A Strategic Approach to Sustainable Shrimp Production in Vietnam

THE CASE FOR IMPROVED ECONOMICS AND SUSTAINABILITY

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A STRATEGIC APPROACH TO SUSTAINABLE SHRIMP PRODUCTION IN VIETNAM

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EXECUTIVE SUMMARY

The Vietnamese shrimp industry must take immediate action to keep up with fast-moving competitors.

- Early in this century's second decade, Vietnam, trailing China and Thailand, was the third-largest shrimp producer in the world, but nations such as India, Indonesia, and Ecuador have surpassed Vietnam in productivity. Vietnam is now the fifth-largest producer, with a global market share of about 11%, and its shrimp production is expected to increase by only about 2% in 2019.

- Vietnam has developed a robust business model around reexports. Other countries, such as India, export raw shrimp to Vietnam for additional processing and reexport. This model has been successful for many years, but it makes product traceability difficult and creates a dependency on other countries for imports.

- The Vietnamese government recently developed a master plan for expanding shrimp exports and supporting more sustainable shrimp-farming methods. To achieve these goals, shrimp producers need to make significant operational changes.

Vietnamese shrimp producers can make short-term changes to improve existing systems and boost EBIT margins, but those changes would be only stopgap measures.

- New and improved farming methods—including functional feed that promotes shrimp growth and health, as well as treatment systems that improve water quality—are emerging. These methods can boost farming efficiency and EBIT margins by up to about 40% in the near term and can improve biosecurity on individual farms.

- But these short-term changes don't address the risks inherent in the Vietnamese shrimp industry's current business model—nor do they help the industry move toward sustainability.

To unlock the industry's potential, boosting productivity, increasing traceability, and conserving resources are imperatives for Vietnamese shrimp producers.

- Import authorities in major markets, such as the US and the EU, are instituting and enforcing tougher regulations to increase food safety. China, too, is demanding higher standards and controlling formal and informal trade more closely. If Vietnam fails to meet these stricter import regulations, it risks forfeiting more than $2 billion in revenues.

- As global consumers and retailers grow increasingly concerned about the environmental and social issues surrounding the shrimp industry—including water pollution, destruction of coastal habitats, and human and labor rights abuses—the push for product traceability is intensifying.

- Traceability will be difficult to achieve in Vietnam because the market is highly fragmented, middlemen play an outsize role, and the reexport model makes it difficult to achieve end-to-end transparency.

- But full product traceability across the supply chain offers significant long-term benefits, allowing producers to maintain full market access, enter new niche markets, charge premium prices for a niche segment, avoid import bans and product recalls, and gain a competitive edge within the industry.

With closed-loop systems and indoor farming, large Vietnamese shrimp producers could position themselves as pioneers among industry leaders.

- Closed-loop systems, such as recirculating aquaculture systems, represent a significant opportunity for increasing efficiency and output on farms while reducing disease risk and pressure on the environment.

- Taking one more step, indoor farming would further accelerate these effects and facilitate traceability for players with control over the supply chain. However, as it requires a major financial investment as well as in-depth technical knowledge, and because it can be difficult to scale, this option is viable primarily for large players, of which there are only a few in Vietnam.

- If implemented on a large scale, closed-loop systems and indoor farming present a path to strong future performance.

By moving toward traceability and indoor farming, the Vietnamese shrimp industry could build a solid foundation for the future. Competitors are moving quickly, and the time to act is now.

This report highlights the current and near-term challenges that face the Vietnamese shrimp-farming industry and offers recommendations for what Vietnamese shrimp producers and traders can do to create a sustainable and traceable business model.

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 metric tons in 2000 to about 4.2 million metric 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 wild-caught and farm-raised shrimp, was valued at about $40 billion. The dominant species of farmed shrimp, Litopenaeus vannamei (L. vannamei), or whiteleg shrimp, accounted for about $14 billion. Shrimp production worldwide is expected to grow by more than 5% 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, Thailand and Vietnam were leaders in the shrimp-farming sector, but the competitive landscape has shifted. Disease outbreaks and rising labor costs have threatened this once-thriving industry in both countries, and competitors such as India and Indonesia have seized the opportunity to dramatically increase their share in the global shrimp market by producing large volumes at low prices. India has become the second-largest shrimp producer worldwide, accounting for 14% of global shrimp production with 600,000 metric tons produced annually, while Vietnam's production is stagnating at 450,000 metric tons.

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.

Vietnamese 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 sustainable, 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. 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 segment is willing to pay a premium for it.

A 2015 survey of approximately 3,000 consumers worldwide found that about 68% wanted to know where their food was coming from and how it was 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 an increasing number of major retailers are requiring suppliers to sign contracts that ensure traceability and adherence to ecofriendly production methods as a form of legal risk insurance. 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. Stated simply, sustainable products should be produced today in ways that do not compromise the ability to produce those same products tomorrow. Products should use no antibiotics, minimize damage to the environment, preserve natural resources, and 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.

These global trends have affected many shrimp-producing countries and will increasingly shape their future. Vietnam is being heavily influenced by these market forces and related risks, but opportunities for the nation's shrimp-farming industry are plentiful. In this report, we analyze the current state of the shrimp-farming industry in Vietnam, examine future implications for the market, and provide recommendations for action.

VIETNAM IS LOSING GROUND TO OTHER SHRIMP-FARMING NATIONS

VIETNAM IS THE FIFTH-LARGEST shrimp producer globally. In 2017, the Vietnamese shrimp industry produced roughly 450,000 metric tons, accounting for about 11% of global output.[1] (See Exhibit 1.) With low production levels, high occurrence of disease, and growing challenges associated with environmental degradation, Vietnam has struggled to compete with low-price competitors. In recent years, Vietnam has been overtaken by Indonesia, India, and Ecuador in terms of production volume.

Growth of the Vietnamese Shrimp Industry Is Sluggish

Despite the Vietnamese government's growth targets of 7%, in the first two months of 2019, the shrimp industry's annual growth rate was only 1%.[2] Overall growth levels for 2019 are forecast at just about 2%, lagging well behind global growth levels of more than 5% and historic growth levels in Vietnam.

According to official—likely overstated—statistics, in 2017, Vietnam's farmed-shrimp export market was valued at $3.4 billion. On the basis of the value of the total shrimp market, this translates to an overall global market share of about 9%.[3]

By volume, farmed shrimp is, after catfish, the second most important aquaculture species in Vietnam, and it accounts for about 50% of the overall value of seafood exports.

