
- It has been estimated that the production of seaweed proteins yields a net savings of 12kg of CO2e per kg
- However, widespread adoption will be required to generate meaningful climate benefits

Environmental factors

- Reducing land-based protein production, especially beef and milk, could preserve land resources, and avoid potential adverse environmental impacts in the process
- However, the overall positive impacts may be limited by the relatively small addressable market in the foreseeable future

Socioeconomic factors [1]

- While no notable adverse effects on food safety and nutritional value have been observed in lab settings, potential exposures to heavy metals in the seaweed farming process are a significant concern
- The switch from land-based protein sources may lead to conflicts with stakeholders with vested interests

Technology factors [1]

- As a single-stream product, seaweed protein is unlikely to be cost competitive vs soy protein
- In its current form, the available technology may constrain the product's long-term viability
- Alternative proteins as a commercial pathway may still be feasible in a seaweed biorefinery system with limited or zero waste and multiple higher-value outputs

Scalability factors [2]

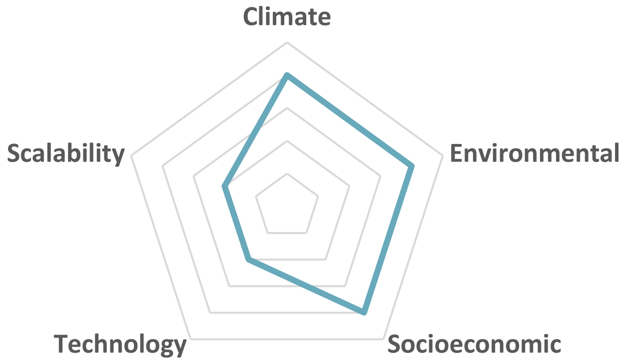
- The global alternative protein market is estimated to be around $10 billion in 2022 and projected to grow 36% per year from 2022 to 2030
- A World Bank study estimates seaweed-based alternative protein's market potential to be close to $450 million in 2030
- Price competition from cheaper biomass options with higher protein concentrations is a limiting factor

Sources: (1) *Seaweed Farming: Assessment on the Potential of Sustainable Upscaling for Climate, Communities and the Planet*, UNEP, 2023; (2) *Global Seaweed: New and Emerging Markets Report*, World Bank, 2023; Seneca Impact Advisors

Application example 3: Bioplastics

Balanced scorecard – *Post-harvest assessment for the typical project*:

Project viability



Climate factors [1]

- Bioplastics use considerably less energy in their production and have a much lighter carbon footprint. Main applications include food packaging, edible containers, and drinking straws
- However, single-use bioplastics that are highly biodegradable may have shorter lifespans. Cost considerations may also limit the climate benefits realized

Environmental factors

- Seaweed-based bioplastics are substantially more environmentally-friendly compared to conventional options. Their adoption could alleviate the strain of municipal solid wastes on land resources
- That said, their use may potentially lead to adverse effects such as eutrophication and acidification, offsetting some of their benefits

Socioeconomic factors [1]

- The use of seaweed as a plastics alternative presents fewer health concerns than applications in direct food consumption
- If cost hurdles and durability concerns are overcome, consumer resistance should not be a constraint
- However, there may be pushbacks from conventional plastics producers and their employees if adoption becomes more widespread

Technology factors [2]

- While significant investments have been made in seaweed bioplastics' research and development, it may take another five to ten years before the technology can become price competitive with conventional options
- If seaweed bioplastics cannot be integrated into existing plastics supply chains, their applications may remain niche

Scalability factors [2]

- The global bioplastics market is estimated to be $11.5 billion in 2022 and projected to grow 20% per year from 2022 to 2030
- A World Bank study estimates seaweed-based bioplastics' market potential to be over $730 million in 2030
- Lower-cost bioplastics competitors are a major growth impediment

Sources: (1) *Seaweed Farming: Assessment on the Potential of Sustainable Upscaling for Climate, Communities and the Planet*, UNEP, 2023; (2) *Global Seaweed: New and Emerging Markets Report*, World Bank, 2023; Seneca Impact Advisors

About Seneca Impact Advisors

Seneca Impact Advisors is a specialist advisory firm based in Hong Kong with extensive experience and networks in the Asia-Pacific region. It specialises in developing innovative financial solutions for scalable and commercially viable nature and climate positive projects. Seneca's aim is to mobilise private-sector capital to protect and restore nature.

Seneca was formed to bridge the financing gap between traditional conservation and private investment capital seeking returns. There is a growing amount of capital with a willingness to invest in nature-based projects with highly impactful and measurable outcomes. However, there have been few scalable and commercially viable projects to attract investment capital. By working with leading NGOs, environmentally passionate entrepreneurs, and ESG-concerned corporates, the team at Seneca has been successfully originating and developing projects to meet the demand from funders. With enhanced public awareness about the climate crisis, biodiversity loss and resource depletion there is a significant amount of capital seeking nature and climate positive investments.

Structuring bankable projects requires knowledge of both conservation and investments. The team at Seneca combines its passion for the natural world with financial and technical expertise to help build commercially viable projects which contribute positively to the environment and society.

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