A Strategic Approach to Sustainable Shrimp Production in Indonesia

THE CASE FOR IMPROVED ECONOMICS AND SUSTAINABILITY

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A STRATEGIC APPROACH TO SUSTAINABLE SHRIMP PRODUCTION IN INDONESIA

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EXECUTIVE SUMMARY

INDONESIA HAS ESTABLISHED ITSELF as one of the world's top shrimp producers, but low-price competitors, tightening regulations, and environmental risks are threatening its strong position. As outbreaks of disease were slowing production in Thailand and Vietnam over the past two decades, Indonesia strengthened its position to become the third-largest shrimp producer globally. The country's farmed-shrimp industry is expected to grow 8% per year through 2022, surpassing global growth rates of 5.6%.

Indonesia has a strong competitive position, with high national and international demand and an optimistic overall market forecast, but three developments are threatening the industry's profitability.

- **Global Competition.** India has flooded the market with low-price shrimp, ramping up the competition, stealing market share, and squeezing profit margins.

- **Strict Traceability Standards.** In 2018, the US Congress extended coverage of the Seafood Import Monitoring Program to cover shrimp, requiring stricter reporting and record keeping for shrimp imports. Given that the US is a major importer of Indonesian shrimp, there's pressure for Indonesia to provide traceability across its supply chain.

- **Natural Disasters.** Tsunamis, floods, and diseases continue to affect shrimp production and disrupt the shrimp supply chain. In 2018, for example, a tsunami that hit Banten province lowered national shrimp production by approximately 10% over a three- to four-month period. Decades of mangrove deforestation make Indonesia increasingly vulnerable to these natural disasters.

Indonesian shrimp producers can benefit from immediate improvements, but there is a much bigger opportunity at hand.

- To increase profitability and resource efficiency, the Indonesian shrimp industry can make immediate changes in three areas: feed, water treatment, and renewable energy.
- However, immediate changes should be viewed as only the first step toward a much more transformative approach to shrimp farming.

To maintain its position as a leading exporter of shrimp to the US, Indonesia needs to offer fully traceable products.

- Regulators and retailers, pushed by consumer demands and reputational concerns, are becoming increasingly concerned about food safety and sustainability.
- With its high dependence on middlemen, Indonesian shrimp producers are not well positioned to fulfill major importers' ever stricter traceability requirements.
- By offering a fully traceable product, Indonesia can respond to changing consumer demands, stay ahead of tightening US import standards, and establish a leading position in both the mass market and the sustainable shrimp market.
- While Indonesia has strong domestic demand for shrimp and is, therefore, less dependent on import regulations, traceability will eventually become the new norm in global shrimp supply chains.
- While a few large players in Indonesia are beginning to focus on certification, sustainability, and traceability, there's still much work to be done.

To protect farms against outbreaks of disease and environmental risks, a shift to closed-loop—and, ultimately, indoor—systems can be a game changer.

- Closed-loop systems, such as recirculating aquaculture systems, represent a significant opportunity to increase efficiency and output on L. vannamei farms while reducing the risk of disease and pressure on the environment.
- Indonesia has already begun to establish closed-loop farming methods through its "supra intensif Indonesia" farming system. While closed-loop farming systems will likely become more common, the ponds are mostly outdoors and, therefore, still vulnerable to disease, contamination, and environmental hazards.
- To protect shrimp ponds from environmental hazards, stabilize water quality, and reduce disease risk, companies can shift to fully closed indoor systems. This production method allows farm operators to increase stocking densities and offer a fully traceable product with low environmental impact.

- As major importers continue to institute stricter regulations on seafood imports, the demand for sustainable shrimp will only grow. By shifting to closed-loop—or even indoor—farming, Indonesian shrimp producers can meet this demand and position themselves at the forefront of this movement.

Fast-moving competitors are threatening to overtake Indonesia in the mass market, and major importers are demanding traceability. To maintain a strong position and strengthen ties with the US market, Indonesian shrimp producers must make a rapid transition to traceability and sustainability.

MARKET FORCES ARE RESHAPING THE GLOBAL SHRIMP INDUSTRY

Farmed shrimp is among the fastest-growing food products in the world. In less than two decades, global production has more than tripled from about 1.2 million tons in 2000 to some 4.2 million tons in 2017. As the global population and consumer affluence grow, farm-raised shrimp is becoming an increasingly important source of protein around the world. In the US alone, the average annual consumption of shrimp has risen to four pounds per capita.

In 2017, the global market for shrimp, including farm-raised and wild-caught shrimp, was valued at around $40 billion. The dominant species of farmed shrimp, Litopenaeus vannamei (L. vannamei), or whiteleg shrimp, accounts for about $14 billion. Shrimp production worldwide is expected to grow by more than 5.6% annually, with the greatest demand coming from China and the US.

The overall industry is growing at a record pace, but not all shrimp producers are thriving.

In the early years of this century, China, Thailand, and Vietnam were leaders in the shrimp farming sector—with Indonesia in fourth place. But the competitive landscape has shifted. Outbreaks of disease and rising labor costs have threatened this once-thriving industry, and India, which has dramatically increased its share in the global shrimp market by producing large volumes at low prices, has become the second-largest shrimp producer worldwide after China—accounting for 14% of global shrimp production with 600,000 tons produced annually. Indonesia was also able to strengthen its already competitive position in the global shrimp market, overtaking Thailand and Vietnam, to claim third place.

In 2018, the global shrimp market experienced a price drop that was the result of high inventory levels in import nations such as the US, further squeezing profit margins and giving low-cost players an advantage.

Indonesian producers must find new ways to stay ahead of fast-moving, low-price competitors while coping with demand dynamics.

The global trend toward environmentally sustainable and socially responsible food production has raised questions about food safety and sustainability within the shrimp industry. Retailers, regulators, and consumers have become much more attuned to the negative environmental and social impact of aspects of unregulated shrimp production, including the use of banned chemicals, environmental degradation, and human and labor rights violations.

In a world with 24-hour access to social media, ongoing consumer awareness campaigns, new regulations in importing countries, and accelerated dissemination of information worldwide, retailers face intense pressure to protect their brands from the damage that results from product recalls, scandals, and supply chains that are disrupted by new import controls.

As more attention is focused on these issues, retailers, regulators, and, in some cases, consumers are demanding sustainably produced, traceable products in nearly all food categories. From 2012 through 2017, the sustainable seafood segment in major European markets grew by about 12% while market demand for other seafood segments declined. Similar trends have been observed in the US, though on a smaller scale, and the growth of sustainable products in China has been driven mainly by food safety scandals and government targets. Overall, there is growing demand for responsibly produced shrimp, and a niche consumer segment is willing to pay a premium for it.

A 2015 survey of approximately 3,000 consumers worldwide found that 68% wanted to know where their food was coming from and how it was being produced. While statistics show that this consumer-driven pressure is currently less urgent in the US and China, these countries have introduced stricter import regulations and government targets.

Nearly all major retail chains, supermarkets, and convenience stores around the world have pledged to increase their share of sustainably produced food, including shrimp and other seafood categories, and, as a form of legal risk insurance, an increasing number of major retailers are requiring suppliers to sign contracts and carry out in-depth due diligence to ensure traceability and adherence to ecofriendly production methods. Regulators, too, are increasing their monitoring of shrimp imports for drug and chemical residuals and are threatening to ban imports. Any company charged with regulatory violations would risk suffering serious economic losses and reputational damage.

As the demand for sustainability grows, there is increasing urgency for a paradigm shift toward truly responsible production and sourcing. Retailers' pledges of sustainability and niche consumers' increasing willingness to purchase sustainable products represent forward movement. However, the definition of "sustainability" is not consistently precise. There are many different ways to define sustainability, and retailers and consumers may unknowingly purchase products that fall short in fundamental areas, such as environmental stewardship and social responsibility.

To foster real change, it is important to establish a clear definition of what it means for food to be labeled sustainable. To put it simply, sustainable products should be produced today in ways that do not compromise the ability to produce those same products tomorrow. Products should minimize environmental degradation and the use of natural resources and should be traceable across the supply chain to provide greater transparency and accountability. For sustainability to have maximum impact, it is important for all stakeholders to understand and adhere to these fundamental principles.

To defend its current strong competitive position, Indonesia needs to embrace sustainability. As changes are implemented across the supply chain, it will be imperative to align on the definition of sustainability and establish mechanisms that will hold all actors accountable.

INDONESIA'S SHRIMP INDUSTRY IS VULNERABLE TO GROWING THREATS

Indonesia, which was able to strengthen its global competitive position owing to outbreaks of diseases and production issues in Thailand and Vietnam in the early years of this decade, is currently the third-largest shrimp producer in the world, with a global market share of 12%. The country produces between 450,000 to 500,000 tons of shrimp.[1] (See Exhibit 1.)

Demand for Indonesian Shrimp Is Rising at Home and Abroad

Indonesia exports 220,000 to 260,000 tons of shrimp: about 60% to the US, 19% to Japan, and 5% to the EU. Indonesia is the second-largest shrimp exporter to the US, just behind India. L. vannamei shrimp accounts for 70% to 80% of export share, while Penaeus monodon, or P. monodon (black tiger shrimp), which is primarily exported to Japan, accounts for 20% to 30%. (See Exhibit 2.) Relative to other Asian countries, domestic demand in Indonesia is high—around 40% of total production.

This high domestic demand gives Indonesia a competitive advantage as the domestic market is less affected by external factors, such as stricter import regulations or retailers' demands for traceability and sustainability. Still, a strong domestic focus that makes them less dependent on global export markets may mean that companies will be less likely to shift toward traceability and sustainability.

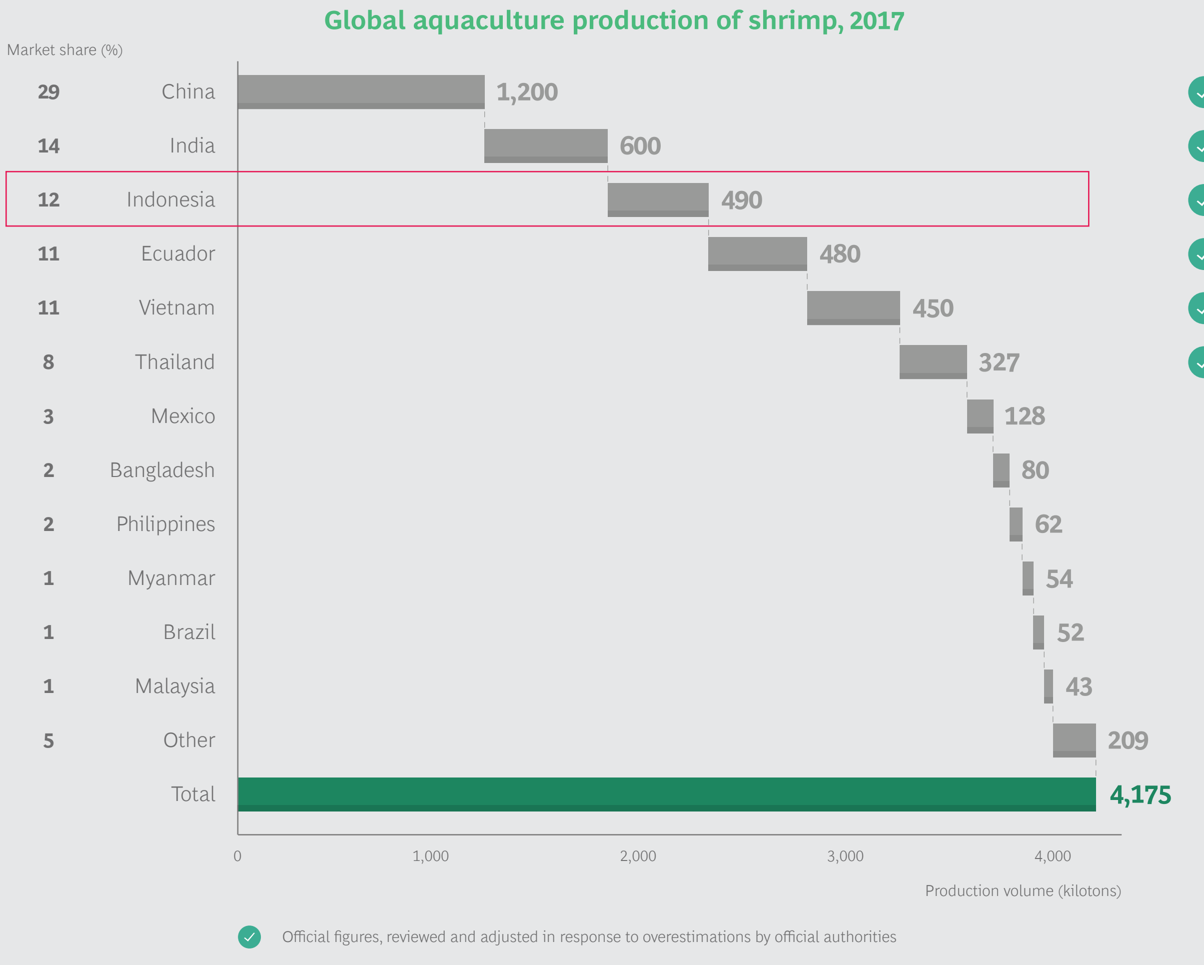
Fisheries contribute about 2% to Indonesia's GDP, and farmed shrimp has a production value of about $4 billion, which represents about 15% of the fisheries sector. Aquaculture in Indonesia, including processing and exports, employs around 8.7 million people, which is about 7% of the total workforce. Of this 8.7 million, approximately 1 million individuals are directly affected by shrimp farming.[2]

It's difficult to estimate the total number of shrimp farms in Indonesia since many do not operate on a commercial scale. Still, it is assumed that some 80,000 to 95,000 farms produce shrimp. Approximately 80% of farms produce shrimp extensively, focusing P. monodon production. However, these extensive farms contribute to only about 10% of the production output volume. (See the sidebar "Once the Main Species, P. Monodon Is Losing Importance.")

Extreme Weather and Diseases Threaten Indonesia's Shrimp Industry

Indonesia's unique environment and location can impede shrimp farming. During the dry season, increased salt content in the water lengthens breeding periods for shrimp, and the rainy season can contribute to increased acidity in ponds, lower water temperatures, and flooding.

Exhibit 1 | With a 12% Market Share, Indonesia Is the World's Third-Largest Shrimp Producer



Sources: Cámara Nacional de Acuacultura; Food and Agricultural Organization of the United Nations (FAO), FishStat Plus (2016); Thailand Department of Fisheries; Imarc Research; BCG analysis.
Note: The figure for India is for fiscal year 2017–2018.

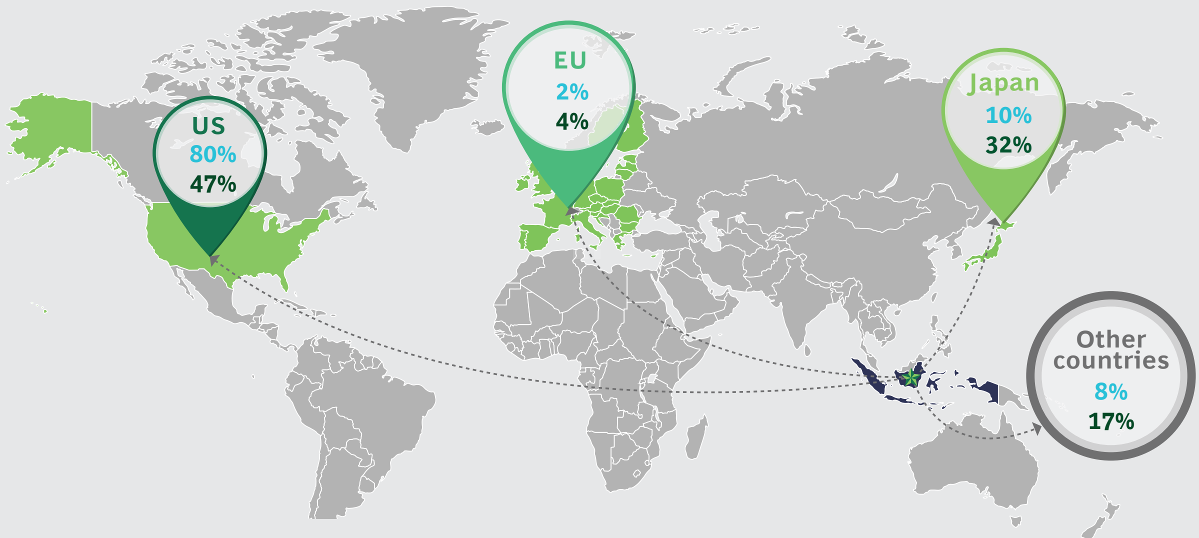
Extreme weather conditions can also affect hatcheries and farms. In 2018, for example, a tsunami that hit Banten province damaged 28 hatcheries and many shrimp farms in Lampung, and national production was reduced by up to 10% over a three- to four-month period. The tsunami also disrupted operations across the value chain, and the feed industry suffered drops in demand of as much as 6,000 tons per month over the same period.

During the late 1980s and 1990s, Indonesia was heavily affected by various disease outbreaks, such as white spot disease, yellowhead disease, and monodon-type baculovirus. These outbreaks of diseases reduced shrimp production by about 50,000 tons—about one-third of the production volume during that time.

In 2012, Indonesia suffered less from the early mortality syndrome (EMS) disease outbreak than other Asian countries. This was partly because of the physical distance between islands, which makes it more difficult for viruses to spread, and partly because the government had taken action to prevent the spread of disease. During the EMS outbreak, for example, the country banned the import of foreign post-larvae shrimp (PL).

Nevertheless, the country is still threatened by outbreaks of diseases. In 2016, disease outbreaks reduced shrimp production by as much as 100,000 tons—about 20% of current overall production. However, this decline in production could partly be offset with intensification efforts and growth in other regions.

EXHIBIT 2 | Indonesia's Shrimp Exports Go Mainly to the US and Japan



L. vannamei = 70%–80% of total exports, or 170 kilotons to 190 kilotons
P. monodon = 20%–30% of total exports, or 50 kilotons to 70 kilotons

Sources: BKIPM; Ipsos; Statistics Indonesia; BCG analysis.
Note: L. vannamei = Litopenaeus vannamei; P. monodon = Penaeus monodon. Export volume in 2017 in the nonfishery category was about 240 kilotons. The data on export distribution is from 2018.

Indonesia's Geography Presents Barriers to Profitability

Indonesia's farms, spread widely over its islands, face two challenges that make it difficult to be highly profitable: dependence on middlemen and energy generation that is unreliable due to unstable grid connections.

Middlemen connect farmers with feed mills, hatcheries, and processors. Each middleman takes 1.4% to 5% of farmers' profits. In some regions, middlemen have extraordinary control over farmers either because the farmers are in debt or because of strong family ties, such as the relationships in East Kalimantan with Buginese middlemen, the so-called Punggawa.

The lack of a stable energy supply poses difficulties for Indonesian shrimp farmers located on remote islands. In these regions, shrimp farmers rely on diesel generators at specific times to secure power for crucial equipment, such as aerators. Energy accounts for 15%—that is 9% for diesel energy and 6% for grid energy—of Indonesian farmers' costs. After feed, energy is the second-most expensive cost driver for Indonesia's farmers. Their energy costs are significantly higher than in other Asian countries—double, for example, the energy costs of Vietnamese farmers.