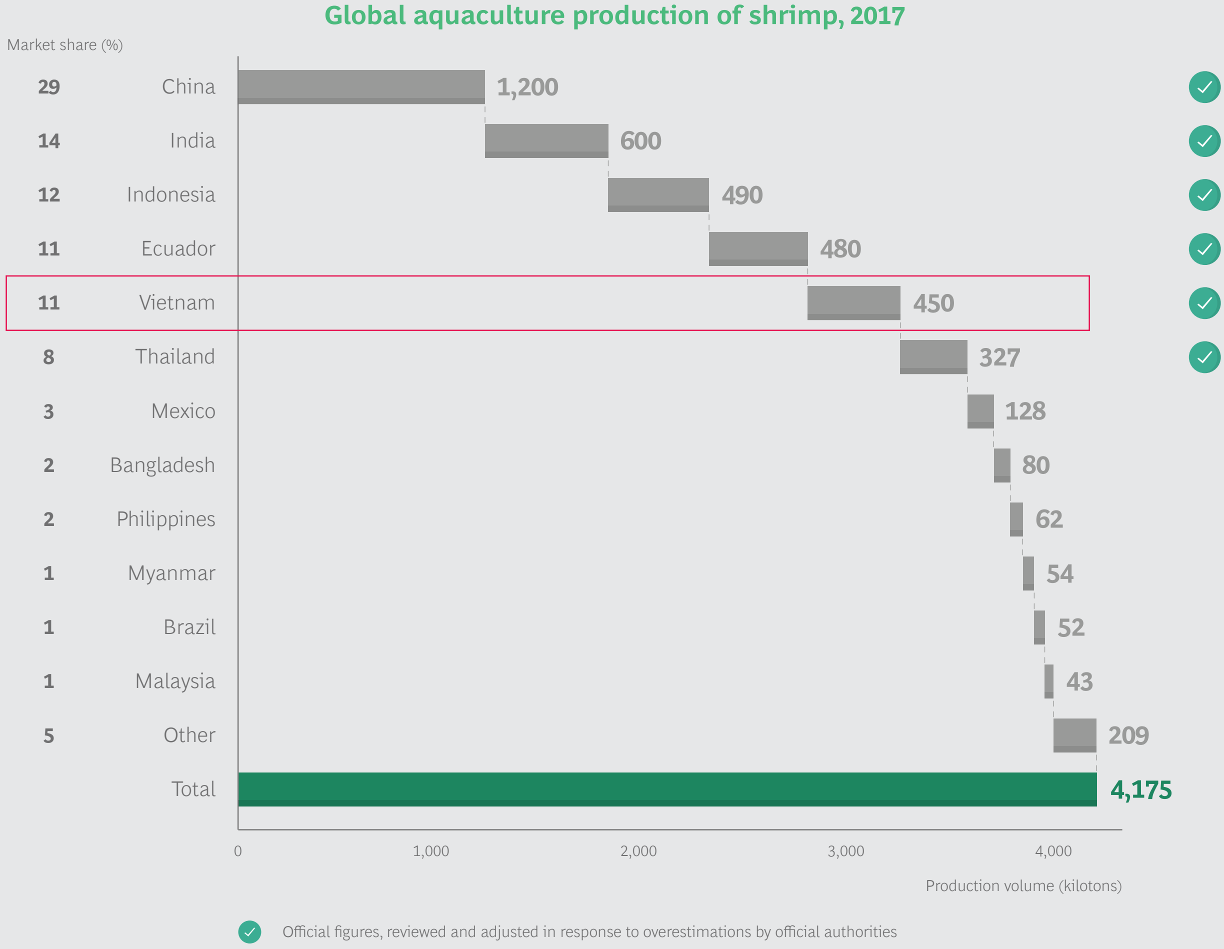
In 2017, the fishery sector contributed about 4% to 5% to the Vietnamese GDP and 0.2 percentage points to overall GDP growth of about 7%. Farmed-shrimp revenues from exports accounted for about 2% of the total GDP.

The aquaculture sector in Vietnam employed about 1.6 million people in 2017, mostly women. Shrimp farming provides a livelihood and income for about 220,000 Vietnamese farmers, mostly on small farms run by families who depend on shrimp farming for their income and suffer considerably when there are harvest losses.

There are two farmed-shrimp species in Vietnam: L. vannamei, also known as whiteleg shrimp, and Penaeus monodon, or P. monodon (black tiger shrimp). L. vannamei accounts for about 60% of production and that share is growing. P. monodon accounts for about 40% of total production, experiencing only marginal and even negative growth rates. Export prices for the two shrimp species vary significantly, but L. vannamei is generally cheaper.[4] Competitors, such as India, are undercutting Vietnam's pricing of L. vannemei by as much as 15%.

In 2017, the most important export nations for Vietnam were the EU, Japan, China, and

EXHIBIT 1 | With 11% Market Share, Vietnam Is the World's Fifth-Largest Shrimp Producer



Sources: Cámara Nacional de Acuacultura; Food and Agriculture 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.

the US. (See Exhibit 2.) Given that shrimp has historically been part of the illicit "grey" trade between Vietnam and China, exports to China may be significantly higher than official statistics indicate.

Overall, Vietnam maintains favorable positions with its major export countries. Vietnam's exports receive preferential tariffs under the EU's generalized system of preferences, and the US lifted its antidumping tariffs in 2018.

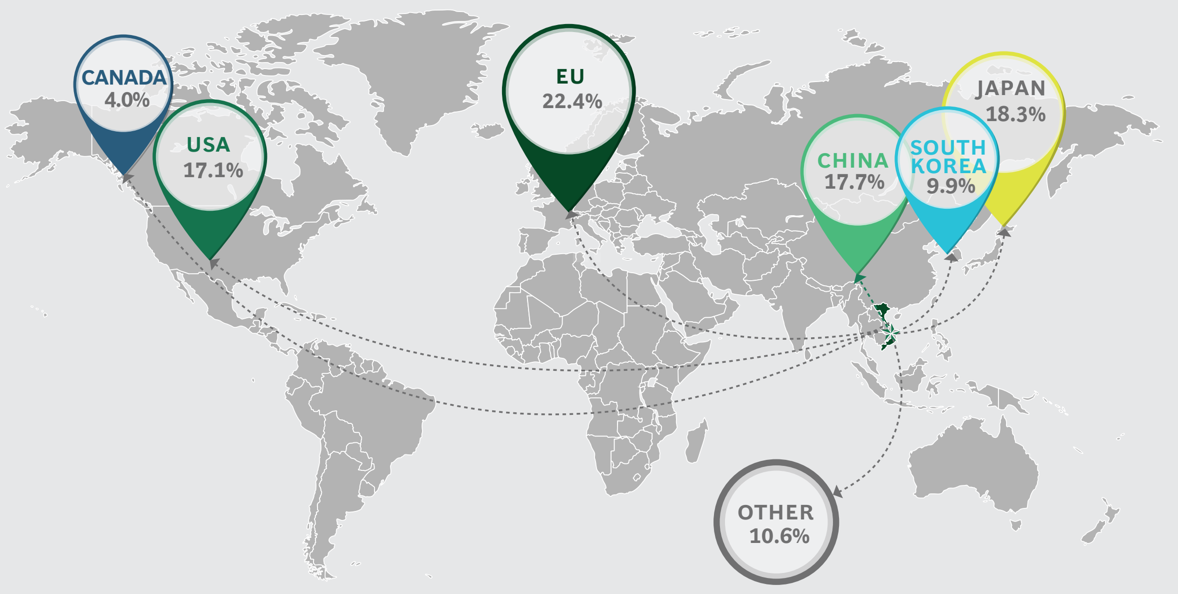
Vietnam's government is also working to secure stronger trade deals with major trade partners.[5] The Vietnamese shrimp industry must bolster its productivity and achieve traceability: the export markets are open and receptive.