Indonesia's Value Chain Is Complex

Indonesia's farmed-shrimp supply chain comprises several interrelated steps: feed mills, hatcheries, farmers, middlemen, processors, exporters, and retailers. (See Exhibit 3.)

This report focuses on the first five steps:

- **Feed Mills.** Six players dominate the Indonesian feed market with 78% of the market. The two most dominant players are Central Proteina Prima (CP Prima) and CJ Aquaculture & Fishery (CJ).
- **Hatcheries.** CP Prima controls 40% to 50% of the market in hatcheries, while the rest of the market is highly fragmented.
- **Farmers.** The overall market is fragmented, with many family businesses. CP Prima and Japfa have high market share—about 20% to 25% and 10% to 15%, respectively—in this segment, but they also rely on middlemen.

ONCE THE MAIN SPECIES, P. MONODON IS LOSING IMPORTANCE

Two main shrimp species are produced in Indonesia: L. vannamei (whiteleg shrimp) and P. monodon (black tiger shrimp). P. monodon is native to Indonesia. L. vannamei was introduced in 2001 after outbreaks of diseases, such as white spot disease, in the 1990s severely hit production of P. monodon. Furthermore, L. vannamei is better suited to intensive farming and can, therefore, be produced with higher yields per hectare.

With the introduction of L. vannamei in Indonesia, market share of P. monodon declined quickly, and that share is now down to some 30%.[1] Production of P. monodon is expected to remain largely stable, growing by 2% per year. In contrast, L. vannamei farming, which makes up some 70% of Indonesia's total production, is expected to grow by 10% annually.[2]

Larger companies, such as the Japanese processor and exporter Alter Trade Indonesia, specialize in producing extensive P. monodon in Indonesia for exports. P. monodon are larger in size and therefore sell at prices that yield up to 33% EBIT margins at the farm level, compared with 16% for L. vannamei.

Because P. monodon can be produced only extensively, annual profits at the farm level are substantially lower than those of L. vannamei. (See the exhibit below.) P. monodon yields around $1,700 in profits per hectare, compared with as much as $17,400 per hectare for L. vannamei.[3] In addition, the extensive production method requires large amounts of land, exacerbating land use challenges and, in some cases, mangrove deforestation.

NOTES

1. Based on overall production volume in Indonesia.
2. Based on overall production volume in Indonesia.
3. Based on a productivity of 400 kilograms per hectare per cycle and 2.5 cycles per year versus 10,000 kilograms per hectare per cycle and 3 cycles per year, respectively.

P. Monodon Cannot Be Intensified Beyond 60 PL per Square Meter

Stocking density per square meter	Extensive	Semi-intensive	Intensive	Superintensive or supraintensive
P. monodon	2 PL	5 to 20 PL	20 to 60 PL	NA
L. vannamei	4 to 10 PL	10 to 30 PL	60 to 300 PL	300 to 750 PL

Disclaimer
Stocking densities depend on country specifics as well as farm characteristics; therefore, wide ranges are provided

Sources: FAO; BCG analysis.
Note: PL = post-larvae shrimp; L. vannamei = Litopenaeus vannamei; P. monodon = Penaeus monodon. NA = not applicable.

EXHIBIT 3 | Indonesia's Farmed-Shrimp Supply Chain

Source: BCG analysis.
Note: This report focuses on feed mills, hatcheries, farmers, middlemen, and processors.

- **Middlemen.** These intermediaries play a role between farmers and all other segments of the value chain. Various small to large players exist.

- **Processors.** Generally, both the processing and the exporting are managed by one company. The market is highly fragmented with some large companies, such as CP Prima, Sekar Bumi, and Japfa, but there are also various midsize players, such as KML Foods and Panca Mitra Multiperdana.

Across the value chain, two fully integrated players, CP Prima and Japfa, own feed mills, hatcheries, farms, processors, and export facilities. In addition to these fully integrated players, various midsize downstream players—such as Sekar Bumi and Bumi Menara Internusa—own farms, processing and export facilities, and, in some cases, hatcheries. Some have a strong regional and species focus for exports. Alter Trade Indonesia (ATINA), for example, supplies P. monodon to the Japanese market. Both fully integrated and downstream players often rely on middlemen to secure a stable supply of shrimp.

INDONESIA
THE CASE FOR CHANGE

The Indonesian shrimp industry is currently in a strong competitive position in the global market, but three market forces are threatening its position: low-price competitors, market demand and traceability regulations, and an intensifying need to cope with the high risk of disease and environmental threats. (See Exhibit 4.)

Low-Price Competitors

The global competition in the shrimp industry has increased sharply for L. vannamei in recent years. India, in particular, has flooded the market with low-price shrimp, and other countries such as Vietnam and Ecuador, are expected to ramp up production as well. With such a large supply of low-price shrimp available, prices will continue to decrease. Because of their relatively high production costs, Indonesian companies cannot compete with countries such as India to sell shrimp at lower prices. A change is needed.

Indonesia's number-one market for shrimp is the US: 80% of L. vannamei exports are to the US, as well as 47% of P. monodon exports. India is currently the leading exporter of shrimp to the US, claiming about 32% of the market and selling at significantly lower prices.

If the prices of Indonesia's US exports dropped to match India's current prices and Indonesia's processors translated just 50% of this price difference to the farm gate, Indonesian farmers would barely make a profit.

Market Demand and Traceability Regulations

In 2018, the US expanded its Seafood Import Monitoring Program (SIMP), which establishes reporting and record-keeping requirements for seafood imports, to cover shrimp.

Because the US is the most important export market for Indonesia, SIMP has had a major impact on the Indonesian shrimp industry, especially when the standards have been strictly enforced. SIMP will likely have a similarly negative impact for the Indian export market given India's relatively low traceability standards.

In the wake of food safety scandals, China has also imposed stricter import regulations by passing new legislation and urging lifetime bans for offending importers. Although China is not a main export market for Indonesia, these moves exemplify the current global trend toward increased traceability and health standards.

The demand for traceability is fueled also by a fast-growing niche market for sustainable and traceable seafood—and some companies are beginning to capitalize on this trend. A group of companies in Ecuador, for example, established the Sustainable Shrimp Partnership to produce fully traceable shrimp while improving social and environmental performance. As first movers act on this trend toward traceability, Indonesia finds itself in a precarious position regarding its exports. It risks losing share in the global shrimp market. Given its strong domestic market for farmed shrimp, the shift toward traceability and sustainability affects Indonesia less than other Asian countries, but over time, it could have a devastating impact on Indonesia's export business.

Some companies in Indonesia have started to make progress on traceability. In 2014, Indonesia's Ministry of Marine Affairs and Fisheries (MMAF) launched Aquacard, a traceability system, that aimed to help buyers trace shrimp back to the farm where it was produced. It is, however, unclear how much this system is being enforced. A small number of companies are also getting their shrimp certified through international certification bodies, such as Best Aquaculture Practices, Aquaculture Stewardship Council, GlobalGAP, and British Retail Consortium, but only a small percentage of shrimp in Indonesia is assumed to be truly certified, and some farms have been accused of not fully complying with certification standards. (See the sidebar "Certifications: There Are No Shortcuts to Full Traceability.")

Exhibit 4 | The Case for Change Is Driven by Three Factors in Indonesia

Source: BCG analysis.

CERTIFICATIONS: THERE ARE NO SHORTCUTS TO FULL TRACEABILITY

Retailers and producers, in collaboration with certification bodies, offer many certifications for seafood and shrimp products. Many of these certifications can have positive impact on certain production and supply chain elements, but not all address environmental and social issues within the farmed-shrimp value chain.

Furthermore, because the supply chain is so complex, it is nearly impossible to guarantee with 100% certainty that shrimp producers adhere to certification standards. Ultimately, the lack of traceability of certified supply chains renders some labeling untrustworthy and provides "perceived" rather than actual sustainability and responsibly produced shrimp.

Because no reliable alternative to these certifications currently exists, many consumers accept them as proof of sustainability and increasingly demand labeled seafood. In 2016, about 14% of farmed and caught seafood was certified, and this number is expected to climb by about 5% annually through 2025. A small proportion of customers will pay premiums as high as 40% in specialty stores for shrimp certified as sustainably produced and fully traceable.

Certification standards and practices can be problematic for the following reasons:

- Certification standards vary, and each certifying organization establishes its own minimum and maximum limits for

CERTIFICATIONS: THERE ARE NO SHORTCUTS TO FULL TRACEABILITY (continued)

such concerns as antibiotics and chemicals, land use, and water pollution. And many fail to differentiate between essential and innocuous requirements.

- Shrimp farm certifications are not necessarily product certifications. They are, instead, focused on farming processes.

- Controls and audits on farms and at processing factories occur infrequently—at most twice a year. Furthermore, only a subset of farms are checked and audited in farm collectives, and there is no mechanism for confirming that all farms within a collective adhere to the stated standards. Even for those that are controlled, only one day's evidence is collected, and neither farming practices nor impacts are monitored over an extended period.

- Many certifications have been awarded before traceability has been demonstrated.

- In many cases, the cost of adhering to certification standards and altering production processes is not shared along the supply chain, burdening only farms or processors. From a social-equality perspective, this represents a major pitfall.

- It is nearly impossible to compare one protein product—shrimp, fish, or meat—with another protein product, because certifications differ so much, depending on species.

- Shrimp from certified farms and noncertified farms are, in many cases, collected from a single middleman and mixed in a single batch, making it impossible to separate the sustainably produced shrimp from nonsustainably produced shrimp.

Certifications aim to provide transparency on sustainability and production standards, but implementation is close to impossible in Indonesia's fragmented shrimp supply chain. To achieve reliable traceability, all players must participate and provide continuous transparency into their production methods and inputs. This can be achieved only with collaboration, constant monitoring, and a platform that captures tamper-free, truthful records. There are no shortcuts to traceability, and as previously stated, what has worked for Indonesia's shrimp industry in the past—providing certified products without proof of traceability—will not work for much longer. More holistic approaches to supply chain integrity are necessary.

For a number of reasons, including the three given below, it's important for Indonesia to shift toward traceability and sustainability now:

- Indonesia has earned a reputation as a reliable shrimp source. From March 2014 through March 2019, only 71 entry lines were rejected at the US border. By contrast, during the same period, 396 entry lines from India were rejected.

  Countries that fail to meet regulatory requirements face serious and lasting repercussions.Adherence, therefore, is critical.

- In 2019, the US announced the end of its preferential trade agreement with India. This means that Indian shrimp could be subject to new duties.

- By increasing sustainability standards within the supply chain, the Indonesian shrimp industry can tap into a new market, build an even stronger competitive position, and become a leader in this segment in the US.

  Other markets in which Indonesia has not yet established a strong position might be more difficult to penetrate, but the US provides an immediate opportunity.

High Risk of Disease and Environmental Threats

Extreme weather events and outbreaks of diseases can dramatically disrupt shrimp production. These risks are expected to increase in frequency and severity, particularly in regions such as Jawa Timur and Kalimantan Timur, due to climate change and ongoing mangrove deforestation. Environmentally harmful shrimp-farming practices also contribute to the problem. Lack of water treatment, for example, leads to eutrophication, diffusion of antibiotics, spread of disease, and ultimately the destruction of coastal areas, biodiversity loss, groundwater depletion, land degradation, and erosion.

There is a strong financial incentive for farmers to become more resilient. For an intensive L. vannamei farm, a natural disaster could lead to crop losses totaling $31,700 per crop per hectare.[3]

To mitigate risk and build resilience, farmers need to protect their farms from changing weather conditions and reduce their environmental footprint. Some Indonesian farmers have already begun to develop supraintensive ponds lined with cement that are more resistant to environmental threats. They are also using a central drain to dump shrimp waste, excess food, and other waste that accumulates at the bottom of the pond. This approach allows for higher stocking densities and less wastewater discharge, and it reduces risk from environmental hazards. However, as the ponds are still constructed outdoors, disease can spread, and complete control over water conditions is not possible.

Indonesia could increase its competitive position in the global shrimp supply chain by shifting to more sustainable and environmentally sound production. New production methods will lead to higher margins and also open up a sustainable niche market for producers. However, immediate changes on the farm and processing levels will not be sufficient. The industry must improve sustainability and traceability across the whole supply chain to truly tackle the challenges the industry is currently facing. (See the sidebar, "Unlocking the Economic Potential of Mangroves.")

UNLOCKING THE ECONOMIC POTENTIAL OF MANGROVES

P. monodon has traditionally been farmed in mangrove areas, shrimp's natural habitat, but this practice is threatening Indonesia's mangrove forests, which are crucial carbon storage ecosystems. As shrimp farming has intensified, it has become evident that mangrove areas are not ideal for the following reasons:

- **Unfavorable Pond Construction.** Low sea levels prevent construction of deep ponds and complete drainage of used water during and after farming cycles.
- **Poor Soil Quality.** Soil used for constructing embankments as natural barriers between the pond and the surrounding environment tends to degrade over time, so the embankments can eventually breach.
- **Poor Water Quality.** Although shrimp farming requires low acidity, soils in mangrove areas are highly organic with a high acid sulfate potential and low pH levels.
- **High Stress Levels That Result in High Risk of Disease.** Low pH levels stress shrimp and can reduce pond water nutrients, leading to serious health threats.
- **Higher Overall Costs.** Construction and production costs are generally higher, as farmers must take measures to improve water quality and mitigate soil degradation.

For these reasons, it is not unusual for shrimp farms in mangrove areas to suffer low yields and productivity, and, therefore, shrimp farming in mangrove areas is not recommended.

UNLOCKING THE ECONOMIC POTENTIAL OF MANGROVES (continued)

Nevertheless, local communities and shrimp farmers continue to destroy mangrove forests to build ponds for aquaculture. Historically, aquaculture has been responsible for around 50% of mangrove deforestation in Indonesia, and in some regions, this destruction continues, mainly as a result of extensive P. monodon shrimp production. From 2014 through 2018, around 28,000 hectares of mangrove area were converted to pond aquaculture.

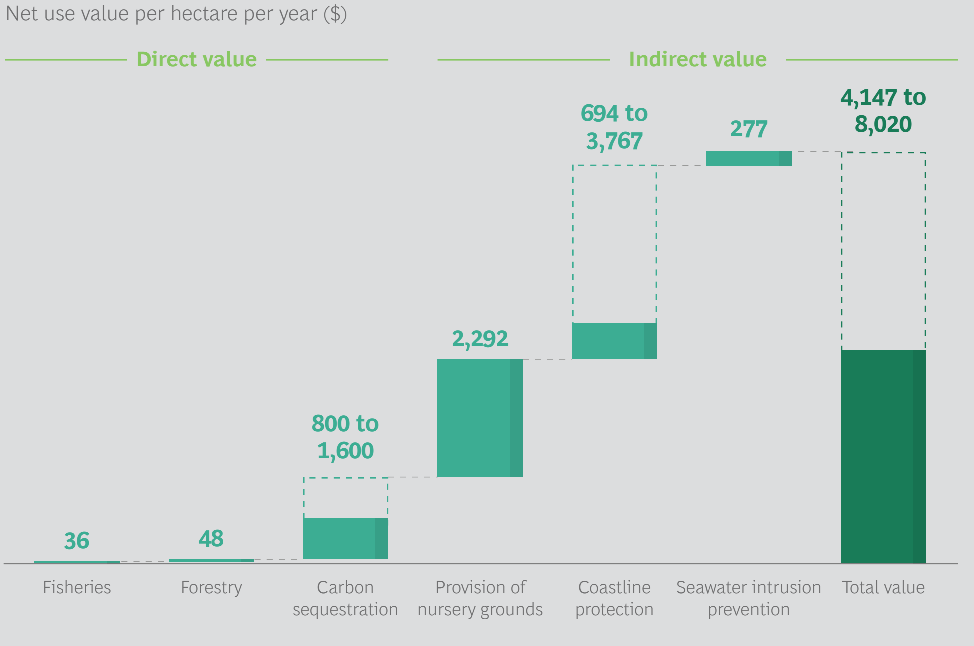
The latest research suggests that mangrove deforestation in Indonesia has halted or even reversed over the past few years. Indonesia's mangrove area increased 6% overall from 2014 through 2018. But mangrove deforestation continues to be a problem in certain regions. In Kalimantan Timur, mangrove cover dropped 5% between 2014 and 2018.

Indonesia is home to approximately 17% of the world's mangrove forests—approximately 3 million hectares as of 2018, which is roughly the size of the US state of Vermont. Mangrove forests protect coasts, impede erosion, prevent seawater intrusion, and are the natural habitats of many plants and animals. They also reduce the occurrence and severity of natural disasters. In addition, they are considered to be the largest carbon storage ecosystems in the world, storing three times more carbon—about 940 tons of carbon per hectare—than boreal, temperate, and tropical forests, which store about 300 tons of carbon per hectare. Owing to their many benefits, mangroves generate a societal and environmental value of $4,000 to $8,000 per hectare per year, and the value of carbon sequestration can be directly monetized through carbon offsets. (See the exhibit "Mangrove Areas Provide Substantial Value.")

Mangrove Reforestation: A Business Opportunity

The growing trend to engage in carbon offsets could generate new economic opportunities. Farmers can generate income by earning certifications, such as Verified Carbon Standard and Gold Stan-

Mangrove Areas Provide Substantial Value



Sources: *Forests, 2015; Biodiversity International Journal*, 2018; BCG analysis.

UNLOCKING THE ECONOMIC POTENTIAL OF MANGROVES (continued)

dard, and receive funding per ton of carbon dioxide storage.

With carbon certification, the direct net present value (NPV) of intact mangrove forests can be up to 20% higher than the NPV for extensive shrimp farming in mangrove areas. (See the exhibit "The Value of Intact Mangroves Is 20% Higher Than Extensive P. Monodon Farming.")

In addition, the payback period for reforestation projects is 2.7 to 3.4 years, which means that intact mangroves and mangrove reforestation are better economic alternatives for shrimp farmers, even in the short term. Still, the certification process remains complicated and costly.

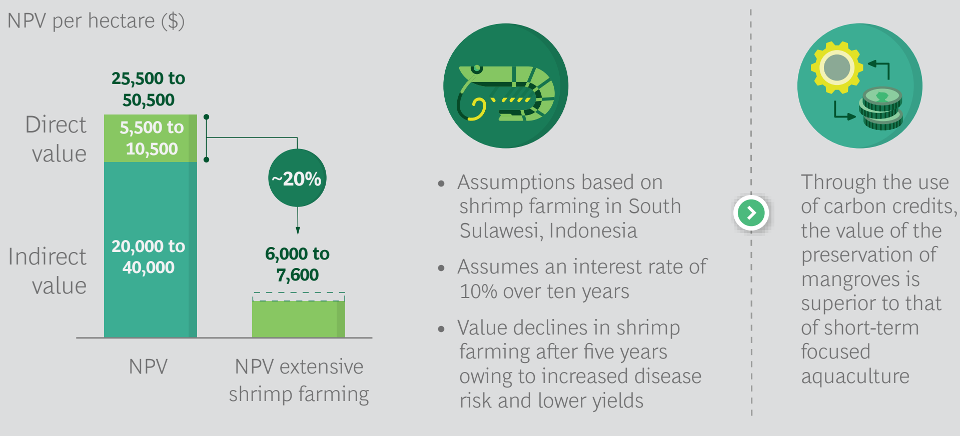
The Carbon Offset Trend

There are various reasons for funding carbon offsets. Many of the international certificates comply with the Reducing Emissions from Deforestation and Forest Degradation (REDD+) standard, and countries can use the certifications to comply with their Nationally Determined Contributions under the Paris Agreement of 2015.[1]

In addition, regulators may include REDD+ projects in their offset programs, such as the EU Emissions Trading System and the California cap-and-trade program.[2] Approximately 240 REDD+ projects—including Afforestation, Reforestation, and Revegetation and Improved Forest Management—were certified in Asia, South America, Africa, and Oceania, and this number is expected to grow. Over their lifetime, these 240 projects are expected to reduce emissions by some 2.2 billion metric tons of carbon dioxide, which, based on 2016 emissions, is around four times as much as Indonesia emits annually. Other certification bodies, such as myclimate and Natural Capital Partners, support smaller-scale projects for individuals' or companies' voluntary offsets.

The current carbon offset trend gives shrimp farmers an economically viable alternative to deforestation and funds reforestation projects. Carbon offsets should be promoted by large processing companies, NGOs, and local communities to raise awareness and unlock the full economic potential of mangrove forests.

The Value of Intact Mangroves Is 20% Higher Than Extensive P. Monodon Farming



Sources: *Forests*, 2015; *Biodiversity International Journal*, 2018; BCG analysis.
Note: NPV = net present value; NPV is for a ten-year period. NPV extensive shrimp farming refers to extensive aquaculture in Indonesia and assumes losses of 0% to 50% per year since year five.

UNLOCKING THE ECONOMIC POTENTIAL OF MANGROVES (continued)

NOTES

1. The Paris Agreement brought together all nations to combat climate change and adapt to its effects. It requires countries to commit to emissions reduction targets—the so-called Nationally Determined Contributions—in the coming years. So far, 185 parties out of 197 have ratified the United Nations Framework Convention on Climate Change.

2. Emissions-trading schemes set a maximum allowance for total greenhouse gasses and issue specific shares—auctioned or allocated for free—to all participants. If emissions exceed allowances, participants must purchase additional allowances.

INDONESIA'S PRODUCERS CAN CREATE IMMEDIATE ECONOMIC VALUE

Three imperatives inform the future of Indonesia's farmed shrimp: pursue immediate change to alter current practices on an individual level, increasing efficiency and productivity while improving profit margins; collaborate to achieve product traceability; and make bold shifts toward indoor shrimp farming by investing in closed-containment indoor facilities designed to reduce contamination, increase output, minimize the environmental footprint, and improve accountability. (See Exhibit 5.)

The shift to traceability, transparency, and indoor farming offers the highest potential for successfully defending the currently strong competitive position of Indonesia's shrimp industry, but this will require considerable capital investment, extensive expertise, and time.

In the meantime, there are several immediate changes that actors along the value chain, particularly feed mills and farmers, can implement to significantly improve financial performance and resource efficiency and create environmental benefits.

In this section, we briefly review the several ways that each player in Indonesia's farmed-shrimp value chain can benefit from these short-term improvements. (See Exhibits 6 and 7.)

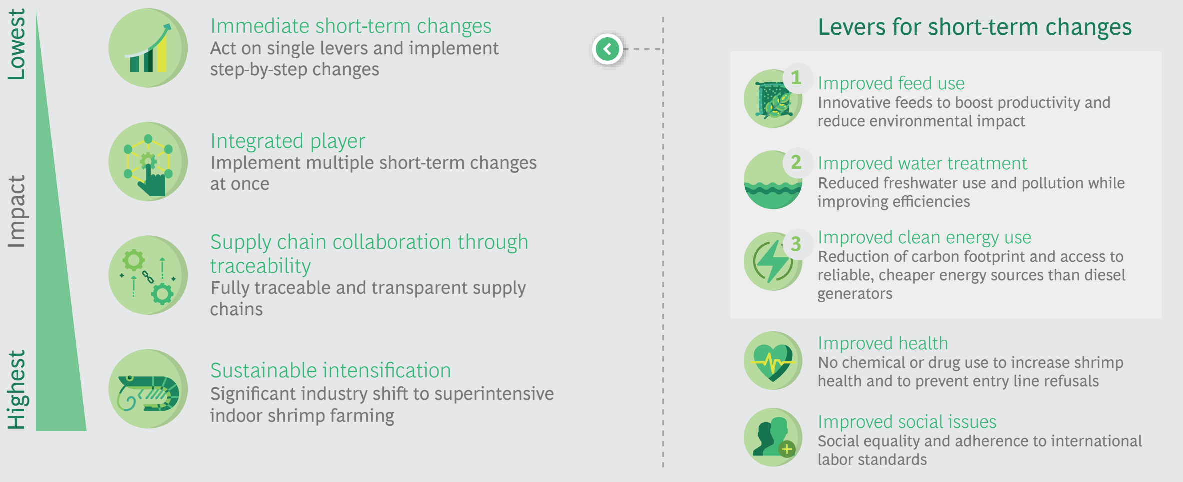
Feed Mills: Increase Profit Margins and Diversify the Portfolio with Functional Feed

The feed market in Indonesia is expected to grow at 8% per year through 2022, in line with Indonesia's overall shrimp market. The shrimp probiotics market, which helps farmers increase shrimp growth and survival rates, is expected to grow at 9% per year through 2020. This growth illustrates the demand from farmers for food additives or new food formulas. Feed mills have an opportunity to respond to the growing demand by expanding their portfolios to include functional feed—basic feed that has been enhanced with additives, such as proteins, vitamins, or probiotics (but never antibiotics), to achieve a specific outcome. It is not uncommon for feed mills to improve basic feed with additives, but functional feed is slightly different from improved basic feed: it is used in specific circumstances to achieve a specific outcome, usually includes more additives, and is therefore defined as its own feed category.

Two types of functional feed have high potential.

Growth Enhancement Functional Feed. This is used to increase shrimp growth rates and allow farmers to sell larger shrimp at a potentially higher price or to accelerate growth cycles and, therefore, farm throughput. It offers a positive business case for feed

Exhibit 5 | Several Levers Can Maximize Business Success While Creating Positive Environmental and Social Impact



Source: BCG analysis.
Note: Our focus in on levers 1, 2, and 3.

mills, potentially increasing EBIT margins by a factor of up to about 2.6 per kilogram of shrimp feed sold. This increase in profitability is achieved by charging a premium of as much as 20%, offsetting the additional production costs.

However, when farmers invest in growth enhancement functional feed, their feed conversion ratio (FCR) is drastically reduced.[4] The immediate demand for feed may drop, reducing revenues by up to 8% per kilogram of shrimp produced, but this decline can be offset by other factors, including the ability to charge higher prices for functional feed and an overall uptick in demand for feed (as shrimp grow faster and demand increases).

Health Enhancement Functional Feed. This type of feed can enhance shrimp health and disease resistance, and it also offers several benefits for feed mills, not the least of which is that feed mills can charge premiums of up to 50%, leading to profit margins that could be more than four times higher than average in an optimal case. Production and feed ingredient costs will likely increase by 10% to 20%, but these costs are typically offset by the revenue boost.

It is fair to assume that the demand for functional feed will increase in the years to come, but it will not completely displace regular feed from the market: farmers will likely purchase the expensive feed only when there's a direct economic benefit, such as when global shrimp prices rise significantly. It does offer a good opportunity for feed mills to diversify their portfolios, boost revenues, and improve profit margins, but a complete shift is not recommended. To attain these benefits, it is important that feed mills market functional feed and educate farmers on its benefits. (See the Appendix for a discussion of growth enhancement and health enhancement functional feed.)

Feed mills that extend their product portfolio by selling functional feed can increase profits, help farmers increase production volumes, and support growth within the shrimp industry as a whole. They have both a clear incentive and a responsibility to act. Switching to functional feed also benefits the environment by decreasing land use—as a result of reduced FCR—by up to 15% per kilogram of shrimp produced, improving water quality by reducing feed waste, decreasing the use of antibiotics, and requiring less fish meal and fish oil. However, these benefits materialize only if functional feed is widely used, and the positive environmental impact depends on what substitutes are used for fish meal.

Feed mills are responsible also for careful consideration of the production of the feed's

EXHIBIT 6 | Current Average Economics per Value Chain Step

		Feed mills	Hatcheries	Farmers	Middlemen	Processors → Local market / Exporters	National retailers / International retailers
L. vannamei	Costs	$0.84 per kilogram of feed	$2,680 per million PL	$3.17 per kilogram of shrimp		$8.49 per kilogram of shrimp	
	Price	$0.90 per kilogram of feed	$3,190 per million PL	$3.75 per kilogram of shrimp		$8.89 per kilogram of shrimp	
	EBIT margins %	~7	~16	~16	~2 to 7	~5	
P. monodon	Costs	$0.84 per kilogram of feed	$1,400 per million PL	$3.50 per kilogram of shrimp		$11.88 per kilogram of shrimp	
	Price	$0.90 per kilogram of feed	$1,700 per million PL	$5.20 per kilogram of shrimp		$13.00 per kilogram of shrimp	
	EBIT margins %	~7	~18	~33	~5 to 12	~9	

Source: BCG analysis.
Note: L. vannamei = Litopenaeus vannamei; P. monodon = Penaeus monodon; PL = post-larvae shrimp. Calculations for L. vannamei are based on large-scale players and shrimp averaging around 60 pieces per kilogram; calculations for P. monodon are based on small-scale players (except feed) with prices based on shrimp averaging around 40 pieces per kilogram; margins include considerations such as survival rate. Rounding errors are possible.

ingredients. Worldwide, the demand for fish meal in shrimp feed has led to the depletion of some wild-capture fisheries and, in some cases, serious human and labor rights abuses on fishing vessels. Similarly, the cultivation of plant ingredients such as soy and corn for shrimp feed creates a high burden on land use. The natural resources used in feed—so-called embodied resources—represent a hidden, but vitally important, depletion of resources and thus need to be considered carefully.

Some feed mills and raw-material suppliers are experimenting with fish meal and soybean meal replacements, using, for example, alternative and less resource-intensive ingredients such as marine microbes. At the same time, some companies are experimenting with black soldier fly larvae, an efficient bioconvertor and a valuable feeding resource. Once applied at large scale, these innovations could have far-reaching impact beyond the shrimp supply chain.

The industry is also working to develop feed production methods, such as extrusion (cooking under high temperature and processing under high pressure) and the manufacture of pelleted feeds (no cooking and processing under much less pressure). Both of these approaches have the potential to improve the digestibility of feed ingredients.

Hatcheries: Ensure the Quality of Post-Larvae Shrimp Through Selective Breeding

PL produced by hatcheries are critically important for farmers. High-quality PL production can improve grow-out farm survival rates as well as the quality and health of shrimp, ultimately benefiting the entire industry. Hence, hatcheries represent a crucial enabler.

Exhibit 7 | The Economics of Short-Term Improvements

	Status quo	Feed	Water	Combination
Feed mill level	EBIT margin: ~7%	**Growth enhancement** EBIT margin: Up to 18% — Increase: 157% **Health enhancement** EBIT margin: Up to 28% — Increase: 300% In the sale of functional feed, overall feed mill EBIT margins depend on the feed portfolio of individual farms	None	**Growth enhancement with biofloc** EBIT margin: Up to 18% — Increase: 157% Potential revenue loss through improved farm efficiency, with a similar increase in farming output
Farm level	EBIT margin: ~16%	**Growth enhancement** EBIT margin: Up to 23% — Increase: 46% **Health enhancement** EBIT margin of up to 17% even during disease outbreaks versus 2% with basic feed	**Biofloc** EBIT margin: Up to 21% — Increase: 34% **RAS** EBIT margin: Up to 25% — Increase: 64%	**Growth enhancement with biofloc and energy** Positive, but further studies are required **Growth enhancement with RAS and energy** EBIT margin: Up to 33% — Increase: 106%

Source: BCG analysis.
Note: EBIT margin is based on feed per kilogram sold. RAS = recirculating aquaculture systems. Rounding errors are possible.

Many hatcheries still rely on imported broodstock, although domestic broodstock and selective breeding techniques ensure better shrimp survival, reduce the risk of disease, and position hatcheries to focus on breeding PL that grow faster and larger. Nonetheless, because it is considered to be of better quality than Indonesian broodstock, many hatcheries purchase imported broodstock. Through further R&D, a shift to domestic broodstock can help the Indonesian shrimp industry become more independent and significantly reduce the potential spread of diseases from foreign countries.

For example, after outbreaks of diseases in the late 1980s and early 1990s, hatcheries successfully produced a specific pathogen-free (SPF) broodstock to make shrimp more disease resistant. Moreover, recent studies have shown that SPF lines of selected stocks maintained under the proper conditions can help reestablish farm populations even in the event of stock losses caused by the outbreak of disease. In providing high-quality and healthy PL, hatcheries significantly help reduce production costs and increase output at the farm level.

Although our analysis did not reveal many opportunities for hatcheries to implement short-term changes in feeding techniques or water treatment systems, hatcheries that offer high-quality PL with benefits such as SPF can charge premiums for their products. Prima Aquatics and Global Gen are examples of Indonesian hatcheries that initiated SPF breeding programs.

Individual hatcheries should focus on improving quality by domesticating broodstock and implementing selective breeding practices to help minimize the risk of disease and allow them to compete more effectively against the significant market power of integrated players.

Because developing better PL involves genetic testing and investments in R&D, implementation might be rather difficult for small hatcheries. Institutions and players with the necessary means should, therefore, support small hatcheries in these efforts. (See the Appendix for a discussion of the business case for hatcheries.)

Farmers: Immediate Change Can Increase Profits, but Broader Changes Will Be Required

The farming market in Indonesia is highly fragmented with profit margins of up to 16% per kilogram of shrimp sold in the base case, but farming carries high risk due to outbreaks of disease and crop failures.

We have identified multiple business opportunities for implementing immediate change at individual farms by slightly altering existing production systems. These opportunities can help farmers improve production efficiencies, reduce resource use, and increase profit margins.

That said, the overall effect remains small compared with the more holistic levers of change, such as sophisticated closed-loop and indoor systems. The environmental benefits and control over the supply chain are also relatively limited in comparison with more holistic changes in production practices.

Key Opportunity 1: Functional feed can increase profits by up to about 46%, and only minimal training is required. Indonesia's farmers have much to gain by using growth enhancement and health enhancement functional feed on their shrimp farms—if they use them in a specialized manner to address specific challenges.

Growth enhancement functional feed has the potential to accelerate shrimp growth rates or to produce larger shrimp. Farmers are likely to opt for growth enhancement functional feed when global shrimp prices rise and they want to take advantage of the opportunity. Under these circumstances, it can be beneficial to use growth enhancement feed during the second half of the growth cycle to boost growth rates and reduce FCR. When growth enhancement functional feed is managed properly, FCR can be reduced by a total of 15%, and the larger shrimp can be sold for up to 6% more, significantly improving EBIT margins. This approach, which drastically reduces quantities of feed needed per kilogram of shrimp produced, compensates for the higher feed price—up to 20% per kilogram. Farmers who manage to sell larger shrimp at higher market prices can achieve EBIT margins of up to 23%, representing as much as 46% increases over average EBIT margins. If global shrimp prices stay high, fast-growing shrimp could allow for an additional production cycle, significantly increasing farming output.

Health enhancement functional feed, which can cost up to 50% more than basic feed, appears quite expensive when the consideration is a single use per kilogram of shrimp produced. However, should farmers anticipate disease outbreaks, health enhancement feed can achieve an EBIT margin of up to 17% because the feed drastically increases survival rates during disease outbreaks.

This scenario assumes that farmers can prevent disease outbreaks that could affect up to 20% of their annual production. A positive business case can be made, but each farmer must evaluate the feasibility and economic viability of purchasing expensive health enhancement feed against the potential losses from outbreaks of disease.

As long as farmers can afford the upfront costs of growth enhancement and health enhancement functional feed, they know when to use it, and they have the management skills to use it diligently, functional feed represents a relatively easy win: no investment or technological upgrade is required. There is also some environmental benefit—the result, for the most part, of better farm management, which is a prerequisite for the success of using this feed. (See the Appendix for a discussion of growth enhancement and health enhancement functional feed.)

Key Opportunity 2: Better water treatment can improve water use and quality while boosting EBIT margins. Intensive outdoor shrimp production systems require considerable amounts of fresh water and are major sources of pollution. In these throughput systems, once a growth cycle is completed, discharged effluents—along with the chemicals, fertilizers, and antibiotics used to treat the water—can leak into the environment.

More farms are using closed-loop systems that improve water quality and reduce water discharge. These applications vary widely in their mode of action, ease of use, and feasibility.

There are farming technologies that use alternatives to chemicals and fertilizers to enhance water quality, as well as filter systems that aim to recycle water and reduce wastewater leakage into the environment.

Two systems that are focused on improving water quality and reducing wastewater discharge through circulation and filtering are biofloc and recirculating aquaculture systems (RAS). (See the Appendix for additional information on water treatment systems.)

Biofloc allows shrimp farmers to improve water quality and provide an additional feed source at the same time. Carbohydrates are added to pond water to compound waste products that can then be eaten by shrimp.

There is significant variability in the business benefits for farmers because it can be tricky to implement and scale biofloc. Results can vary widely from one farm to the next, and a preparation phase is required to ensure a successful introduction of this method.

In a best-case scenario, farmers benefit from an EBIT increase of up to 34%, resulting in an EBIT margin of about 21% per kilogram of shrimp sold. At worst, if farmers are not able to fully benefit from the advantages of biofloc, they can suffer a minimal decrease in EBIT, leading to an EBIT margin of about 14%. The change in EBIT margins is a result of decreased costs for feed and chemicals, combined with the potential, because of biofloc's high protein content, to grow shrimp faster or larger within a given period of time, thus increasing revenues.

With this opportunity, large farms tend to have an advantage over small farms because they have better access to knowledge and expertise—imperatives for the successful use of biofloc. However, as it can be difficult to scale this method, small farms have the advantage of being positioned to apply the method on a limited scale. For farmers with the right equipment—such as aerators and monitoring equipment—as well as access to the necessary training and knowledge to maintain biofloc in ponds, this approach is a promising option. When used properly, it can reduce water pollution and prevent eutrophication of natural ecosystems by reusing water. In some cases, however, its incorrect application can have an adverse effect on the heterotrophic pond environment by adding excessive waste material to the water, possibly reducing shrimp survival rates. (See the Appendix for additional information on biofloc.)

Biofloc is already being used in some areas of Indonesia. In 2014, *Aquaculture* magazine suggested that Indonesia might have more farms using biofloc technology than any other country. International organizations are also beginning to promote the use of probiotics and biofloc. Lim Shrimp Organization (LSO), a large shrimp-farming group in Southeast Asia, established a network of integrated farming projects aiming to increase the use of sustainable-farming principles, including the use of biofloc. In 2018, LSO completed 12 integrated farming projects in Indonesia. Despite these developments, many farmers struggle with the right flocking equilibrium in ponds, and the method is still not in wide use among Indonesia's farmers. The lack of a stable grid connection is an additional layer of complexity. Indonesian farmers in remote areas still rely on expensive diesel generators as backup in case of grid outages. For the biofloc method, continuous aeration of the ponds is essential to ensure sufficient oxygen in the water; therefore, a stable grid connection is a prerequisite for a profitable application.