The Government Is Pushing for Sustainability and Efficiency in Shrimp Farming

Shrimp farming has taken a toll on the environment. Mangrove deforestation, which was a serious problem from the 1980s and into this century, has exposed coastlines to storms and tsunamis, and water pollution contributes to eutrophication and the loss of biodiversity.

The Mekong Delta is in special danger. According to government officials, in the years from 2010 through 2015, the delta sank five to ten centimeters, and erosion has eliminated 300 hectares of land since 2005. Government officials have warned that if this trend continues, the Mekong Delta could disappear within the next 100 years.

EXHIBIT 2 | Vietnamese Official Shrimp Exports to Major Buying Markets, 2017



Sources: Vietnam Association of Seafood Exporters and Producers, 2018; BCG analysis.

The government has issued a number of decrees aimed at halting environmental degradation and improving the economic performance of the industry. They address the following:

- Improving conditions of L. vannamei shrimp hatcheries and farming, including technical standards for breeding, facilities, and farming methods
- Implementing certification standards, such as VietGAP and better management practices
- Improving technical expertise and training for small-scale farmers
- Fostering collaboration along different supply chain segments, for example, between hatcheries and farms
- Reducing land conversion and protecting forests
- Phasing out the use of antibiotics and chemicals

Officials view certified ecofarming and indoor superintensive shrimp farming, which is an option primarily for large players, as the future of sustainable shrimp farming in Vietnam.

In 2013, the government, through the Ministry of Agriculture and Rural Development, issued a master plan for the development of the shrimp industry. With the help of various government-led incentives, such as credit access and technology grants to spur investment, by 2020, the shrimp-farming industry should be established as a key economic segment. The government has set out ambitious targets: to produce 1.3 million metric tons of farmed shrimp and to achieve about $12 billion in export revenues by 2030. Industry experts, however, judge these growth targets to be somewhat unrealistic, especially the multifold increase in export revenues: it assumes a steep increase in shrimp prices at a time when global shrimp prices are declining and the Vietnamese shrimp industry is stagnating.

The national master plan sets out aggressive growth levels and aims to promote shrimp farming, but without clear economic incentives and responsibilities, the successful enforcement of regulations related to more sustainable and responsible farming will be limited. Players across the supply chain must take action.

The Shrimp Value Chain Is Complex

Vietnam's farmed-shrimp industry consists of several interrelated value chain steps: feed mills, hatcheries, farmers, middlemen, processors, exporters, and retailers. (See Exhibit 3.)

This report focuses on the first five steps of the value chain:

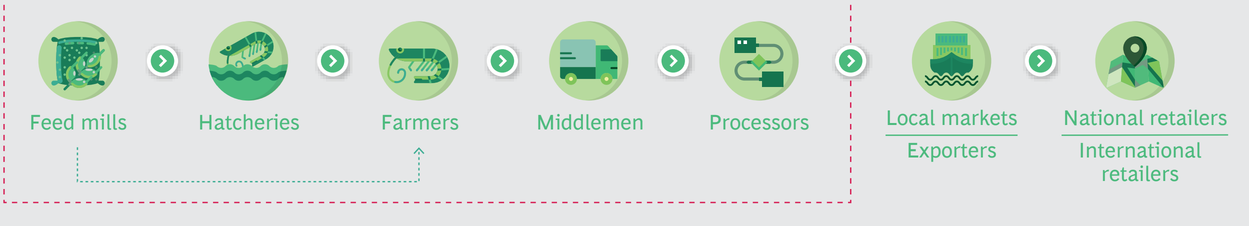
- **Feed Mills.** Vietnam's feed mill market is highly consolidated: four players account for about 85% of market share. Generally, feed is distributed by shops or middlemen, not directly by feed mills.
- **Hatcheries.** The hatchery business is fragmented. One large player, Viet Uc Seafood, controls about 25% of the market, along with a limited number of other large-scale and international players. Approximately 2,500 small hatcheries claim about 50% of the market.
- **Farmers.** The farming industry is largely fragmented. Commercial players account for about 35% of production output, mainly for L. vannamei, but most of the farmers operate on a small scale with limited knowledge of efficient farm management and new technologies. Moreover, most farmers have only minimal access to capital and financing.
- **Middlemen.** Middlemen handle about 80% of all farmed shrimp in Vietnam, and many play a role in helping farmers financially by, for example, offering credit.
- **Processors.** About 70% of the shrimp processed in Vietnam is exported, and generally, the processing and the exporting are handled by one company. These are typically medium- to large-scale companies, formerly state run and now undergoing privatization. Many processors also import unprocessed shrimp from other countries, especially India and Ecuador, for reexport to China and other importing nations.

Across the value chain, fully integrated players—companies that own both upstream suppliers and downstream buyers—are still relatively rare: Minh Phu Seafood, which operates on a global scale, is the largest integrated player in Vietnam and sells both L. vannamei and P. monodon. (See the sidebar "A Comparison of Two Species: L. Vannamei and P. Monodon.")

There are partially integrated players. These are companies with some upstream or downstream expertise that are beginning to diversify but are not yet fully integrated across the value chain. Processors such as Quoc Viet Foods, Fimex VN, and Vietnam Clean Seafood, for example, have integrated vertically into farming or hatcheries in order to function more independently.

Several companies—such as Stapimex and Camimex Group—specialize in combined processing and exporting. "Pure" players—such as Grobest Industrial Viêt Nam, Cargill Vietnam, and Uni-President Enterprises—exist mainly in the feed mill sector or are small, family-owned businesses, particularly in farms and hatcheries.