RAS are sophisticated filtering systems that treat water so that it can be reused in the same location.[5] Such closed-loop systems offer two significant benefits: no unfiltered wastewater is discharged into the local environment, and demand for "new" water is reduced. In an ideal case, no water exchange is required. Moreover, these systems can improve farm and resource efficiency and boost productivity, as they reduce the need for production inputs such as chemicals, feed, and fertilizers, and therefore can lead to higher EBIT margins for farmers. RAS can be basic biofilters or more sophisticated water recirculating systems and can vary in effectiveness, investment and operating costs, and environmental impact.

In most cases, effective RAS implementation requires considerable financial investment owing to the need to install new facilities and train workers in what is an advanced farming technique. However, because RAS offer the opportunity to intensify production, these systems also allow larger output per hectare.

For producers that can afford the investment, sophisticated RAS—some costing $150,000 per hectare—can potentially increase EBIT margins by up to 64% per kilogram of shrimp produced, resulting in an overall EBIT margin of about 25%. This increase assumes that farmers can reduce fixed costs by 50% and variable costs by 25%, owing to higher stocking densities, reduced labor costs because of automation, and reduced pond preparation costs. The margin increase will counterbalance the capital investment that results in the 30% increase in deprecation per kilogram of shrimp as well as the higher costs for the electricity needed to support the use of the filters and constant aeration.

RAS is expensive and requires special knowledge to implement. Its application is, therefore, limited to supply chain actors with access to sufficient funding and expertise. There are simple, low-cost filter systems available as alternatives to RAS, but they tend to be less effective. To reduce the investment costs per farmer, RAS can be used in farm collectives to spread costs among adjacent farms.

The use of RAS likely reduces the intake of new water (except to make up for seepage and evaporation), but it also causes a surge in total energy and feed use owing to increased stocking densities. Using renewable energy and functional feed and leaving a minimal environmental footprint could potentially mitigate this negative effect.

Beyond these benefits, the application of water filters combined with higher stocking densities represents a first step toward sustainable intensification of shrimp farming, which is the direction the industry will likely take in the near future. (See the Appendix for additional information on the business case for RAS.)

Indonesia's MMAF has already started to develop an ultraintensive shrimp-farming system that combines RAS with a microbubble technology to increase the dissolved oxygen content in the water. However, this water treatment method is used by only a limited number of farms.

Key Opportunity 3: Solar energy can reduce local energy generation costs. In Indonesia, energy represents a major cost sink for farmers, accounting for up to 15% of their total costs. This is significantly more than in other Asian countries. Shrimp farms located in remote areas are faced with frequent energy outages, so they often have to resort to using diesel generators, which are expensive (accounting for up to 9% of total costs) and sources of pollution. Because of Indonesia's island geography, various farmers have to deal with this problem. For these farms, renewable solar energy represents a reliable, economic, and clean alternative.

There are three types of solar energy available to shrimp producers: photovoltaic (PV) cells that can be installed on the ground in close proximity to ponds and with a tracking system, PV cells that can be installed above the surface of ponds, and PV cells with a tracking system that can be installed above ponds. Through the tracking system, the angle of cells is adjusted depending on the direction of highest solar radiation. Moreover, battery storage is required to ensure a continuous supply of energy.

Although on the basis of the cost per megawatt hour, solar energy is more expensive than grid energy, it is significantly less costly than diesel. Replacing diesel generators with solar energy can yield a 9% EBIT increase per kilogram of shrimp, resulting in a total EBIT margin of about 17%. This said, the initial costs for PV systems requires significant capex investments—up to $26,000 per hectare, depending on the system, or about $15,000 not including battery use. Small farms in remote areas might not be able to afford this. But as the cost of batteries and solar power continues to decline, this option could eventually become more affordable for remote farms as well as grid users.[6]

In Indonesia, some companies, such as Power Technology ASEAN, are already implementing solar power projects for shrimp farmers. However, like biofloc and RAS, solar power has not yet been widely adopted among shrimp farmers. (See the Appendix for a more detailed discussion of the business case for solar energy.)

Key Opportunity 4: Combining functional feed, water treatment systems, and solar energy could maximize economic benefits and environmental impact. Producers that seek to maximize the effect of immediate, short-term change can combine growth enhancement functional feed, closed-loop systems such as RAS, and solar energy. If they implement them correctly, farmers that combine these three strategies can achieve EBIT margins of up to 33%—2.1 times today's average. This is an improvement of as much as 43% when compared with the standalone use of functional feed, up to 33% when compared with the standalone use of RAS, and a twofold increase compared with a standalone solar energy solution.

The combination of functional feed and RAS offers several benefits, including an increase in volume through higher stocking intensities, more efficient production, higher survival rates, better water treatment, and reduced wastewater discharge. Nevertheless, the risk of disease remains high and cannot be fully mitigated in this scenario. When combined with RAS, farms would not continually use functional feed. Rather, they should take advantage of growth enhancement feed whenever there is a surge in global shrimp prices to maximize shrimp production volumes.

Another option is to combine growth enhancement functional feed with biofloc and solar energy. The combination of growth enhancement functional feed and biofloc affects the same production parameters, and its efficacy is difficult to predict. However, it is likely superior to standalone options. While these combined approaches have promise, they also require farming expertise and changes in production and farm management. They are, therefore, not likely to be widely adopted unless farmers receive guidance from key partners across the value chain, including representatives from feed mills and processors, as well as technology providers for sophisticated systems such as RAS. Without knowledge sharing across the industry, these techniques will very rarely be used. (See the Appendix for a detailed discussion of combining functional feed and water treatment systems.)

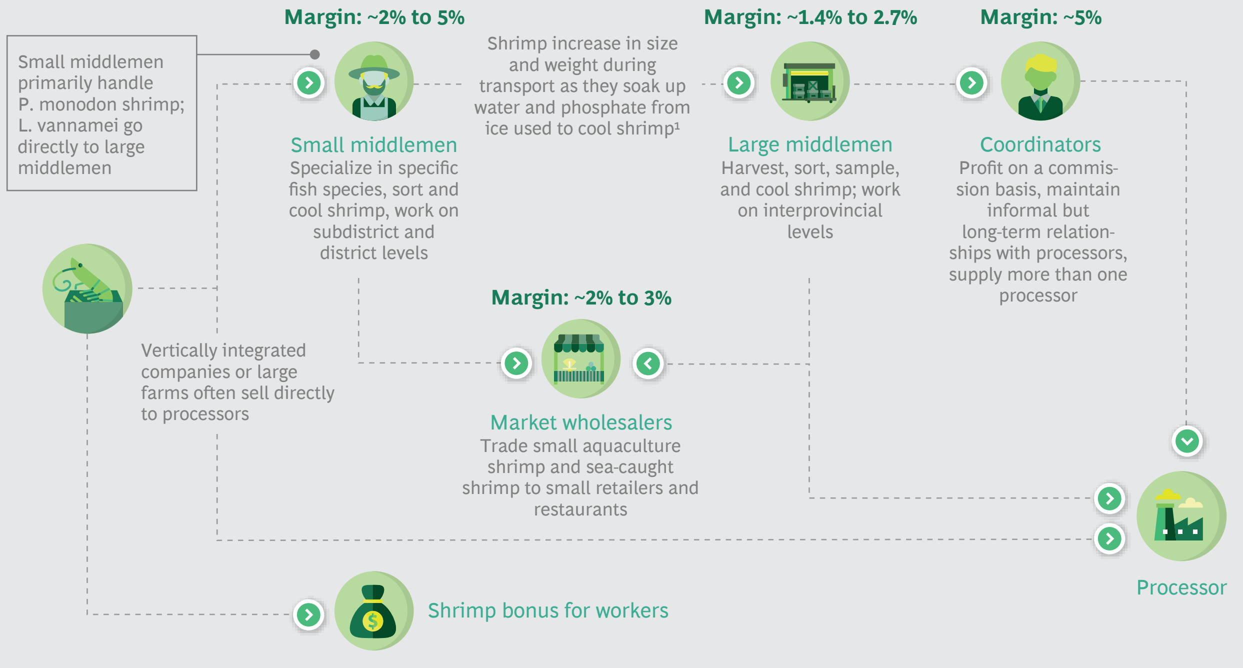
Middlemen: Increase the Pace of Change Through Education, Finance, and Traceability

Middlemen play a key role within the farmed-shrimp supply chain. They frequently serve as gatekeepers and facilitators between shrimp farmers and feed mills, hatcheries, and processors. (See Exhibit 8.) Middlemen often provide raw materials and financing for farmers. They also help processors sort, preprocess, and transport shrimp. In some cases, farmers depend heavily on middlemen—for services and also because of high debt and family ties.

Because of Indonesia's geography, middlemen play an especially important role in connecting remote farms with other players across the supply chain, but they also work closely with most large, integrated corporations. They play an informal role in the value chain, keep minimal records on shrimp purchased and sold, and receive little regulatory or company oversight, so a shift in how middlemen conduct their business will be key to the industry's successful transformation to a more traceable and sustainable supply chain.

Middlemen are uniquely positioned to support farmers as they improve their production systems and technologies across the value chain. For example, middlemen can provide detailed records to help track shrimp along the value chain and can inform farmers about ways to produce shrimp more sustainably and thus differentiate their product in the market. By becoming more involved in the shift toward sustainability, middlemen can stay relevant in an industry that might otherwise, over time, cut them out. Until this threat materializes—most likely from processors—middlemen are unlikely to see the need to make the required effort. (See the Appendix for a discussion of the business case for middlemen.)

EXHIBIT 8 | Middlemen Play a Critical Role from Farmers to Processors



Sources: Australian Centre for International Agriculture Research; expert interviews; University of Technology, Sydney; BCG analysis.
Note: L. vannamei = Litopenaeus vannamei; P. monodon = Penaeus monodon.
[1]Phosphate use must be labeled on shrimp packaging.

Processors: Important Drivers for Change as the Industry Moves Toward Sustainability

Shrimp processing in Indonesia is highly fragmented, with processors' profit margins averaging about 5%. Most processors handle exports as well, and that means that they have a clear incentive to help mitigate risk in the supply chain. When importing countries establish new regulations, such as the Seafood Import Monitoring Program (SIMP) in the US, processors and exporters must translate these requirements into actions.

Processors work directly with farmers, so there is an opportunity to encourage the production of high-quality, responsibly farmed shrimp and to reduce disease risks to ensure a stable shrimp supply. Processors stand to benefit when farmers produce sustainable shrimp, because they can obtain a price premium.

Due to the fragmented market, this is especially critical for large standalone processors that face stiff competition from integrated players with more control over their supply chain, as well as players in other shrimp-producing markets that are already at the forefront of traceability.

Nevertheless, many integrated players still source large quantities of shrimp from middlemen—an added challenge to achieving traceability. Processors can step up and deliver the much-needed transparency that middlemen typically fail to provide. (See the Appendix for a more detailed discussion of the business case for processors.)

Immediate Change Is Limited—Disruptive Transformation Is Needed

The short-term changes outlined above offer several immediate benefits for Indonesian shrimp producers, but because they are implemented on an individual basis, they do not promote the kind of wide-ranging change that's needed to secure the industry's future. Short-term shifts in production systems and value chain practices could total $70 million in export revenues over the next five years, whereas—assuming that larger shrimp translate to higher export prices—shrimp producers are currently positioned to create just $8 million of additional value (based on exports) within the next year. Farmers alone have the potential to add $15 million to $30 million in value over the next five years by implementing these immediate changes.

Over the next five years, the industry could reduce the required feed by 30,000 to 60,000 metric tons, which would save 10,000 to 20,000 metric tons of wild fish.[7] In addition, the introduction of RAS could save up to 20 million cubic meters of water, assuming no water exchange is required within the system.

Although this represents a meaningful step forward, individual changes pale in comparison with the value that could be created should the industry set its sights higher. If Indonesia attains its projected growth rate of 8% per year over the next five years, this would add about $400 million in value. Compare this with the global growth rate of 5% per year.

Immediate change on an individual basis enables short-term gains, but true change can be achieved only when industry players work together on a larger scale. What's needed is an innovative business model focused on long-term, inclusive sustainability.

INTEGRATED PLAYERS MUST SUPPORT THE SHIFT TO TRACEABILITY

STANDALONE PLAYERS CAN MAKE short-term changes that help their business thrive, but integrated players are uniquely positioned to leverage changes on a grand scale. The two largest integrated players in Indonesia—CP Prima and Japfa—own their own feed mills, hatcheries, and processing facilities, and they manage their exports. In addition, they either own farms or they contract with individual farmers and closely supervise farm management and shrimp quality.

As these integrated players shift toward more environmentally sound production, they must think carefully about how changes will play out at each step along the value chain. For example, when integrated players use growth enhancement functional feed, their feed mills will likely experience an 8% decline in feed sales, but if their farms adopt RAS and solar energy at the same time, farmers can more than double their profit margins and achieve a twofold increase in stocking densities. These dramatic improvements in the farming segment could, as a result, more than compensate for the losses in feed mills and support a virtuous cycle: higher farming output encourages additional shrimp farming, which increases the overall demand for feed.

In addition to short-term change, integrated players have a much more transformative opportunity within reach. With strong market power, access to financing, and the ability to scale, integrated players can push the entire industry in a new direction and advocate for an industry that delivers superior results at every level—for businesses, the environment, and society as a whole. Once leaders blaze the trail, others will be inclined to follow.

Two major shifts in the industry are already observable in some countries, and these will significantly transform the global shrimp market: full traceability and closed-loop systems. Traceability is key. No market claims can be made in the absence of transparency and traceability. With traceability, supply chain actions become visible, and actors can be held accountable for their actions. This, in turn, creates an incentive for sustainable and responsible production. Importers and regulators, as well as a niche consumer segment, are pushing for this at the global level. Retailers, too, want to track and trace products from pond to plate so that they can avoid product recalls and minimize the potential for reputational damage. Integrated players in Indonesia are positioned well to achieve full product traceability and become leaders for the rest of the industry.

For companies vying to become industry leaders, closed-loop systems are the next logical step. These allow for the production of large shrimp quantities in a controlled environment, reducing disease risk as well as mitigating major environmental hazards.

WITH TRACEABILITY, PRODUCERS CAN MEET EXPORT STANDARDS

To create value along the entire supply chain, leaders in the shrimp industry must ensure greater accountability and transparency and ultimately implement full product traceability throughout the supply chain.

As noted, regulators are requiring greater transparency as a precondition for shrimp import approvals, and they have repeatedly refused shrimp imports that fail to provide clean, contamination-free products. Between 2014 and March 2019, 71 lines of entry from Indonesia were rejected at the US border, mostly because the products were unclean. In comparison, 396 lines of entry from India were rejected during this same period. Still, rejections may increase now that the SIMP program requires stricter data reporting and record keeping.

Retailers and importers are pushing for full traceability, because it represents a necessity and a business opportunity. As one former executive of a major retailer in North America said, "If you could establish a fully traceable supply chain, so you know where your product is coming from at each step of the chain… that would have tremendous value. That is what everyone wants and needs." Consumers, too, are increasingly demanding it.

While traceable shrimp is still a niche market, that market is growing quickly, and Indonesian shrimp suppliers and buyers have much to gain from adhering to new government regulations focused on source, or origin, as well as from catering to environmentally and socially conscious consumers who are willing to pay more for greater assurances. First movers in this space can expect to achieve price premiums for fully traceable shrimp. Although traceability will eventually become the new norm and prices will come down accordingly, Indonesia should act now to differentiate itself and avoid being surpassed by competitors already moving in this direction. As noted earlier, the strong national demand for shrimp could potentially hinder the fast implementation of traceability in Indonesia.

The Far-Reaching Business Benefits of Traceability

Exhibit 9 outlines the following advantages and potential economic benefits of traceability for all players across the value chain:

- **More Efficient Farms.** With detailed data- and analytics-based records for each step along the supply chain, shrimp farms and production facilities can streamline operations, thereby increasing production volumes. Traceability can increase operational efficiency through record keeping, but that works only if farms take action accordingly.

EXHIBIT 9 | The Business Benefits of Traceability Are Multifold

More efficient farms
- Traceability allows for leveraging of data analytics
- With traceability, production can be streamlined to increase volumes
- Traceability is an enabler: farms and producers must act to increase efficiency

Sustainable production
- Transparency and accountability along the supply chain induce sustainable behavior
- Traceability allows for rewarding and punishing producers of sustainable and unsustainable products, respectively

Improved logistics
- Transportation routes are optimized with analytics
- Traceability allows for the minimization of food waste during transfer
- Traceability enhances the ability to deliver fresh products reliably

Sustainable access to markets
- There is a growing demand for traceable products
- Transparency is likely to become a major purchasing criterion
- Increasing numbers of regulatory bodies require traceability

Brand enhancement
- Traceability can be leveraged as a marketing differentiator
- Branding as a high-quality, high-value traceable supply chain attracts buyers and consumers alike

Opportunity for premium pricing
- Some consumers are willing to pay premiums for traceable food
- Increased wealth will spread along the value chain through token currencies and other rewards

Source: BCG analysis.

- **Sustainable Production.** With traceability, retailers can punish producers for their unsustainable practices by refraining from buying, and retailers along with consumers can reward producers for their sustainable practices by paying price premiums. And traceability enables precise tracking of production locations, potentially identifying farms located in, for example, protected or no-go areas such as protected mangrove forests.

- **Improved Logistics.** Transportation routes can be analyzed and optimized, minimizing food waste during transport and maximizing the ability to deliver fresh products.

- **Sustainable Access to Markets.** Buyers, especially those in sophisticated markets, will increasingly demand traceable products and eventually drop suppliers and markets that are not fully transparent and that represent a sustained reputational risk. Import authorities are establishing reporting and record keeping requirements for imports of certain seafood products to prevent illegal, unreported, and unregulated and misrepresented seafood from entering their markets.

- **Brand Enhancement.** Traceability secures the brand image and can be used as a key marketing differentiator when other claims cannot be validated.

- **Opportunity for Premium Pricing.** Some consumers are willing to pay a premium for traceable food products, making traceability a market differentiator. To spread the wealth along the supply chain, some technology providers, for example, are working to develop ways to share the rewards with upstream players through token currencies and other incentives.

To achieve these benefits, every player in the supply chain must participate and share trusted data with multiple stakeholders. Shielding supply chain data in modern value chains challenges the trust of those purchasing products and calls into question the reliability of companies that are perceived to have something to hide.

In addition to the business opportunities, there are also environmental benefits. Traceability can drastically reduce the ongoing mangrove deforestation. Today, it is nearly impossible to discern whether shrimp are coming from mangrove areas, but traceability could provide much-needed insight into this issue. Moreover, players that are not destroying mangroves gain the opportunity to credibly provide this type of information to retailers and consumers and differentiate their product.

Middlemen pose a major challenge: their movements are hard to track, and virtually no records of their operations exist. To avoid losing significance or, worse, posing an obstacle to industry advancement, middlemen will need to formalize their operations to provide greater transparency and accountability. The industry is also quite fragmented at the farm level. There is minimal data collection and little incentive to share data. In a fully traceable supply chain, each player must contribute to the collective industry effort. When traceability is done right, everyone wins.

Traceability Can Be Managed with Different Levels of Effectiveness and Maturity

There are many ways to implement traceability in supply chains, including supply chain integration and software solutions. (See Exhibit 10.)

For example, integrated players that have full control over their supply chains could provide traceability. This is easier said than done. Some integrated players produce less shrimp than their processing facilities have the capacity to process. As a consequence, they turn to middlemen for shrimp to fill their excess capacity, creating a significant traceability challenge. And because they rely on middlemen, it's very hard to trace shrimp.

Another technique is to verify the country of origin through elemental profiling. This new technique has emerged to provide a check on traceability claims. The procedure involves the analysis of a set of elements that make up a material or a species. Analysts can identify the country of origin of imported shrimp with up to 98% accuracy.[8] This technology represents a significant advance, but it serves only to verify the country of production. It does not represent full supply chain transparency, because it cannot track back to the specific farm that raised the shrimp, verify the production technologies and methods applied during production, or trace the trading route of the shrimp from production to point of entry.

Consequently, the technique adds another layer of oversight on the path toward traceability, but it is insufficient on its own. To achieve full supply chain traceability, technology and software-enabled solutions represent the most promising options.

Technology-Enabled Traceability Offers a Promising Path Forward

Traceability along the supply chain allows retailers to demonstrate environmental and social compliance, but it is not enough simply to make the claim. The industry needs tools that can accurately monitor and verify sustainable practices and hold players accountable to uniformly agreed-upon standards. Various technology-enabled traceability solu-

EXHIBIT 10 | Traceability Is the Future Norm for Supply Chains

Traceability can be addressed in multiple ways

Vertically integrated players	Full control of the supply chain by one vertically integrated company overlooking operations from production to export and sale
Elemental profiling	Analysis of shrimp species, allowing for determination of country of origin with up to 98% accuracy
Software solutions such as blockchain	Technology-enabled traceability ranging from easy-to-deploy mobile applications to sophisticated blockchain and Internet of Things solutions
Certifications	Production standards implemented on the farm and processing levels and labeled accordingly at the point of sale

Certifications provide only perceived traceability

Necessity

- **Regulators** require traceable products to authorize imports
- **Retailers** select suppliers upon provision of traceability and sustainability standards
- **Consumers** are increasingly aware of sustainability issues and are beginning to adapt buying decisions

Opportunity

- **Niche market** allows for premium pricing of up to 40% for traceable and sustainable products
- **New market access** is provided through high-quality traceable products
- **Reduction of bottlenecks and increased efficiency** are results of supply chain tracking

Source: BCG analysis.

tions, with differing levels of sophistication, are currently being developed.

Mobile applications can capture farm, production, and transaction data in real time to ensure full transparency. In this scenario, all players across the supply chain share records for each transaction: farmers can easily upload data to accessible online platforms, and all product transactions and movements are registered at each step of the supply chain.

Multiple countries and seafood companies are already experimenting with digital tools. In Indonesia, for example, RIKILT Institute of Food Safety of the Netherlands, working with FoodReg and Indonesia's MMAF, has implemented small-scale electronic traceability systems for individual family farmers. Additionally, Fishcoin, with technology providers such as FishTrax and SourceMap, has traced back to Indonesian fishers of P. monodon broodstock. However, these approaches have not yet been used on a national or industry-wide basis.

Mobile apps are easy to use, accessible, and affordable even for the smallest farmers, but they require every player along the supply chain to share truthful, verifiable data. Therefore, traceability must be coupled with transparency.

Pairing the Internet of Things (IoT) with blockchain represents another promising technological solution for tracing global food chains, in part because these technologies are rapidly becoming more affordable and accessible. Here is a quick look at how IoT and blockchain can be used:

- IoT devices capture production data at the source—for example, from shrimp farms.
- This captured data is stored in ledgers, which can time stamp, track, and automate transactions so that events can be audited in real time.
- As long as the suppliers enter accurate data, the blockchain establishes proof of quality and provenance across the entire value chain.

Several large supermarkets, including Walmart in the US and Carrefour in the EU, have already deployed blockchain to track the provenance of products in their food supply chains. Although they have determined that they can no longer opt not to know where food originates, they do not yet apply this standard to shrimp. The shrimp supply chain is complicated. Shrimp farmers are highly fragmented, middlemen play an outsize role in the value chain, and very little farming or hatchery data is collected, let alone shared across the supply chain. Consistent data collection is a prerequisite for successful traceability, and its lack consequently poses a significant barrier to implementation.

Many technology companies, including IBM, VeChain, Provenance, ConsenSys, and the newly founded OpenSC food-tracking platform are enabling traceability for various products, but these are more appropriate for products with less complex supply chains than that of the shrimp industry. Will shrimp be next?

Due to the dispersion of hatcheries, farms, and processors across Indonesia, full traceability will present challenges to implementation. Nevertheless, the industry as a whole needs to act to ensure continuing access to major markets as well as to reduce mangrove deforestation. Although traceability has the potential to improve farm management and preserve natural resources, it does not boost production volumes. For that, an even bolder approach is needed.

INDOOR FARMS WILL TRANSFORM INDONESIA'S SHRIMP INDUSTRY

While economic value can be derived from immediate change, traceability is rapidly becoming a business imperative, and many companies are pioneering disruptive new farming methods. Indonesian shrimp producers have the opportunity to innovate in this area before sustainability and traceability become the new normal.

One of the most promising opportunities is the shift to high-intensity, high-volume shrimp farming in closed systems. Compared with outdoor production, closed-loop systems provide significant environmental and financial advantages. These systems aim to reduce, reuse, and recycle water on the farm through various methods, such as filters. With higher biosecurity, farmers can increase stocking densities while reducing wastewater discharge.

The benefits of closed-loop systems can be further accelerated by operating indoors. The pond environment can be fully controlled so that external factors have only minor impact on shrimp production. In addition, farmers can ensure constant conditions in ponds, respond to diseases quicker, and mitigate environmental hazards and risks.

Closed-loop systems in indoor facilities are already in use in Thailand, Vietnam, the US, and Europe. The Thai conglomerate CP, for example, has invested in indoor farms and plans to shift all production to indoor ponds over the next five to ten years. With this shift, CP expects to increase capacity to at least 100 metric tons per hectare compared with the typical 18 to 50 metric tons per hectare produced annually in traditional outdoor systems.

Similarly, in Vietnam, the shrimp-producing company Viet-Uc is investing heavily in indoor-farming complexes and plans eventually to achieve 100% indoor production.

Some Indonesian farms have invested in the "supra intensif Indonesia" farming method, an environmentally friendly technique designed to boost shrimp production in cement-lined ponds with central drainage. These systems are considered closed-loop systems and, like RAS, they provide a first step in the right direction toward more environmentally sound shrimp production. However, this method is still outdoors, which makes it difficult to fully monitor and avoid contamination.

Because of the high capital investment, scale, and new construction required to implement indoor farms, these farms will—in the short-term—be financially viable for large-scale integrated players only. Furthermore, integrated players can combine indoor farming with full traceability if they exert power throughout the value chain. With indoor farming, integrated players could build even a state-of-the-art facility that combines all stages of shrimp production—from breeding to processing—under one roof, thereby guaranteeing total biosecurity and control over the culture environment.

Continung to compete on a global level, Indonesia's next step should be indoor farming. It makes it possible for companies to mitigate the increasing environmental hazards and risks the shrimp industry faces.

The closed-loop system offers the following clear advantages:

- Higher yields and reduced operational risks that are the result of having complete control over input, lower disease rates, smaller land requirements, and efficient feed use
- Improved and stable revenue streams
- Significantly reduced environmental impact due to less water and land use

Indoor farming offers the following advantages:

- Traceability, as long as the entire production process is integrated and the shrimp is not sold to processors by middlemen
- Reductions in costs and logistics because production can be located close to processing
- Simplified transportation and faster access to global markets
- Consistent year-round production with a secure supply of high-quality commodity shrimp
- No mangrove deforestation due to construction in highlands
- Control over inputs and no use of antibiotics
- Opportunity to increase control over social responsibility and ensure ethical conduct

The business case for indoor farming is still evolving. The costs—investment costs of up to $200,000 per hectare of pond area and operational costs of up to $4.14 per kilogram of shrimp for large indoor farms in Southeast Asia—are high compared with current costs for conventional farming: $3.18 per kilogram of shrimp. And international sales prices for commodity shrimp are, at least for the foreseeable future, low, making the business case for wholesale transformation an uphill climb in the short term and midterm. (See Exhibit 11.)

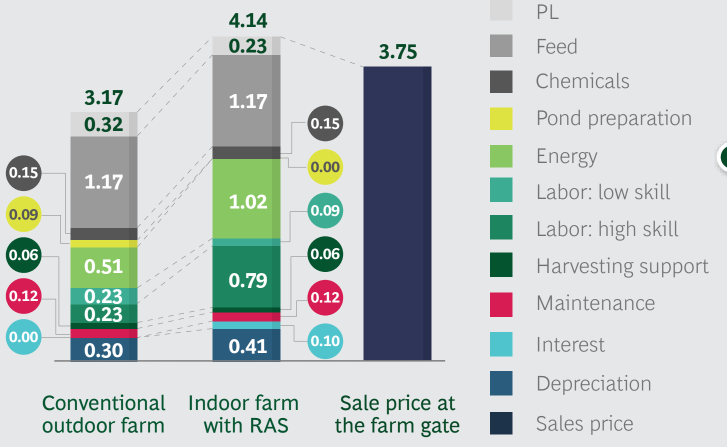
Although indoor-farming industry disruption will likely be led by large-scale industry leaders, small to midsize producers can begin moving in this direction by implementing closed-loop systems, such as RAS. When combined with removable pond covers, which add protection against external contaminants, even small to midsize players can create closed systems with better control and increased productivity, supporting the long-term industry shift to low-impact indoor farms.

As Indonesia's shrimp-farming industry moves toward intensification, closed systems and indoor farming represent a natural next step. Throughout the history of shrimp farming in Indonesia, industry players have moved from basic extensive systems—characterized by low stocking densities and high land use levels per kilogram of shrimp produced—to more intensified systems.[9] With higher levels of intensification, stocking densities and farm output per hectare have grown, and the amount of land required to produce a kilogram of shrimp has typically decreased. In turn, there will be increases in the risk of disease, total energy use, and per unit energy use. The disease risk can be mitigated by closed-containment farm operations and indoor systems.

Indonesian farmers use an intensive production method for 75% of shrimp. Stocking densities for average intensive farms in Indonesia range from 50 to 150 PL per square meter. (See Exhibit 12.)

Exhibit 11 | In Indonesia, Indoor-Farming Production Costs Are Higher Than Conventional Production Costs

A cost comparison of conventional outdoor and indoor farming with RAS ($ per kilogram of shrimp)[1]



Main cost driver: energy with additional higher labor, interest, and depreciation costs

PL costs are slightly reduced owing to improved survival rates (from 60% to 83%)

Feed, chemical, harvesting support, and maintenance costs are stable

Pond preparation is not required anymore

Energy consumption and costs double with RAS and increasing use of technology solutions and automation

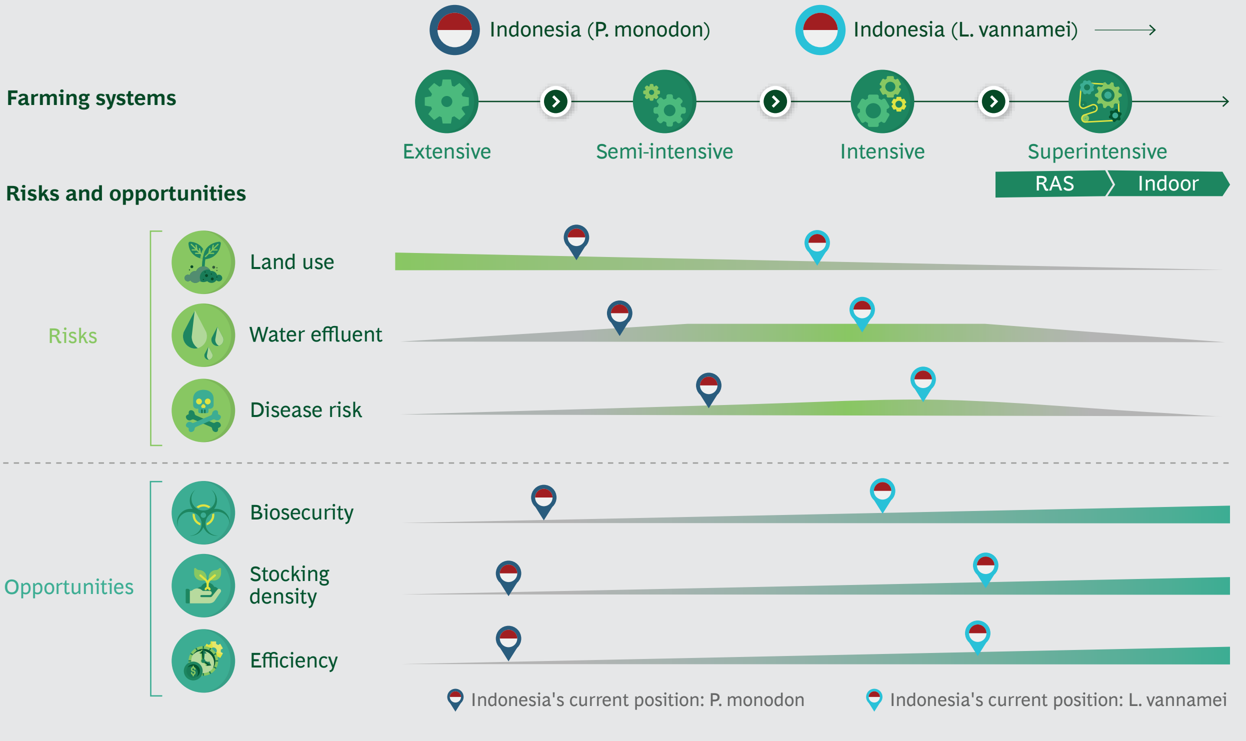
Labor costs increase slightly owing to a shift from low-skill to high-skill labor despite the overall reduction in the amount of labor required

Depreciation reflects high investment costs of $20,000 per 1,000 square meters of pond, around $0.20 per kilogram, based on production of 10 kilograms per square meter annually over ten years

Interest reflects financing through bank loans

Sources: Expert interviews; BCG analysis.
Note: RAS = recirculating aquaculture systems. PL = post-larvae shrimp. Because of rounding, not all numbers add up to the totals shown.
[1]Expert estimates.

Exhibit 12 | Comparison of P. monodon and L. vannamei production systems in Indonesia



Source: BCG analysis.
Note: L. vannamei = Litopenaeus vannamei; P. monodon = Penaeus monodon; RAS = recirculating aquaculture systems.

THE SHRIMP INDUSTRY MUST TRANSFORM WHILE TIMES ARE STILL GOOD

SOME 3 BILLION PEOPLE rely on wild-caught seafood and aquaculture products as their primary sources of protein, and it is becoming an increasingly important source of protein around the world. Shrimp consumption within Indonesia is projected to increase as well, accounting for about 45% of Indonesia's total shrimp production in 2020.

Indonesian producers are already feeling the pressure from policymakers to provide traceability, and because of their strong competitive position and reputation as reliable sources of shrimp, they have an excellent opportunity to be among the frontrunners in traceability and sustainability. Although Indonesia's demand for domestic shrimp is strong, the push for traceability is gaining momentum and will eventually become the new norm in global shrimp supply chains.

This is not just a business imperative. In light of the growing global population and increasing demand for food, shrimp producers will face increasing pressure to safeguard the biodiversity and ecosystems that are vital for our planet's well-being. There is already strong pressure, globally and nationally, to halt mangrove deforestation and support mangrove reforestation. These challenges affect the entire food industry and require all its participants to reduce their environmental impact.

Indonesia must respond. A small number of players in Indonesia as well as Indonesia's MMAF are blazing the trail toward more environmentally friendly production, but they are lagging behind other Asian countries, such as Thailand and Vietnam, that have already taken steps toward closed-loop indoor intensification. Despite these early initiatives, there is no clear winner in the sustainable and traceable market segment yet.

To defend Indonesia's global leadership position and deliver lasting environmental and social impact, Indonesian shrimp producers must invest in full supply chain traceability as well as R&D for closed-loop indoor farming. In embracing this approach, Indonesia will have opportunities to increase profitability across the board while satisfying consumer demand and regulatory requirements for food safety, traceability, and ecofriendly business practices. If the industry can successfully navigate these transitions, participants will reap rewards for generations to come.

APPENDIX

This Appendix provides an overview of the technical details of functional feed, water improvement systems, and solar energy, including a discussion of the business case for solar energy, as well as the market dynamics and short-term business case analyses of the various value chain participants: feed mills, hatcheries, farmers, and middlemen, as well as processors and exporters.

APPENDIX

FUNCTIONAL FEED, WATER IMPROVEMENT SYSTEMS, AND SOLAR ENERGY

This section of the Appendix focuses on three factors—functional feed, water improvements and solar energy—that can drive improvements to both the economics and environmental footprint of shrimp farming.

Details on Functional Feed

The costs and operational requirements associated with functional feed vary among farmers. (See Exhibit 13.)

Growth enhancement functional feed is a complete feed (rather than an isolated compound) that is designed to promote specific physiological effects that allow farmers to grow larger shrimp faster and more efficiently. Many varieties of functional feed are available on the market, and companies are competing to develop the most effective products. We define growth enhancement functional feed as feed that includes a variety of additives—such as special proteins, vitamins, and probiotics—that promote faster growth.

For example, bioactive powder (Novacq) can improve growth rates of farmed shrimp:

- It reduces reliance on harvesting wild fish for feed.
- Its use promotes up to 20% to 30% faster growth.

This improvement in growth, which helps farmers increase the number of production cycles per year if they use the feed continuously, can lead to significant improvements in biomass and productivity.

Health enhancement functional feed aims to improve shrimp survival and to increase productivity by optimizing the shrimp's digestive efficiency. This type of feed is especially useful for mitigating risk when the threat of disease is high.

For example, phytobiotic additives can promote better health:

- They can be used in functional feed or as separate additives.
- Phytobiotics produced from herbs and organic acids are known to be effective at boosting immunity and improving functional properties of the compounds in the gut.
- Similarly, additives such as Digestarom improve gut health and improve FCR.
- In tests with CP basic feed in Thailand, Liptofry increased FCR and survival rates under normal conditions and led to stable survival rates when challenged by EMS bacteria.

Exhibit 13 | Functional Feed: The Impact, Costs, Requirements, and Results

	FOCUS				
	Growth enhancement functional feed	Health enhancement functional feed	Transportation and storage	Feeding method and technology	Farming system and management
Operational impact	Potential for FCR improvement Possibility of larger shrimp	Avoidance of crop loss at times of high risk of disease	Appropriate storage important to maintain feed quality	Method and technology relevant to FCR and survival rate	Critical for overall operational success and controlling risk of disease
Cost impact	Higher feed costs; less feed required	Higher feed costs; crop loss avoided	Minor cost factor	Possibility of high investment costs for new technology Potential impact on labor	High impact on costs based on efficiency and risk management
Requirements and assumptions	Larger shrimp; higher sale price possible	Consideration of the risk of disease and crop loss	Farmers have appropriate storage No known major issues	New technology to support new feeds and improve impact and success	Farmers rely on feed mills for information and best management practices
Results	✓ EBIT margins are 46% higher for Indonesian farmers	✓ Loss from diseases avoided; higher revenues	✗ No significant impact on farmers' P&L	+ Support for successful introduction of new feeds	+ Critical for FCR, survival, and risks on farms

✓ Clear quantifiable business case   + Prerequisite for quantifiable business cases   ✗ Not relevant to the business case

Source: BCG analysis.
Note: FCR = feed conversion ratio.