EXHIBIT 3 | Vietnam's Farmed-Shrimp Supply Chain



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

A COMPARISON OF TWO SPECIES: L. VANNAMEI AND P. MONODON

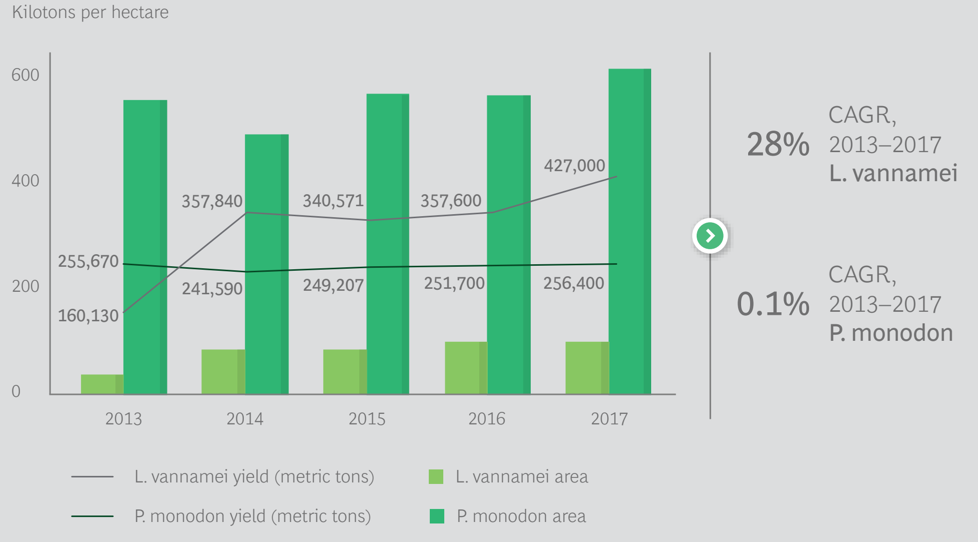
Litopenaeus vannamei, also known as whiteleg shrimp, makes up 60% of Vietnam's shrimp market. This species was introduced into Vietnam in the early years of this century and has fueled the growth of the Vietnamese shrimp industry since then.

Penaeus monodon, a species native to Vietnam, accounts for about 40% of its shrimp market. Although Vietnam is the global leader in P. monodon production, this market has grown by less than 1% per year, and recently that rate has declined.

L. vannamei, which has been the popular choice for farmers because it can be farmed intensively and has a reputation for being more disease resistant, is typically produced by large companies. P. monodon, on the other hand, is produced mostly in extensive or semi-intensive farms that require large amounts of land. (See the exhibit below.)

This species is typically produced by small-scale farmers in the Mekong Delta. P. monodon farmers achieve higher profit margins—47% compared with 21% for L. vannamei. The output is, however, much lower than L. vannamei output—200 to 550 kilograms per hectare compared with 7 to 15 metric tons per hectare.

Vietnam's Shrimp Production and Production Area, 2013–2017



Sources: Vietnam Association of Seafood Exporters and Producers, 2018; BCG analysis.
Note: L. vannamei = Litopenaeus vannamei; P. monodon = Penaeus monodon. The official production numbers are categorically overstated, but the split of species is indicative for the market.

VIETNAM

THE CASE FOR CHANGE

The Vietnamese shrimp industry is facing four key vulnerabilities that have the potential to further undermine its position in the global market: low productivity levels, disease and environmental degradation, lack of traceability, and overreliance on reexports. (See Exhibit 4.)

Low Productivity Levels Harm Vietnam's Ability to Compete in the Mass Market and on Price

Although the Vietnamese shrimp industry is generally profitable with positive EBIT margins across all levels of the value chain, productivity on shrimp farms is low relative to production levels in competing countries.

There are about 220,000 shrimp farms in Vietnam, and 65% of them are small family farms. The implied average farming output per hectare in Vietnam is only about 1.3 metric tons per hectare per year; competing nations achieve average implied output levels of up to 6.6 metric tons per hectare—approximately five times Vietnam's productivity.[6]

Many small-scale farmers lack the expertise and financial means that would allow them to implement more sophisticated farming technologies and farm management techniques. Instead, many of them are challenged by high production costs, as well as high costs for feed due to the power of the concentrated foreign feed market. Additionally, there is still heavy reliance on imported broodstock, further increasing costs and dependency on foreign markets and making it difficult to compete on volume and price.

These farm-level problems ultimately cascade along the entire supply chain. Competitors such as Indonesia and India have surpassed Vietnam in total shrimp production, with predicted growth rates of about 8% and 11% per year, respectively, compared with Vietnam's current growth rate of about 2%.

At current growth levels, Indonesia and India are on track to achieve, by 2025, output of some 900,000 metric tons and about 1.4 million metric tons, respectively. If growth continues at recent rates, Vietnam will produce about 630,000 metric tons by 2025, reducing its global market share to less than 10% and further diminishing its role in the global marketplace.[7]

If Vietnam were to match the growth of its competitors by increasing efficiency at the farm level, it could produce up to 65% more shrimp by 2025, adding up to about $300 million in value each year, based on export value.

By increasing its efficiency on farms, the shrimp industry in Vietnam has the potential to increase yields, spread fixed costs, and reduce input costs, leading to higher EBIT margins and an enhanced ability to compete on price.

Exhibit 4 | The Case for Change Is Driven by Four Factors in Vietnam

Low productivity

High risk of disease and environmental degradation

Regulations of import authorities, retail pressure, and consumer demand

Reliance on raw-material imports for processing

Source: BCG analysis.

Diseases and Environmental Degradation Threaten Farm Survival

Poor farm management and excessive use of natural resources has not only reduced productivity in Vietnamese shrimp supply chains but has also exposed farms to high disease risks and harvest losses owing to environmental disasters such as droughts, floods, and storms.

The major shrimp farming areas in the Mekong Delta, including the Ca Mau, Bac Lieu, Soc Trang, and Tien Giang provinces, have been affected by disease outbreaks in recent years. These regions were less affected by the 2012–2013 early mortality syndrome (EMS) outbreak than was Thailand, which, for example, lost about 50% in production volume. However, they have endured several disease outbreaks. Depending on the exact location and year, these provinces have lost from 20% to 60% of their harvest, owing primarily to poor farm management and the impact of environmental disasters.

Disease outbreaks undermine Vietnam's ability to compete. If a disease outbreak in the Mekong Delta were to cut harvest rates by 50%, affecting as much as 60% of the region's farms, that would translate into harvest losses of about 70,000 to 220,000 metric tons, accounting for about 15% to 50% of overall annual industry production. Major losses like these can bankrupt small farmers, many of whom are heavily in debt for feed and antibiotics. Additionally, large players do not have the farm production capacity to serve demand by themselves and, hence, rely on the additional production of small-scale farmers who are protected but not sufficiently supported by the government.

Furthermore, shrimp farming has caused widespread environmental damage. In the Mekong Delta, which accounts for about 80% of Vietnam's overall farming output, nearly all the land has been cleared for shrimp farming. This practice has exposed the coastline to erosion and made shrimp farms more vulnerable to storms, typhoons, and strong winds. In addition, groundwater pumped to fill ponds causes the land to subside and allows brackish water to encroach on the delta and damage other crops, such as rice. As mentioned earlier, a confluence of factors puts the Mekong Delta at risk of vanishing altogether.