Details on Water Improvement Systems—Biofloc and RAS

Water treatment systems aim to improve water quality, reduce water use, and recycle water. They vary in application and effects, terms of sophistication, levels of water reuse, and cost. Many systems use microbes to regulate water quality and imitate natural water conditions. Exhibit 14 provides an overview of commonly used closed-loop and microbial systems.

Two approaches to improving water quality during shrimp production—biofloc and RAS—have been modeled in detailed scenarios. (See Exhibit 15a.)

With biofloc, carbohydrates are added to the water, increasing the carbon-to-nitrogen ratio. The nitrogenous waste blends with other bacteria, algae, and fungi, creating a biofloc that increases water quality while reducing FCR, as it can also be used as a feed source for shrimp. (See Exhibit 15b.)

Biofloc can have positive environmental impact. It leads to a statistically relevant decrease—up to 73%—in pond water nitrite levels: 0.13 milligrams per liter of nitrite-nitrogen. This represents a significant improvement and is in line with the maximum nitrite level—0.18 milligrams per liter—mandated to protect freshwater aquatic life.

With RAS, water is treated through multiple filters, allowing for its reuse, and no unfiltered wastewater is discharged into the local ecosystem. The most common systems include a mechanical biofilter and a degasser. The water is enriched with oxygen and disinfected with ultraviolet light before it is readmitted to ponds.

Exhibit 14 | Overview of Water Quality Enhancement and Closed-Loop Systems

Nonexhaustive

Zero water discharge	• Low-to-no water discharge • Better than conventional systems • Emphasis on microbial manipulation • Use of microbial loop system to remove toxic nitrogen compound • Microbial consortia added regularly to the system • Microbial component kept dominant in the system • Need for additional compartment for separated microbial cultivation
Biofloc	• Low-to-no water discharge • Better than conventional systems • Addition of carbon source to enhance heterotrophic bacteria consortium • Emphasis on the system's carbon-to-nitrogen ratio • Conversion of "waste" nitrogen to highly concentrated total suspended solid (microbial biomass) that can act as high-protein feed for cultured animal • Optimal aeration and biofloc ingredient mix required
Periphyton	• Low-to-no water discharge • Better than conventional systems • Need for organic substrate such as bamboo for periphyton attachment • Organic input such as manure and chemical fertilizers to trigger periphyton growth • Occasional need for additional carbon source to maintain the carbon-to-nitrogen ratio • Periphyton acts as toxic nitrogen removal system and food source for cultured animals
Biofilm	• Low water discharge • Better than conventional systems • Use of formed biofilm to remove toxic nitrogen compound during culture period • No control of microbial consortia • A potential food source for cultured animals
Defined biofilm	• Need for additional reactor and attachment substrate • Defined microbial consortia in biofilm (predominantly nitrifying bacteria) • Main purpose: removal of toxic nitrogen substance from the system • Applicable in the system or in an external unit such as a biofilter
RAS	• No water discharge • Involvement of many treatment processes, including physical and chemical treatments • Microbial compartment in the biofilter • Biofilter has defined microbial consortia • Isolated, clear-water system • Main purpose: biologically secured and hygienic aquaculture product • Higher investment and operational costs than for other systems
Green-water technique	• Low water discharge • Use of batch system • Use of primarily autotrophic microalgae as microbial component in the system • Utilization of chemical fertilizer and organic waste to trigger phytoplankton growth • No control of the system's microbe community • Main purpose: to provide natural food for cultured animals

Sources: Gede Suantika et al., *Aquaculture Engineering*, 2018; BCG analysis.
Note: RAS = recirculating aquaculture systems.

RAS offers significant advantages for farmers:

- The various filters and water treatments improve water quality.
- Water conditions are continuously monitored and, if necessary, automatically adjusted, reducing the stress level of the shrimp and enabling farmers to increase stocking densities.
- RAS reduce the need for chemicals, and automation decreases labor requirements.

Still, it's important to consider the challenges that RAS pose to wide implementation:

Exhibit 15a | Capital Investment and Operating Costs Are the Main Concerns in Method Selection

FOCUS

	Water treatment: biofloc system	Water recycling: RAS	Integrated aquaculture: integrated multitrophic system
	Inserting bacteria or chemicals to reduce water pollution	Treating water to allow for water reuse within farms	Introducing additional species that use waste as a source of nutrients
Advantages	• Improved feed conversion rate • Decreased required protein content in artificial feed • Increased growth rate	• Increased survival rate • Increased stocking densities • Decreased disease risk • Stabilized water conditions	• Diversified economic income
Disadvantages	• Increased energy costs (energy outtakes critical) • Advanced technical skills required • Constant monitoring needed • Further research necessary	• Significant initial investment costs from $15,000 to >$300,000 • Increased energy costs • Advanced technical skills required • Constant monitoring needed	• Decreased shrimp productivity • Disease spread among additional species or plants • Advanced technical skills required • Further research necessary

Source: BCG analysis.
Note: RAS = recirculating aquaculture systems.

Exhibit 15b | The Addition of Carbohydrates to the Water Leads to the Assimilation of Nitrogenous Waste

Input: carbohydrates

Farmers add carbohydrates in the form of molasses or cornmeal to water

Chemical reaction

Increases the carbon-to-nitrogen ratio

Owing to the additional carbohydrates, the ratio of carbon to nitrogen increases

Stimulates heterophobic microbial growth

The nitrogenous waste (unused feed and excreta) is assimilated and—together with other bacteria algae, and fungi—compounded as biofloc

Shrimp use biofloc as a feed source

Similar or higher protein levels (25% to 50%, compared with 35% in regular feed) and fat content (0.5% to 15%, compared with 4% to 6% in regular feed) of biofloc

Improved water quality

The reduction of nitrogen improves the water quality

Reduced FCR

Because it has nutritional value, biofloc reduces the amount of additional feed required

Source: *Aquaculture*; BCG analysis.
Note: FCR = feed conversion ratio.

- Installation of the necessary filters and treatment tools imposes high upfront investment costs that vary depending on the overall size of the farm (larger farms benefit from economies of scale), sophistication of the system, and the equipment used (some of which requires higher energy use).

- Basic biofilters that are integrated into existing production systems without further investments in equipment can be obtained at a cost that ranges from $15,000 to $50,000 per hectare, which could be high for farmers.

- Investment costs for more sophisticated systems that use filtration systems and specialized pond equipment range from $50,000 to $150,000 per hectare.

- Sophisticated RAS that include significant alterations to the production facilities, equipment, and possibly even involve indoor operations, can cost $300,000 per hectare or more to set up.

- With greater control over the culture environment, it is possible to mitigate the outbreak of disease. However, should an outbreak occur, it would affect a larger amount of shrimp as a result of increased stocking densities, resulting in greater losses.

Details on Solar Energy

Farmers in remote islands can reduce their environmental footprint and avoid disruptions in energy supply by shifting to renewable energy. Four types of renewable energy are available—solar power, wind power, biomass, and solar thermal power. Our analysis focused on solar. (See Exhibit 16.)

There are three types of solar energy available to shrimp producers: photovoltaic (PV) cells that can be installed on the ground in close proximity to ponds and with a tracking system, PV cells that can be installed above the surface of ponds, and PV cells with a tracking system that can be installed above ponds.

Each option has different implications in terms of land use, water evaporation, electricity production, and investment costs, which range for ground-mounted PV from $1 million per megawatt to $1.7 million per megawatt, including storage costs. Farm size, loca-

EXHIBIT 16 | Evaluation of Four Types of Renewable Energy Sources for Shrimp Farming

	FOCUS Solar power	Wind power	Biomass	Solar thermal power
Location requirements	Evaluation of solar radiation required	Evaluation of average wind speed required	Evaluation of available biomass in region required	Evaluation of solar radiation required
Advantages	Potential synergies with aquaculture in the case of floating PV systems	Relatively small land footprint in the case of small-scale wind turbines that can be placed close to the ponds or on the aerators	Potential synergies: biomass can be grown in the same ponds as shrimp; seaweed also improves water quality	Can be stored more efficiently than electrical energy
Disadvantages	PV has a relatively large footprint and occupies land that could be used for ponds	Shrimp farms located in flat coastal areas that offer only light sea breezes instead of strong winds	Limited commercial small-scale projects and technologies; environmental impact of generated gas	Limited commercial small-scale projects and technologies; required land is a potential issue (similar to solar power)

Sources: Commonwealth Scientific and Industrial Research Organisation; BCG analysis.
Note: PV = photovoltaic.

tion, and regional characteristics—including the cost of fuel, reliability of the energy supply from the grid, and solar irradiation—should all be taken into account prior to making an investment.

APPENDIX

MARKET DYNAMICS AND THE ENVIRONMENTAL IMPACT OF IMMEDIATE CHANGE

To calculate the business case for each step along Indonesia's shrimp value chain, the base case (today's average) was derived from BCG knowledge, proprietary data, and industry expertise and was subsequently validated in expert interviews and with secondary research. The analysis then identified key parameters affected by changes to current operations and estimated their business impact. Each business case calculation is displayed as a relative delta to today's average, the base case. For each step along the value chain, we also analyzed the overall market structure and the environmental impact of immediate change.

Feed Mills

Market Dynamics. In 2017, annual production of Indonesia's shrimp feed industry was about 450,000 metric tons of shrimp feed. Production is expected to grow at about 8% per year. Shrimp probiotics are expected to grow in volume at about 9% per year. (See Exhibit 17.)

The feed market is dominated by six players with a combined market share of 78%: CP Prima, Cheil Jedang Indonesia, Japfa, Gold Coin, Matahari Sakti, and Grobest. CP Prima alone has around 27% of the market. Approximately 80% of the feed is sold directly through the companies rather than through wholesalers or agricultural input stores. Nevertheless, for small-scale farmers, these intermediaries play an important role.

Business Case. Exhibit 18 shows the average economics of today's feed mills. We looked at two types of functional feed: growth enhancement and health enhancement.

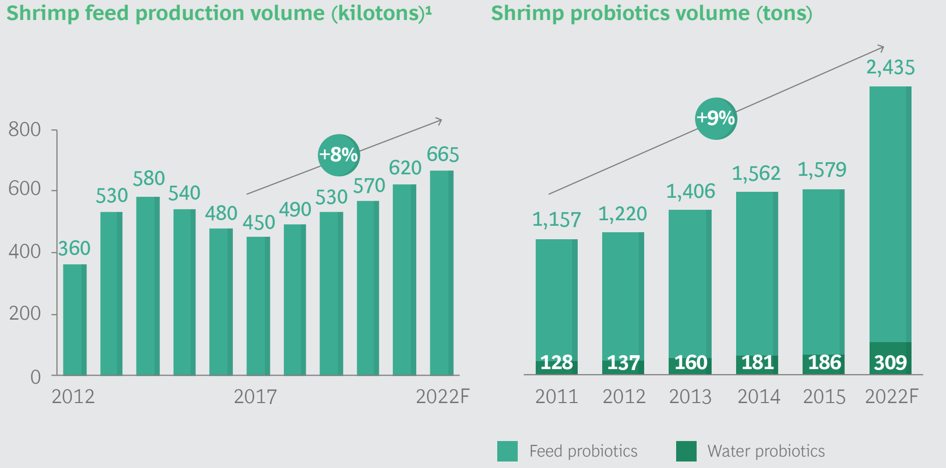
Growth Enhancement Functional Feed. The use of growth enhancement functional feed enables higher efficiency in shrimp farming. Demand falls when farmers use functional feed, and revenues could decline by as much as 8% owing to lower feed mill sales.

However, there is the possibility of increasing today's EBIT margins by a factor as high as 2.6, and, as farmers will not use functional feed continuously, the impact on feed mill revenues is expected to be marginal.

The following are the assumptions on which we based the business case calculations for growth enhancement functional feed for feed mills:

- Revenues per kilogram of feed sold increase because feed mills can charge a price premium of up to 20%.
- Production and input costs increase about 6% per kilogram of feed produced.
- The potential FCR improvement at the farm level is 30% for half of the growth cycle, leading to an overall FCR of 1.11, reducing demand.

Exhibit 17 | Shrimp Feed and Probiotics Production in Indonesia Is Expected to Grow, Owing to Higher Farm Intensification and Expansion



Comments

Low growth from 2012 through 2017 due to shrimp disease outbreaks and closure of PT Dipasena group farms by CP Prima

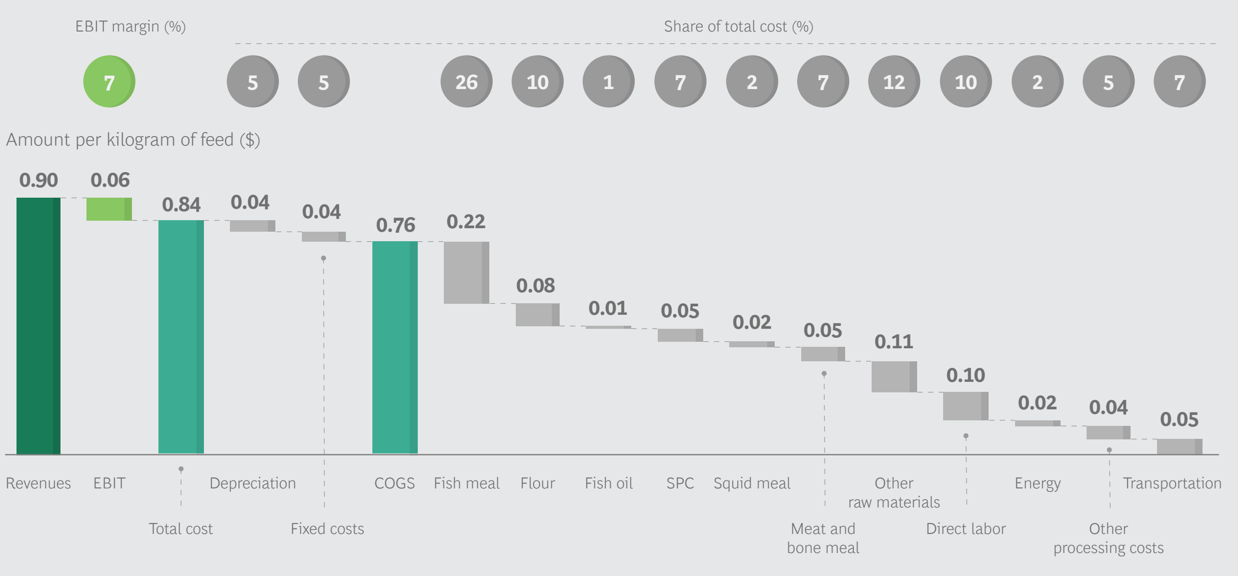
Probiotics growth due to a ban on the use of antibiotics and increases in production volume and farming area

Steady growth from 2017 through 2022 due to continuing expansion and intensification of farms

Sources: Global Aquaculture Alliance, GOAL; Indonesian Feedmills Association; Ipsos; Rabobank; FAO; expert interviews; literature research; BCG analysis.

[1] The overall production output estimates, which do not include farm-based feed, are underestimated in comparison with total shrimp production.

Exhibit 18 | The Economics of Today's Average Feed Mill

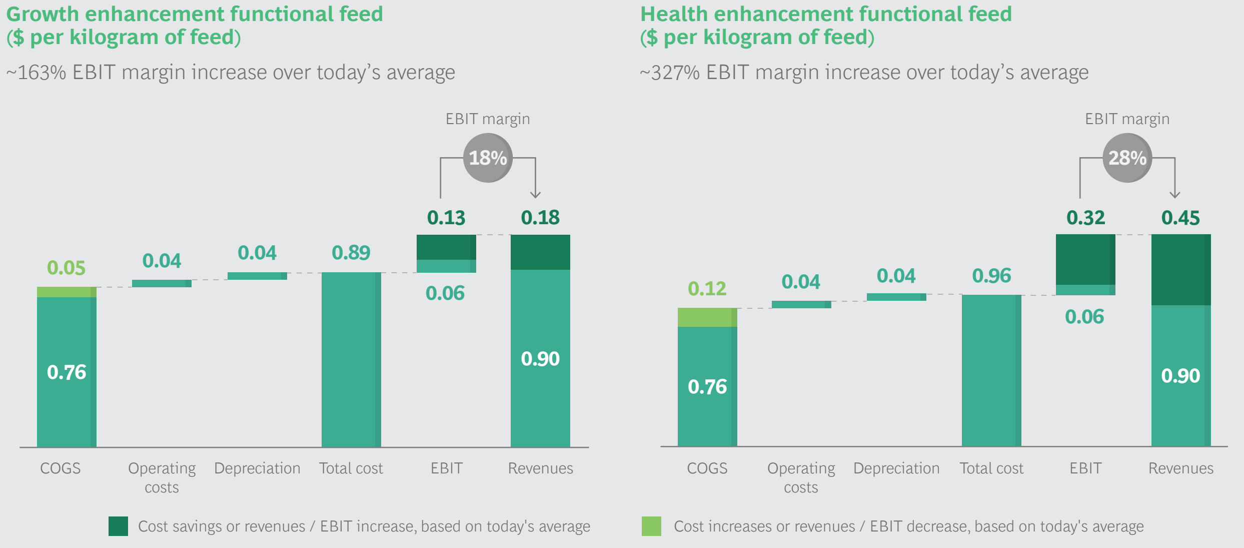


Source: BCG analysis.
Note: SPC = soy protein concentrate; COGS = cost of goods sold. Because of rounding, not all numbers add up to the totals shown.

Health Enhancement Functional Feed. Feed mills can achieve revenue increases of up to 50% owing to high price premiums. The premiums result in profit margins that are about 4.3 times today's average EBIT margin. (See Exhibit 19.) The following are the assumptions on which we based the business case calculations for health enhancement functional feed for feed mills:

- Revenues per kilogram of feed sold increase because feed mills can charge a price premium of up to 50%.
- Production and input costs increase about 15% per kilogram of feed produced.

EXHIBIT 19 | Feed Mills Can Increase Margins Fourfold



Source: BCG analysis.
Note: COGS = cost of goods sold. Because of rounding, not all numbers add up to the totals shown.

- The disease survival rate increases from a range of 20% to 30% to a range of 70% to 75%. (This is particularly relevant for farmers who deal with high risk of disease.)

Environmental Impact. The overall impact on the environment is limited, but feed mills enable positive change at the farm level:

- The use of health enhancement functional feed for feed mills improves efficiency and reduces farm waste. With lower mortality rates, for example, less feed goes to waste.

- Through reduced feed use in general and through the inclusion of ingredients that replace fish meal and oil, the use of land, water, antibiotics, and the need for wild-caught fish is reduced. (See Exhibit 20.)

- It's important to further consider ingredients used in functional feed—as a substitute for fish meal—in terms of their effect on the environment. Greater dependence on soy, for example, has negative implications for the environment, because soybean production is causing widespread deforestation.

Hatcheries

Market Dynamics. The overall market volume for PL in Indonesia is about $25 billion to $32 billion per year. Hatcheries are spread throughout the islands to ensure a secure supply of PL for farmers. The market is dominated by large and midsize hatcheries, which account for about 80% of market share. L. vannamei broodstock is sourced primarily from Hawaii, Florida, and Taiwan, as well cheaper options in China. (See Exhibit 21.)

CP Prima dominates the PL market for L. vannamei, with about 40% to 50% of market share. Multiple smaller players exist that have invested in the production of specific pathogen-free L. vannamei broodstock.

High-quality PL are essential for preventing disease, and therefore the relationship between hatcheries and farmers is crucial. In addition, the hatchery sector is regulated to prevent nationwide outbreaks of diseases and ensure a stable supply of PL. During the EMS disease outbreak in Asia, the Indonesian government also established import barriers to ensure that no foreign or contaminated PL could enter the country. By law, hatcheries in Indonesia must be certified.

Exhibit 20 | A Shift to More Efficient Functional Feed Reduces Negative Environmental Impact

	Land use	Water use and pollution	Chemicals and antibiotics	Use of fish and wild catch
Nutrient content: growth enhancement	Up to 15% land use reduction for feed due to increased feed efficiency (during half of the growth cycle)	Reduced water pollution due to more efficient feed with less feed waste in the water	Replacement of antibiotics with probiotics	**For growth and health enhancement:** Substitution of fish meal and fish oil in development for both kinds of functional feed
Nutrient content: health enhancement	Improved resource use and reduced waste due to increased survival rate and shrimp loss avoidance	Reduced water pollution due to more efficient feed with less feed waste in the water	Replacement of antibiotics with probiotics; health improvements through, for example, the use of phytobiotics and amino acids reduce the need for medical interventions	Ambition to replace all fish meal use with plant-based nutrients

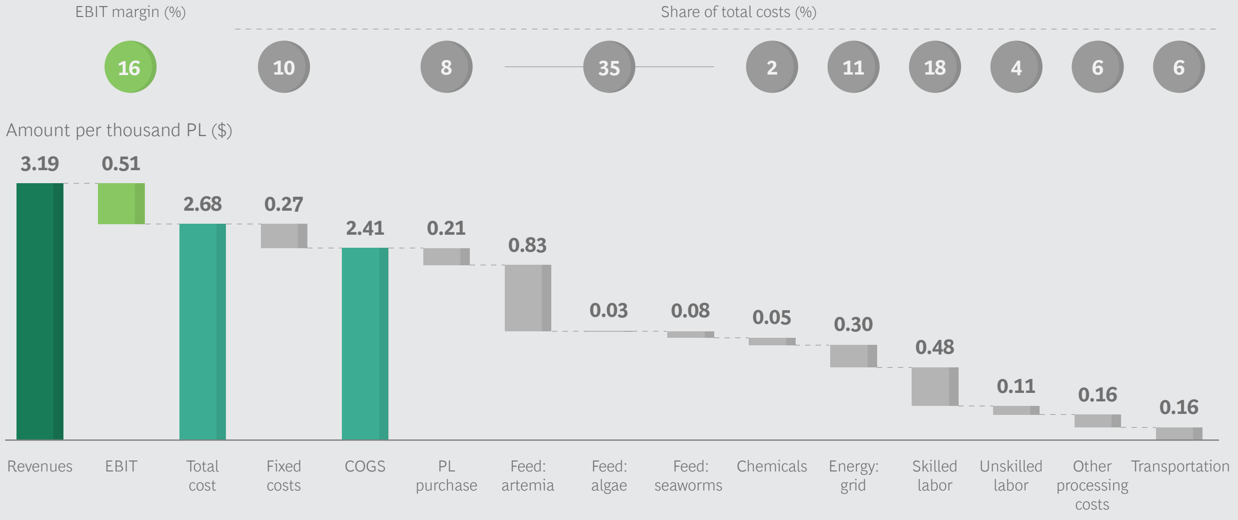
Source: BCG analysis.

Exhibit 21 | L. Vannamei Broodstock Sourcing and PL Sales Through Different Channels

Sources: Australian Centre for International Agricultural Research; expert interviews; University of Technology Sydney; BCG analysis.
Note: L. vannamei = Litopenaeus vannamei; PL = post-larvae shrimp; F1 type = imported; N1 type = local.

Business Case. Exhibit 22 illustrates the average economics of today's hatcheries. Even with no quantitative business case assessment, it's clear that high-quality PL contribute to better results for the industry overall.

Exhibit 22 | The Average Economics of Hatcheries Today



Source: BCG analysis.
Note: COGS = cost of goods sold; PL = post-larvae shrimp. Because of rounding, not all numbers add up to the totals shown.

Environmental Impact. The hatcheries have only limited impact, and water treatment and antipollution measures could further reduce their impact. Better PL quality leads to better survival for shrimp, reducing the impact of failed production on farms. This is a key driver for future value.

Farmers

Market Dynamics. The farming market in Indonesia is highly fragmented, with small "contract" farmers and independent corporate farmers—farmers that sell to preferred companies and have direct contracts or agreements with these companies—making up around 50% of the market. Integrated corporate farmers account for about 30% to 40% and individual small-scale farmers for about 10% to 20%.

CP Prima dominates the farming market with 20% to 25% of the market. Japfa has 5% to 10% of the market, and Sekar Bumi, Bumi Menara Internusa, and ATINA are also well represented.

Approximately 80% of Indonesian farms are extensive, with low stocking densities per unit area, but they make up only 10% of total production. In contrast, intensive farms—with high production per unit area—account for 75% of total production while representing only about 20% of farms. The remaining production volume is produced by a small number of superintensive or supraintensive farms.

Middlemen still play a significant role in the lives of individual farmers, particularly small-scale farmers who may have had limited access to schooling or finance. A study of 138 small-scale farmers in Indonesia found that only 60% had self-financed farms. The rest relied on loans from family or middlemen. (See Exhibit 23.)

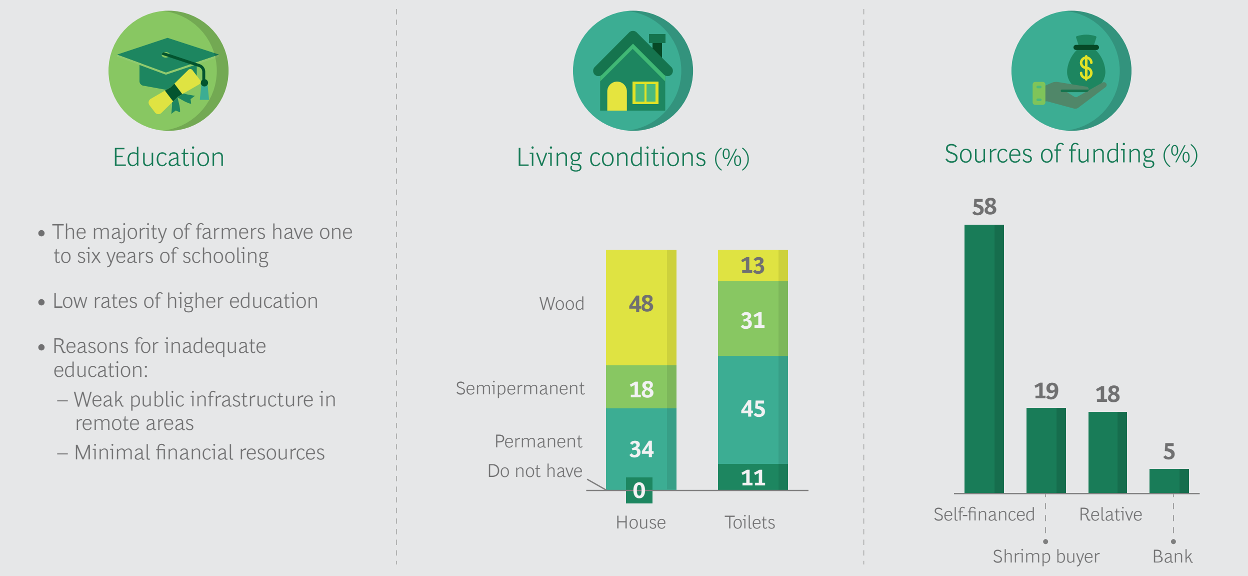
Business Case. Exhibit 24 shows the average economics of today's farms. We explored the impact of a number of factors related to farm economics and environmental impact, individually and in combination: functional feed, biofloc, RAS, and solar energy.

Functional Feed. The use of growth enhancement functional feed can lead to EBIT margins of up to 23% at the farm level, representing an increase of up to 46% in EBIT margins over today's average. (See Exhibit 25.)

The assumptions for the business case calculations for growth enhancement functional feed are the following:

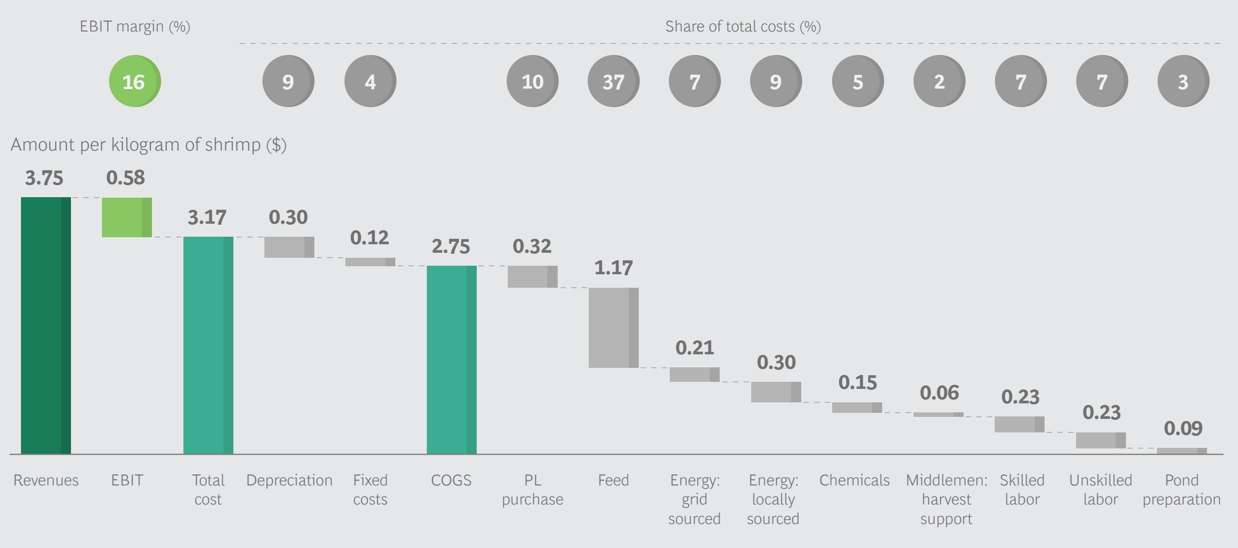
- Farms that can grow shrimp faster and larger within the same timeframe can charge a sales price that is 6% higher.

Exhibit 23 | Case Study: It's Difficult to Make a Living as a Small-Scale Shrimp Farmer



Sources: University of Technology Sydney; BCG analysis.
Note: The data is based on a case study of 138 small-scale farmers across Indonesia.

Exhibit 24 | The Average Economics of Farms with Successful Harvests



Source: BCG analysis.
Note: PL = post-larvae shrimp; COGS = cost of goods sold. Because of rounding, not all numbers add up to the totals shown.

- Growth enhancement functional feed lowers FCR by 30%, but because it is used during only half of the growth cycle, the FCR would be lowered by 15%, compensating for the 20% increase in feed prices.

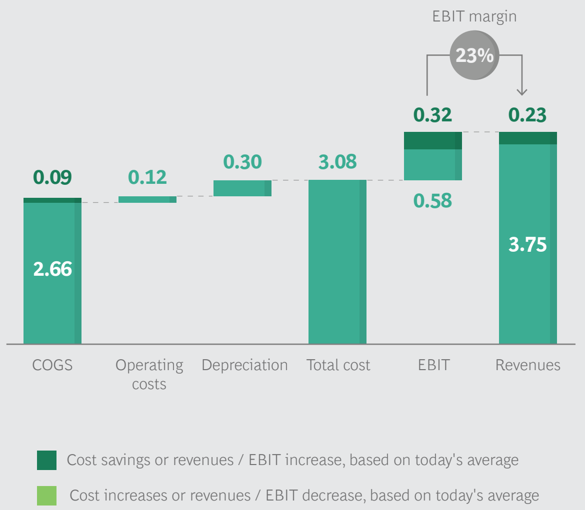
- There is no need for larger investment, but farmers can pay higher feed costs up front.

The use of health enhancement functional feed is not economically viable for farmers if used continuously: that would result in a steep decrease in EBIT and possibly negative EBIT margins caused by sharp increases—as much as 50%—in feed costs. However, if disease outbreaks are anticipated, it would be possible to achieve an EBIT margin as high as 17%, com-

EXHIBIT 25 | Growth Enhancement Functional Feed with an EBIT Margin Increase of up to 46%

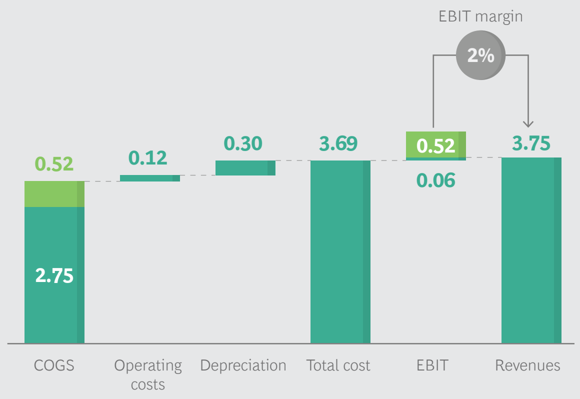
Growth enhancement functional feed ($ per kilogram of shrimp)

Up to 46% EBIT margin increase over today's average



Health enhancement functional feed ($ per kilogram of shrimp)

Close to 90% EBIT margin loss from today's average



Health enhancement functional feed needs to be considered in times when harvest losses would normally occur owing to disease outbreaks. In this case, health enhancement feed can achieve up to **17% EBIT margins** compared with a drop to **2% EBIT margins** with basic feed.

Source: BCG analysis.
Note: COGS = cost of goods sold. Because of rounding, not all numbers add up to the totals shown.

pared with 2%, when disease hits and basic feed is used. This assumes that 20% of crops are affected by disease and treated with health enhancement feed. Health enhancement feed serves as a risk management tool for farmers. Although it offers a clear financial incentive, to achieve its benefits requires long-term planning, management, and foresight.

The business case calculations for health enhancement functional feed for farms are based on the following:

- Feed is sold at a premium of up to 50% above the price of conventional feed.
- There is no change in FCR, but survival rates rise from a range of 20% to 30% to a range of 70% to 75%.
- Scenario 1. Using basic feed for the entire production, about 80% of the crops are successful with a 60% survival rate, and 20% of crops hit by disease have a survival rate of only 20%.
- Scenario 2. Using basic feed two-thirds of the time, successful crops have a 60% survival rate, and using health enhancement functional feed one-third of the time to avoid disease achieves a survival rate as high as 74%.

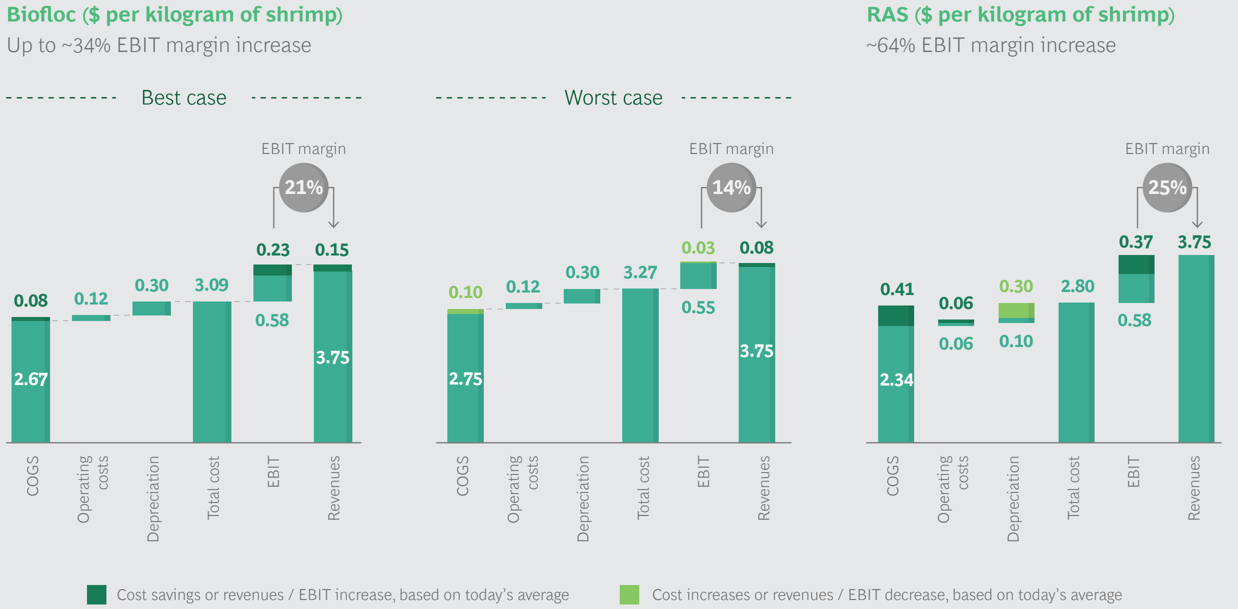
Environmental Impact. If farmers increase their efficiency, less feed will pollute the water, and the use of growth enhancement feed can indirectly reduce the impact of overfishing and lead to a positive environmental impact.

Biofloc and RAS. The business case for using biofloc depends on a farm's technical management, which influences prices, costs, and production parameters such as FCR and growth cycles. In the best-case scenario, farmers achieve EBIT margins as high as 21%, increasing margins as much as 34%. By contrast, in the worst-case scenario, margins drop slightly, leading to overall EBIT margins as low as 14%. If farmers are knowledgeable and consistently monitor the system, they can expect to achieve the best-case scenario. (See Exhibit 26.)

The assumptions for business case calculations for biofloc for farms include the following:

- Energy costs increase 20% to 40% owing to the extended need for aerators.

Exhibit 26 | Biofloc Can Increase EBIT Margins by as Much as 34%, While RAS Can Increase Them by as Much as 64%



Source: BCG analysis.
Note: RAS = recirculating aquaculture systems; COGS = cost of goods sold. Because of rounding, not all numbers add up to the totals shown.

- The costs for skilled labor increase 5% to 10% owing to the need for higher controls and constant supervision.
- FCR decreases by 25% because biofloc can be used partly as a feed source.
- The costs for chemicals decrease by 3% to 7% due to water quality improvement through biofloc use.
- The additional cost for cornmeal as a carbohydrate source ranges from $0.23 to $0.36 per kilogram. (For a kilogram of shrimp, approximately 0.6 kilograms of cornmeal is a required biofloc ingredient.)
- The survival rate is similar to that of a system without biofloc.
- Due to the protein content in biofloc, the growth rate increases by as much as 27%, allowing farmers to benefit from a 2% to 4% higher sales price for larger shrimp.