Heavy use of antibiotics also harms the environment, limits biodiversity, and endangers the health of shrimp and consumers alike. After every harvest, untreated wastewater is discharged into the waterways. The World Bank estimates that about 3.3 billion cubic meters of wastewater from shrimp farming is leaked into rivers and waterways each year. Because this contaminated water is pumped up again and used by other farmers, chemicals are added to remove organic matter from the water, creating more pollution and further increasing disease risk.

Collective action is required to break the downward spiral of disease outbreaks, low productivity, and environmental degradation. It is crucial to educate small-scale farmers about practical changes that they can and must make and to equip them with the means for improving farming methods while reducing their environmental footprint. By doing so, there is the potential to add about $0.5 billion to $1.5 billion in value (based on exports) to the entire industry.

Lack of Traceability Poses the Risk of More Import Refusals

In recent years, import authorities in major shrimp-importing nations have increased their requirements for traceable products and started scrutinizing imports for drug contamination. The US Seafood Import Monitoring Program, for example, requires product traceability for farmed shrimp, and the EU requires preapproval of export companies in their trade databases.

Vietnam's shrimp industry has already experienced a large number of entry line refusals to the US, the EU, and Japan owing to drug and chemical residuals. From 2012 through 2017, the US refused about 155 entry lines of Vietnamese shrimp, the EU refused 48, and Japan refused 169, accounting for about 30% of all rejected entry lines for shrimp.[8] (See Exhibit 5.)

Although the industry standard is just 30%, Japan currently examines all Vietnamese shrimp imports. South Korea issued an explicit warning in 2018 after discovering that shrimp imports from Vietnam were contaminated with nitrofuran and other antibiotics.

High use of chemicals and antibiotics in Vietnamese shrimp farming remains a common practice: many small farms continue to use drugs and chemicals to control diseases and treat polluted water.

Middlemen add to the complexity of the Vietnamese shrimp supply chain by mixing batches of shrimp from different farms, in some cases, combining healthy, clean, sustainably farmed shrimp with contaminated shrimp.

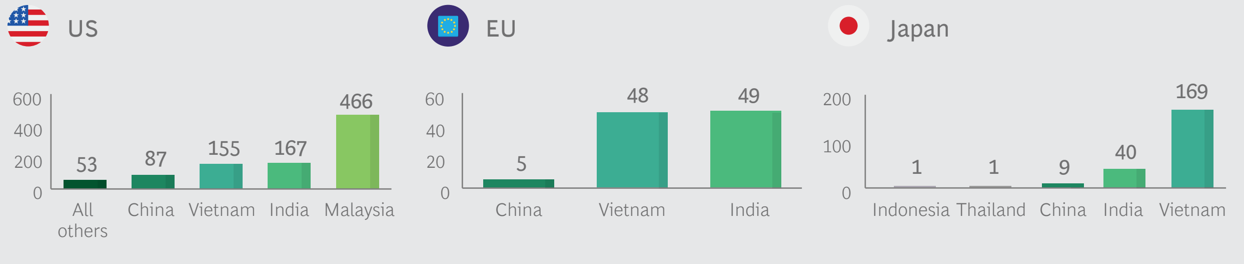
Furthermore, shrimp is often soaked in sugar water to increase the weight and achieve higher sales prices. This is legal, but at times, illegal substances, such as carboxymethyl cellulose powder and agar, are injected into the shrimp to increase the weight.[9] The local authorities and the Vietnamese police continue to investigate and prosecute such illegal activities, but the players are sophisticated at hiding these practices.

The Vietnamese shrimp industry generates $2.5 billion in value from exports to the US, the EU, Japan, and South Korea, but the lack of traceability puts much of this value at risk. Just as Vietnam was able to increase its market share when India faced drug contamination issues in the past, competitors will be able to absorb Vietnam's market share if its shrimp exports are refused. Despite Vietnam's favorable relationship with major trade partners, the reputational damage from drug-contaminated Vietnamese shrimp has already taken effect. In 2018, Vietnam saw its exports to major markets decreasing, resulting in an overall annual decline in export value of about 8%.

Vietnam's government and large processors recognize the need to mitigate the risk and are increasing inspections. They are implementing traceability tools such as a blockchain-enabled traceability platform from Te-Food, which is supposed to go live in Vietnam in 2019. However, this initiative includes just a limited number of farms and does not involve middlemen. To ensure sustained access to crucial export markets, action is needed at all levels of the value chain.

EXHIBIT 5 | Significant Amounts of Vietnamese Shrimp Have Been Refused Because of Antibiotic Use

Shrimp antibiotic and antimicrobial refusals
(Number of occurrences, 2012–2017)



Sources: Southern Shrimp Alliance, 2018; BCG analysis.

There is a clear need and opportunity for Vietnamese shrimp producers to increase traceability and provide environmentally friendly and clean products to ensure sustained market access and tap into a highly lucrative future market. Some players in Vietnam are recognizing the need as well as the market for responsibly and efficiently produced shrimp, and they are seizing the opportunity. Viet Uc, for example, has established full-containment indoor shrimp farms with integrated operations in Vietnam.

Reliance on Imports for Reexport Renders Processors Vulnerable to Market Developments

The Vietnamese processing industry currently imports from low-cost countries such as India and Ecuador, processes the imported shrimp, and then reexports it to major import markets.

The reexporting business model has been in place since 2009, and it has proved successful thus far. It means, however, that the Vietnamese shrimp industry is heavily dependent on the production and export prices of other shrimp-producing nations.

From January through September 2017, Vietnam imported about 150,000 metric tons of shrimp from Ecuador and about 110,000 metric tons from India—together accounting for more than 50% of Vietnam's total annual processing output. This approach increases input costs for processors and decreases transparency within the supply chain, making it difficult to implement traceability.

India, in particular, is beginning to shift its processing capabilities toward more value-added, sophisticated production, and the growth of the segment is estimated at about 11% annually. If India were to increase its processing capabilities by adding some 5,000 metric tons to its value-added production, and if these 5,000 metric tons were deducted directly from the volume that Vietnam currently imports from India, Vietnam would lose about 2% of its overall processed exports—a value estimated to be as much as about $60 million.

If Vietnam should suffer a supply shortage, India could fill the gap, threatening Vietnam's position as a trusted and reliable supplier.

Such a scenario would have dramatic impact on the Vietnamese shrimp industry, reducing the revenues of shrimp processors and exporters and threatening the livelihoods of thousands of people employed in the segment.

Improvements on farms could greatly benefit Vietnamese processing companies. If Vietnam's farmers were to increase their yield, they could offer more input to processing companies at cheaper prices than current imports.

Even including the added cost of middlemen, farm gate prices for L. vannamei stand at about $4.50 per kilogram in Vietnam—significantly less than import prices from Ecuador (about $6.60) and India (about $7.10). The lower cost of the raw materials would enable processors to achieve higher margins or compete better on price in the overall market.

It is important to acknowledge the presence of Vietnam's grey exports to China. Experts estimate that up to about 270,000 metric tons of shrimp are exported to China each year through the port of Hai Phong. But these illegal exports to China are declining as well, further destabilizing Vietnam's position.

If Vietnam builds up its domestic production, ends its reliance on outsourced shrimp, and rebrands itself as a price-competitive-but-high-quality exporter, it will have a niche opportunity that few global players can offer.

The Vietnamese shrimp industry is losing ground in the global marketplace. Although some individual players and the government recognize the need for change, a collective effort is required to push the industry toward sustained economic success.

Only then can the risks be turned into opportunities and the Vietnamese shrimp industry as a whole can continue to compete successfully in the international market.

IMMEDIATE CHANGES CAN DELIVER SHORT-TERM ECONOMIC VALUE

Vietnam's farmed-shrimp industry has three paths into the future: pursue immediate, short-term changes that will increase resource efficiency and improve profit margins; collaborate to achieve product traceability; and make a bold shift to intensive, closed-containment facilities to reduce contamination, boost production, and ensure traceability. (See Exhibit 6.)

In the long-term, a fully traceable supply chain and closed-containment intensification will yield the highest business, environmental, and social impact, but certain other actions that can be taken immediately—especially by feed mills and farmers—can improve performance and create positive change. These improvements are focused on three areas: feed, water quality, and energy.

Exhibits 7 and 8 illustrate the ways that each player in Vietnam's shrimp value chain can benefit from these short-term improvements. (See the Appendix for business case details on each player in the value chain.)

Feed Mills: Higher Profits When the Portfolio Is Expanded to Include Functional Feed

The feed market in Vietnam is dominated by international players. Basic feed accounts for more than 95% of the feed supply, but farmers in Vietnam are still struggling with low survival rates and low levels of productivity.

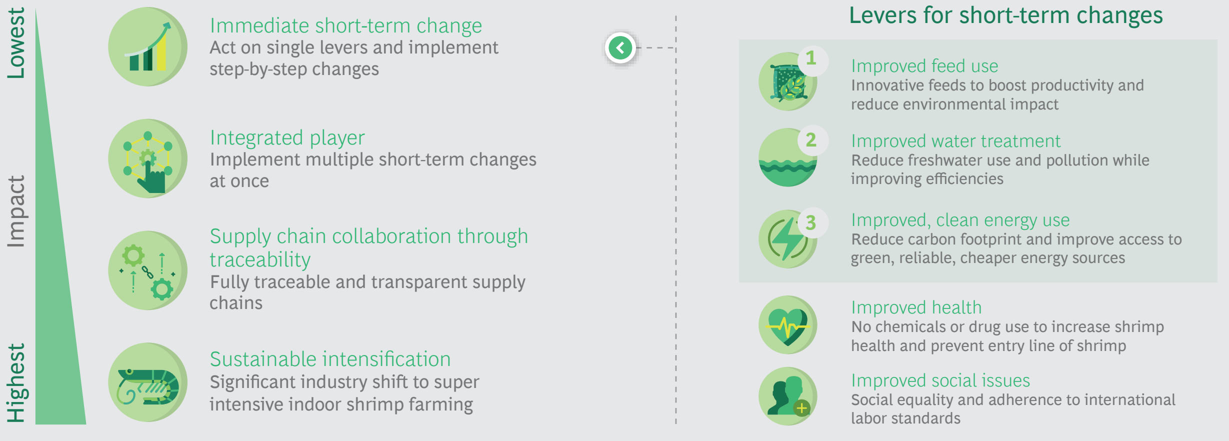
Feed mills have an important opportunity to expand their portfolio by using functional feed. Functional feed is basic feed that has been enhanced with additives, such as proteins, vitamins, or probiotics (but never antibiotics), to achieve a specific outcome. It is not uncommon for feed mills to improve 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.

The use of functional feed represents a significant opportunity for feed mills and farmers alike. Feed mills can sell premium feed at premium prices and benefit from the innovation in their markets, and farmers can significantly increase production and shrimp quality.

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 mills. Although its production cost per

Exhibit 6 | Several Levers Can Maximize Business Success While Creating Positive Environmental and Social Impact



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

kilogram of product sold is 6% higher, feed mills can charge price premiums of up to 20%, leading to an EBIT margin of as much as 26%—an increase of up to about 58% over today's average EBIT margins. At the same time, farmers using functional feed can drastically reduce their feed conversion ratio (FCR), which reduces feed mill revenues based on farm sales per kilogram of shrimp produced. However, as functional feed is used only as a supplement to basic feed, it offers the opportunity for feed mills to expand their product portfolios: they can offer a higher-margin premium product without endangering overall sales.

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, in an optimal case, charge premiums of up to 50%, generating profit margins of up to about 36%, more than double today's average.

A total industry shift to functional feed is unlikely given its high cost and the fact that it is used only when global shrimp prices are high. However, an increase in market share is highly likely and could boost total feed market growth due to faster growth rates and better survival rates. A 1% increase in the total feed market volume, currently estimated at 550,000 metric tons per year, would generate up to $7 million of value per year. Feed mills that are able to tap into this value will ultimately benefit from a diversified feed portfolio, added revenues, and higher average profit margins. It is, therefore, important for feed mills to market functional feed, educate farmers on its application and benefits, and highlight how these benefits outweigh the upfront costs. Even so, many farmers in Vietnam will not be able to afford the feed.

Functional feed reduces FCR, so less feed is required. Reduced feed demand ideally translates into reduced land required for feed production. Switching to functional feed also benefits the environment by decreasing land use by up to 15% per kilogram of shrimp, improving water quality by reducing feed waste, decreasing the use of antibiotics, and requiring less fish meal and fish oil.[10] However, these benefits manifest only if functional feed is widely used, and the positive environmental impact depends on what is substituted for fish meal. (See the Appendix for a discussion of growth enhancement and health enhancement functional feed.)

Feed mills are responsible also for considering the production of input ingredients for feed. Worldwide, 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

EXHIBIT 7 | Current Average Economics per Value Chain Step

	Feed mills	Hatcheries	Farmers	Middlemen	Processors	Local market / Exporters	National retailers / International retailers
Costs	$0.92 per kilogram of feed	$2,774 per million PL	$3.30 per kilogram 80 pieces per kilogram	$4.35 per kilogram	$8.83 per kilogram exported product		Markups: 20% to 30% for shrimp sold in supermarkets
Price	$1.10 per kilogram of feed	$3,814 per million PL	$4.17 per kilogram 80 pieces per kilogram	$4.48 per kilogram	$9.70 per kilogram exported product		
EBIT margins %	~15	25 to 30	~20	~0.5 to 3	~10 (For cooked (value-added) shrimp)		

Source: BCG analysis.
Note: PL= post-larvae shrimp; L. vannamei = Litopenaeus vannamei; P. monodon = Penaeus monodon. Calculations for L. vannamei intensive production are based on the average price for 80 pieces per kilogram; costs are the average costs per value chain step; margins include considerations such as survival rates; because of rounding, not all numbers add up to the totals shown.