Farms that use RAS can see EBIT margins rise by up to 64% per kilogram at the farm gate, achieving EBIT margins as high as 25%. Additionally, overall revenues are boosted owing to higher stocking densities and, consequently, higher yields.

Assumptions for business case calculations for RAS include the following:

- Stocking densities could double, owing to better water quality and improved monitoring of water conditions.
- Investment costs of $150,000 per hectare, depreciated over ten years, could lead to an expected yearly yield of 60,000 kilograms per hectare (based on increased stocking densities).
- The risk of disease is lower due to superior water quality and higher biosecurity, leading to improved survival rates.
- Variable costs decrease by 15%, reflecting increased energy and maintenance costs, reduced labor costs due to higher automation and higher stocking densities, reductions in the amount of chemicals required, and lower disease risk.
- Higher stocking densities lead to a 50% decrease in fixed costs.

The increase in stocking densities is maximized in indoor systems. Therefore, an investment in RAS is recommended only as part of a shift to indoor systems. With indoor farming, the water quality and shrimp conditions can be fully controlled to minimize contamination, allowing for even higher stocking densities and higher survival rates.

Environmental Impact. The environmental impact of biofloc and RAS is positive. With biofloc, better water quality leads to less pollution, eutrophication, and ground water contamination, permitting water recycling and reducing water intake. Lower FCR has an indirect impact on feed production and the potential to reduce the amount of wild fish used in feed. RAS reduce the intake of new water (except to make up for seepage and evaporation), but because energy consumption is higher, there is the risk of higher air pollution if diesel generators are used. Still, the use of RAS has the potential to reduce land use, because the increase in stocking densities allows for higher output per hectare.

Solar Energy. The use of solar energy can be beneficial for farms in remote areas with an unstable grid connection. Currently, these farms use diesel generators to ensure a constant energy supply. Diesel generators are expensive and a source of pollution. For remote farms, renewable solar energy represents a reliable, economic, and clean alternative.

Although on the basis of the cost per megawatt hour, solar energy is more expensive than grid energy, it is significantly less costly than diesel. Replacing diesel generators with solar energy can yield an increase of up to 17% in EBIT margins.

This said, the initial investment for PV systems requires significant investments—up to $15,000 to $25,000 per hectare, depending on the system and whether battery storage is required—which small farms in remote areas may not be able to afford.[10] But as the costs of batteries and solar power continue to decrease, this option could eventually become more affordable for remote farms as well as grid users.

The total EBIT margin can be as high as 17% when solar energy is combined with grid energy, representing an increase of up to 9% EBIT margin compared with today's average. (See Exhibit 27.)

Assumptions for business case calculations for solar energy for farms include the following:

- A levelized cost of energy for solar options, including batteries, is estimated to be higher than for grid energy but significantly lower than for diesel generator use.
- The shift to solar energy is relevant and applicable only for farms in remote areas with high diesel generator use.
- A levelized cost of energy for solar is $150 per megawatt hour for a ground-mounted PV system with the tracking option.
- The grid energy price is $83 per megawatt hour, and the diesel energy price is $183 per megawatt hour.

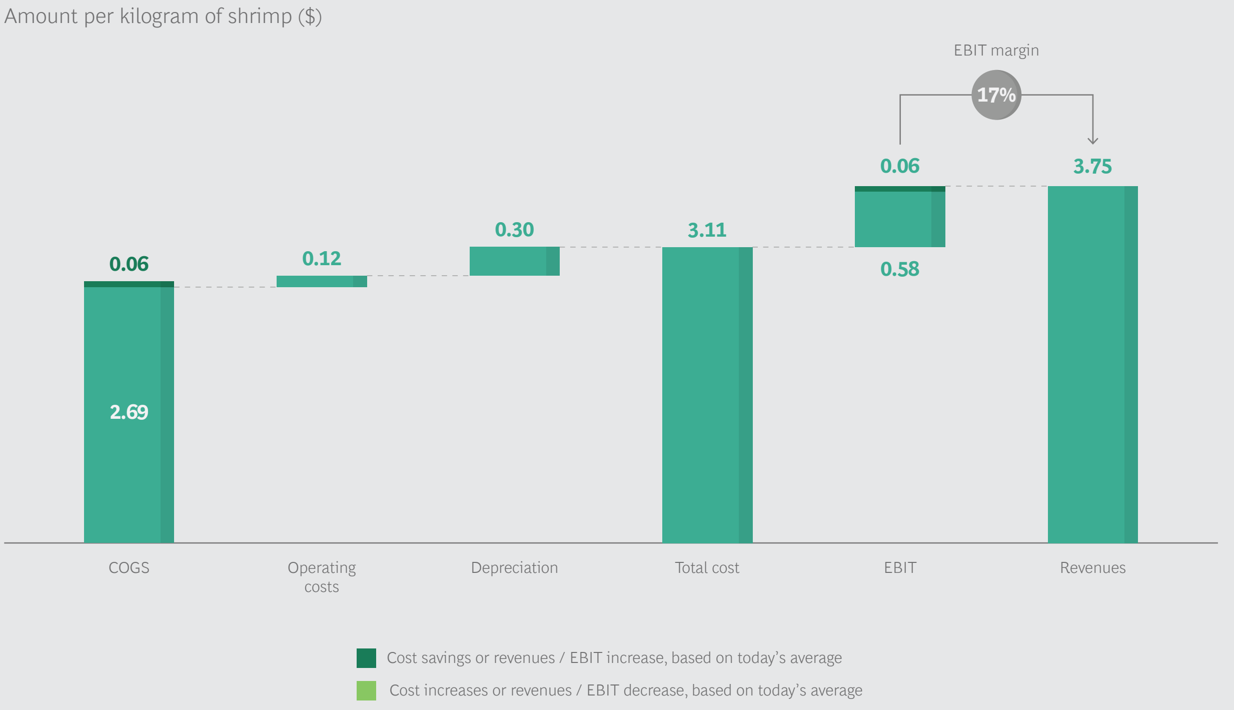
Environmental Impact. In terms of environmental impact, solar energy, unlike diesel-generated and grid-sourced energy, reduces carbon emissions. However, in some cases, construction of solar panels still affects land use.

Combined Options: Growth Enhancement Functional Feed, RAS, and Solar Energy. The combination of growth enhancement functional feed, RAS, and solar energy yields EBIT margins of up to 33%, representing an increase over the base case by a factor of about 2. (See Exhibit 28.)

The assumptions for business case calculations for the combined use of growth enhancement functional feed, RAS, and solar energy for farms include the following:

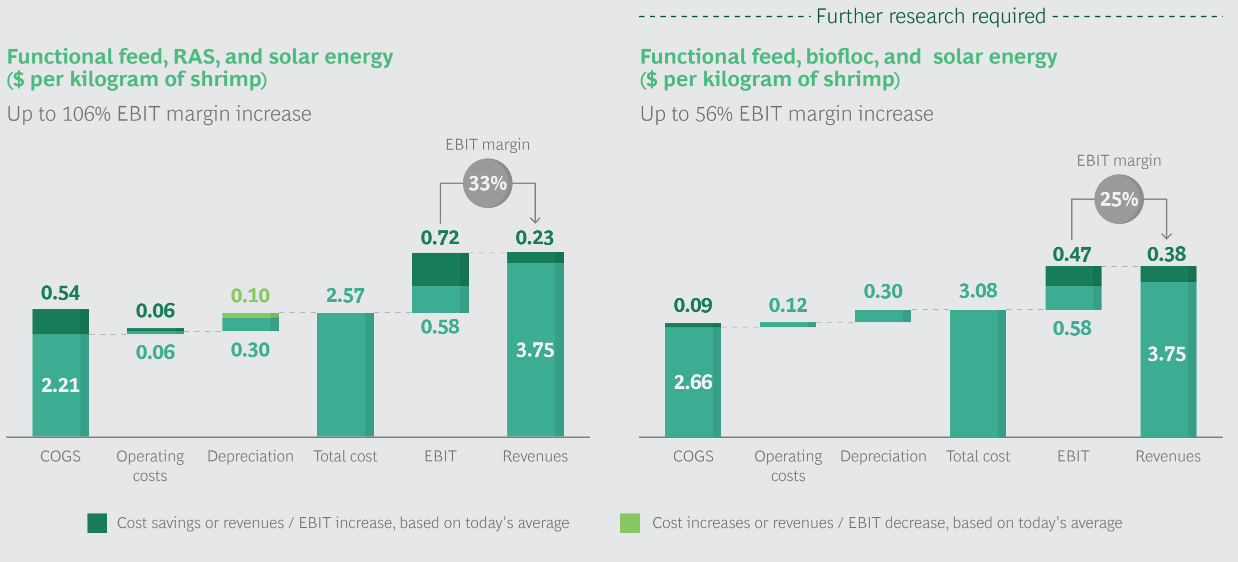
- The assumptions are comparable to standalone solutions, as the three methods affect different variables.
- Doubled stocking density is possible due to higher water quality and improved monitoring of water conditions.

Exhibit 27 | The Use of Solar Energy Generates a 9% Increase in EBIT Margins



Source: BCG analysis.
Note: COGS = cost of goods sold. Because of rounding, not all numbers add up to the totals shown.

Exhibit 28 | A Combined Solution Can Double EBIT Margin, Yielding a Higher Potential Benefit Than a Standalone Solution



Source: BCG analysis.
Note: RAS = recirculating aquaculture systems; COGS = cost of goods sold. Because of rounding, not all numbers add up to the totals shown.

- FCR is reduced by 15% owing to the use of functional feed during half of the production cycle.

- A 6% increase in the shrimp sales price is due to larger shrimp size based on the use of functional feed.

- For half the growth cycle, there is a 20% increase in the feed sales price, and additional feed mill costs are incurred.

- A 20% decrease in overall variable costs is the result of the combination of a cost increase that is due to the use of functional feed and a decrease in the cost per kilogram that is due to the use of RAS and solar energy.

- There is a 50% decrease in fixed costs due to RAS.

- Investment costs of $176,000 per hectare are depreciated over ten years with an expected yearly yield of 60,000 kilograms per hectare—double today's average.

Combined Options: Growth Enhancement Functional Feed, Biofloc, and Solar Energy. The combination of functional feed, biofloc, and solar energy provides a better business case than today's average economics. Nevertheless, it is difficult to compare it with the standalone feed or biofloc business case, as both improvement levers—growth enhancement functional feed and biofloc—affect the same production parameters (for example, FCR) and their combined impact has not been studied yet.

Assumptions for business case calculations for the combination of growth enhancement functional feed and biofloc for farms include the following:

- FCR improves up to 32%, as the functional feed and biofloc can reduce FCR. Compare this with a 15% reduction through the use of growth enhancement functional feed and a 25% reduction through biofloc. (The effect on the FCR is not the sum of both standalone options, as the combined impact has not yet been studied in depth.)

- The sales price increases up to 10% because a higher price can be achieved for larger shrimp. Accelerated growth through the combined use of functional feed and the high protein content of biofloc lead to even higher prices achievable in the market if global shrimp prices are correspondingly high.

- Additional cost assumptions for biofloc (averaged best and worst cases) include for skilled labor, increases of 8%; for energy, increases of 30%; for chemicals, decreases of 5%; and for cornmeal as a carbohydrate source, about $0.30 per kilogram—about 0.65 kilograms of cornmeal per kilogram of shrimp produced—needed for biofloc development.

However, as indicated above, the combination of the two options still needs in-depth assessment, and these assumptions must be validated through further research.

Middlemen

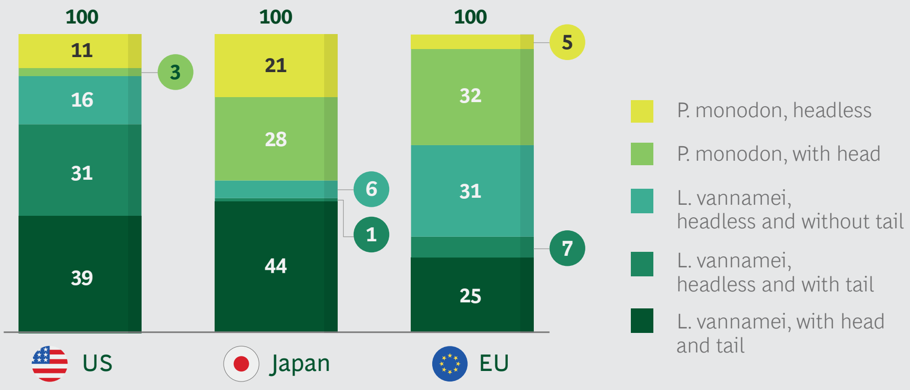
Market Dynamics. Middlemen handle business interactions between the largely fragmented farmers and processors and wholesalers. There can be as many as three different middlemen playing a role between farmers and processors, with profit margins of 1.4% to 5%. Farmers choose middlemen for various reasons: to ensure transportation of shrimp across the islands, to obtain the required input materials, and to provide financing.

The network of middlemen—collecting and aggregating shrimp from multiple farms and then delivering the regrouped batches of shrimp to processors—is a major point of nontransparency along the value chain. During this process, the origin of single shrimp products becomes untraceable. Due to their practices and the sector's informality, middlemen present major challenges to progressing toward traceable supply chains.

Business Case. No quantitative business case was assessed, but middlemen can play a key role in moving the industry toward traceability. Currently, it is difficult to trace and track shrimp in Indonesia because, in many cases, middlemen mix and sort shrimp from multiple farms.

Exhibit 29 | Countries Demand Different Types of Processing

Distribution of export volume per country, by type of processing (%)



Comments

US demand is primarily for L. vannamei shrimp with tails

Japan demands more P. monodon shrimp than the US and EU

EU prefers L. vannamei with or without tails

Sources: Fish Quarantine Inspection Agency, Indonesia; BCG analysis.
Note: L. vannamei = Litopenaeus vannamei; P. monodon = Penaeus monodon. Percentages are based on exports of five processing categories; other types of shrimp and types of processing are not accounted for.

Environmental Impact. If the industry aims to provide fully traceable shrimp, middlemen might have to be cut out. Alternatively, shrimp producers could formalize the role, working with a few trusted middlemen who provide buyers with clean, traceable shrimp. Middlemen can also decrease their environmental footprint by ensuring that no drugs are injected into shrimp and by providing guidance to farmers on best practices.

Processors and Exporters

Market Dynamics. Shrimp processors in Indonesia are highly fragmented. Integrated players, such as CP Prima (15% to 20% market share) and Japfa, play an important role in both processing and exporting. In addition, many midsize downstream integrated players, such as Bumi Menara Internusa, Sekar Bumi, and ATINA, process and export shrimp. There are various types of processed shrimp, such as shrimp with or without heads and shrimp with or without tails. The type of processing depends on the preferences of export countries. For example, the US imports less shrimp without heads and tails than the EU. Moreover, in Japan, there is a clear preference for P. monodon shrimp. (See Exhibit 29.) In 2017, approximately 240,000 tons in total were exported from Indonesia, mainly to the US (60%) and Japan (19%).

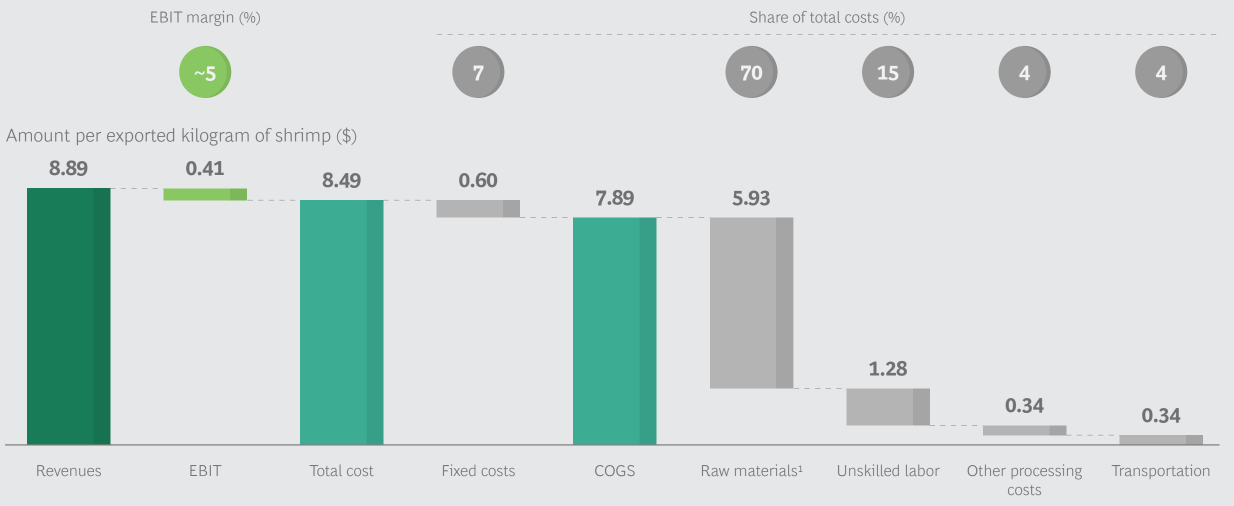
Business Case. Exhibit 30 illustrates the average economics of today's processors.

Because processors are at the intersection of buyers and retailers, they are directly affected if retailers refuse to buy Indonesian shrimp owing to environmental concerns, including the ongoing mangrove deforestation in selected shrimp-producing areas, or if retailers want better traceability and sustainable supply chains and are willing to pay a premium.

This opportunity for premium pricing currently exists only for niche markets: the mainstream market is competing on price. If processors drive positive change in the upstream supply chain, they will yield high benefits, including sustained access to larger quantities of high-quality shrimp, market access, and good relationships with buyer markets.

Environmental Impact. Processors' support for traceability would reduce land use, including mangrove deforestation, as well as water and energy consumption. Additionally, processors have an obligation to improve social norms and concerns, including labor conditions.

Exhibit 30 | Today's Average Economics of Processors



Source: BCG analysis.
Note: COGS = cost of goods sold. Because of rounding, not all numbers add up to the totals shown.
[1]At least 1.3 kilograms of raw shrimp are required to produce output of 1 kilogram of frozen shrimp.

NOTES

1. Although exact production estimates differ by source, an overall output volume of 490,000 tons of shrimp in 2017 is assumed throughout this report.
2. This estimate is based on the number of households involved in brackish-pond farming in 2010.
3. Based on crop losses incurred for shrimp production at the end of the production period.
4. FCR indicates how much feed is needed for the production of 1 kilogram of shrimp.
5. RAS provide farmers with a way to reuse water on the farm, hence dramatically reducing freshwater intake as well as wastewater discharge into the environment.
6. Based on energy use per hectare of shrimp produced per year: approximately 30 tons of shrimp with electricity requirements of about 125 megawatts per year.
7. Based on an equal production output and unchanged content of wild fish per kilogram of shrimp feed.
8. Li Li, Claude E. Boyd, Phoebe Racine, Aaron McNevin, et al. "Assessment of elemental profiling for distinguishing geographic origin of aquacultured shrimp from India, Thailand and Vietnam," *Food Control* 80 (2017): 162–69.
9. PL stocked per square meter in brackish water for the production of shrimp.
10. This is based on the energy use per hectare of shrimp produced per year: 30 tons of shrimp with electricity requirements of 125 megawatt hours per year.

NOTE TO THE READER

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