EXHIBIT 8 | The Economics of Short-Term Improvements

	Status quo	Feed	Water	Combination
Feed mill level	EBIT margin: ~15%	**Growth enhancement** EBIT margin: Up to 26%; Increase: +58% **Health enhancement** EBIT margin: Up to 36%; Increase: +117%	None In the sale of functional feed, overall feed mill EBIT margins depend on the feed portfolio of individual farms	**Growth enhancement with biofloc** EBIT margin: Up to 26%; Increase: +58% Potential revenue loss through improved farm efficiency with similar increase in farming output
Farm level	EBIT margin: ~20%	**Growth enhancement** EBIT margin: Up to 28%; Increase: +36% **Health enhancement** EBIT margin of 20% even during disease outbreaks versus 8% with basic feed	**Biofloc** EBIT margin: Up to 29%; Increase: +40% **RAS** EBIT margin: Up to 27%; Increase: +29%	**Growth enhancement with biofloc** Positive, but further studies are required **Growth enhancement with RAS** EBIT margin: More than 34%; Increase: +61%

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

feed creates a burden on land use. The use of natural resources for making feed—so-called embodied resources—represents a hidden, but vitally important, depletion of resources and thus requires careful consideration.

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. Viet Uc is already using feed that replaces fish meal with marine microbes, imitating what shrimp would eat in their natural habitat. Reportedly, these microbes enhance growth. 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 using such feed-producing innovations as extrusion (cooking under high temperature and processing under high pressure) and pelleting (no cooking and processing under much less pressure) as well. Both of these approaches have the potential to improve the digestibility of feed ingredients.

Hatcheries: It Is Time to End the Dependence on Imported Broodstock

Post-larvae shrimp (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.

There are about 2,500 hatcheries in Vietnam. The hatchery industry in Vietnam is widely fragmented with many small-scale backyard hatcheries and only a few large commercial hatcheries. The largest, owned by Viet Uc, produces about 15 billion PL per year using intensive indoor-production methods.

The hatchery survival rate in Vietnam is only 35% to 40%—lower than survival rates in competing shrimp-farming nations such as Ecuador, where the survival rate is about 60%. The Vietnamese government is making an effort to improve these numbers by tracking broodstock imports and imposing strict rules on how often broodstock can be used and recycled for the production of shrimp.

The large majority of hatcheries still rely on imported broodstock. The local supply cannot satisfy demand, so hatcheries import 200,000 to 250,000 L. vannamei breeding shrimp per year. Domestic broodstock and selective breeding techniques can improve shrimp survival, reduce the risk of disease, and enable hatcheries to focus on breeding PL that grow faster and larger.

Recent studies have shown that specific pathogen-free lines of selected stocks, maintained under the proper conditions, even bear the potential to reestablish farm populations in the event of stock losses caused by disease outbreaks. It is not uncommon for farmers to return poor-quality PL to hatcheries and demand replacement PL to compensate for production losses. In providing high-quality, healthy PL, hatcheries significantly reduce production costs and increase output on farms, and reduce their own costs.

Our analysis did not reveal many opportunities for hatcheries to implement short-term changes in feeding techniques or water treatment systems, but hatcheries that offer high-quality PL can charge premium prices for their products. Viet Uc, for example, is the first company in Vietnam to cultivate high-quality broodstock, eliminating its dependence on broodstock imports. Viet Uc also uses high-quality PL in its indoor systems.

To help minimize disease risk and allow standalone players to more effectively compete against the significant market power of integrated players, individual hatcheries should focus on improving quality by domesticating broodstock and implementing selective breeding practices. Because developing better PL involves genetic testing and investments in R&D, this can be difficult for smaller hatcheries to implement. Therefore, institutions and players with the necessary means should support small hatcheries in these efforts. (See the Appendix for a more detailed discussion of the business case for hatcheries.)

Farmers: Opportunity to Boost Production and Quality and to Reduce Environmental Damage

Too many shrimp producers in Vietnam work inefficiently and fail to maximize their potential. They lose large portions of their harvest owing to poor farming management and a lack of technical expertise.

We have identified multiple business opportunities for implementing immediate change at individual farms by slightly altering existing production systems. Four opportunities, in particular, enable farmers to improve production efficiencies, reduce resource use, and increase profit margins. That said, the cumulative effect of these four key opportunities remains small compared with the more holistic levers of transitioning to traceability and indoor farming.

Key Opportunity 1: Under the right circumstances, functional feed boosts profitability. Farmers can use different types of functional feed under specific circumstances to reduce FCR and improve shrimp survival rates. When applied in a specialized way to address specific challenges, growth enhancement and health enhancement functional feed can benefit Vietnamese shrimp farms.

Growth enhancement functional feed has the potential to accelerate shrimp growth rates or to produce larger shrimp, and farmers can benefit from prices that are about 6% higher for larger shrimp. When global shrimp prices rise, farmers might want to take advantage of the opportunity: 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%, reflecting a 30% reduction during the second half of the growth cycle.

Using growth enhancement feed, farmers can achieve EBIT margins of up to about 28% per kilogram of shrimp sold—a relative increase of more than about 36% in EBIT margins. If global shrimp prices stay high, fast-growing shrimp could allow for an additional production cycle, significantly increasing farming output. These gains will offset the additional upfront costs of purchasing functional feed, which is significantly more expensive than basic feed.

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 functional feed could help them achieve an EBIT margin of up to 20% because the feed dramatically increases survival rates during disease outbreaks. This compares quite favorably with the 8% EBIT margin when only basic feed is used. This scenario assumes that farmers can prevent a disease outbreak that would affect up to 20% of their annual production, and it offers a significant opportunity for farmers to achieve reliable output and break out of the boom-and-bust cycle. This is particularly valuable for small-scale Vietnamese farmers who may find themselves forced to take out loans to finance farm operations and who run the risk of bankruptcy when faced with major harvest losses.

A positive business case can be made for this approach, but each farmer must evaluate the feasibility and economic viability of purchasing expensive health enhancement functional feed against the potential losses from disease outbreaks.

Still, the analysis suggests that there is a clear value proposition for farmers in Vietnam to shift to growth enhancement and health enhancement functional feed when specific circumstances call for it. It represents a relatively easy win since no investment or technological upgrades are required. That said, because most Vietnamese farms operate on a small scale, farmers may not be able to afford the upfront costs. And those who can afford such an investment may need to be trained to know when to use functional feed and how to manage it optimally. There are also some environmental benefits, most of which are the results of better farm management, which is a prerequisite for the success of using this feed. (See the Appendix for a more detailed discussion of growth enhancement and health enhancement functional feed.)

Key Opportunity 2a: 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 complete, 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 treatment systems to improve water quality and reduce water discharge. These applications vary widely in their mode of action, ease of use, and feasibility.

Some farming technologies 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 of these systems 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 simultaneously provide an additional feed source. Carbohydrates are added to pond water to aggregate waste products that are eaten by shrimp.

There is significant variability in the business benefits for farmers because implementing and scaling biofloc can be tricky. In the best-case scenario, biofloc can yield EBIT margins of up to 29%, increasing today's average by as much as 40%. If not implemented diligently, the effect can be EBIT margins as low as 24%.

The change in EBIT margins is a result of decreased costs for feed and chemicals, for example, combined with the potential to grow shrimp faster or larger during a given period of time, thus increasing revenues. This is due to biofloc's higher protein content.

This approach, which is relatively inexpensive and easy to implement and doesn't require significant changes in current farming systems, is suitable for small-scale farmers with limited financial means. However, because the application of biofloc must be monitored carefully and requires advanced farming expertise and equipment, it's not an option for all small-scale farmers.

When using biofloc, most large companies have an advantage over smaller farms in terms of the required knowledge and expertise. For farmers with the equipment that is required in large-scale production systems—such as aerators and monitoring equipment—and access to the necessary training and knowledge for creating equilibrium in each pond, this 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, creating excessive waste material in the water and possibly reducing shrimp survival rates.

RAS are sophisticated filtering systems that treat water so it can be reused in the same location.[11] Such closed-loop systems offer two significant benefits: no unfiltered wastewater is discharged into the local environment, and the demand for "new" water is reduced. Ideally, no water exchange is required. Moreover, as these systems reduce the need for such production inputs as chemicals and fertilizers, RAS improve farm and resource efficiency and boost productivity, leading to higher EBIT margins for farmers.

The systems range from basic biofilters to more sophisticated water recirculating systems. They vary in effectiveness, investment and operating costs, and environmental impact. The implementation of such systems is urgently needed, especially in regions such as the Mekong Delta, where ground water use and pollution are endangering the environment. As noted, the Mekong Delta is currently at risk of disappearing if current processes continue.

Effective RAS implementation usually requires a high financial investment owing to the need to install new facilities and train workers in this advanced farming technique, but it also promotes higher output per hectare since it offers the opportunity to intensify production.

For producers that can afford the investment, sophisticated RAS—some at a cost of $150,000 per hectare—can boost EBIT margins by as much as 29% per kilogram of shrimp produced. This increase in EBIT margins assumes that farmers can double stocking densities to counterbalance the capital investment and the higher electricity costs due to the use of aerators. Hence, the implementation of RAS not only leads to higher EBIT margins per kilogram of shrimp produced but also to higher overall output and revenues.

Because these systems are expensive and require special knowledge to implement, RAS application is limited to supply chain actors with access to sufficient funding and expertise. There are simple, low-cost filter systems available as an alternative 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 freshwater needs, but it also causes increases in energy and feed use due to increased stocking densities. Using renewable energy and functional feed with a minimal environmental footprint could potentially mitigate this negative effect.

Beyond these benefits, the application of aerators 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 RAS.)

Key Opportunity 2b: Combining water treatment with growth enhancement functional feed compounds the business and environmental benefits. Producers that seek to maximize the effect of immediate, short-term change can combine growth enhancement functional feed with either RAS or biofloc.

When using growth enhancement feed in combination with closed-loop systems, such as RAS, farmers can obtain EBIT margins of up to about 34%—an increase of as much as about 61% over today's average. It is also an improvement of as much as about 26%, compared with the standalone use of RAS and as much as about 21%, compared with standalone functional feed.

The combination of functional feed and RAS offers several benefits: increased volume through higher stocking intensities, more efficient production, higher survival rates, better water treatment, and reduced wastewater discharge. Nonetheless, traceability remains unchanged, risk of disease is still high, and the structural problems of the Vietnamese shrimp supply chain are not addressed in this scenario.

Another option is to combine growth enhancement functional feed with biofloc. The combined impact of these two solutions affect the same production parameters: the feed conversion and growth rate. Still, even though its efficacy can be hard to predict, it is in the end likely to yield results that are superior to standalone options.

While these combined approaches have promising potential, 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 be very rarely used. Additionally, funding these changes will challenge small-scale farmers. (See the Appendix for a detailed discussion of combining functional feed and water treatment systems.)

Key Opportunity 3: Solar energy offers superior EBIT margins and a dependable energy source for farms that rely on diesel generators. Electricity is a necessary but costly and sometimes unreliable component of shrimp farming. Although grid-sourced energy is economical, in farming regions with frequent energy outages, such as the Mekong Delta, generators are frequently used to provide backup energy. Diesel generators are costly (with up to about 5% higher energy costs if 30% of energy is from generators rather than the grid), and they contribute high carbon emissions. Renewable energy sources, such as solar energy generated by photovoltaic (PV) systems, are viable, relatively inexpensive, and environmentally friendly alternatives.

When farms rely on generators for backup energy, EBIT margins are reduced to about 17% owing to high fuel costs of about $224 per megawatt hour. In contrast, solar energy could offer absolute EBIT margins of up to about 20%. While this represents a drop of up to about 6% in EBIT margins compared with running purely on grid energy, it increases EBIT margins by more than about 17% compared with diesel generator use due to lower unit costs.

Farmers exposed to frequent electricity outages should consider implementing renewable energy. There is, however, one drawback: ground-mounted PV systems require significant capex investments of up to $20,000 per hectare, depending on the system (about $12,000 not including battery use), which small farms in remote areas might not be able to afford. But as the cost of batteries and solar power continue to decrease, this option could become more affordable for remote farms as well as grid users. (See the Appendix for a more detailed discussion of solar energy.)

The immediate changes regarding feed, water quality, and energy can help farmers improve production methods, be more environmentally sound producers, and achieve higher profit margins. Currently, farmers represent a significant bottleneck in the Vietnamese farmed-shrimp supply chain. Operating with low productivity and efficiency, these farms have low shrimp survival rates and poor farm management. Short-term changes are a first step for tackling these problems. Farmers are key to the transformation of the entire supply chain's profitability, output, and quality.

Because these short-term changes in production methods are implemented on an individual basis, it is unlikely that they will sufficiently address the structural and environmental challenges the industry is facing. To truly transform the industry and create lasting financial returns and environmental change, a holistic approach is needed.

Middlemen: A Major Challenge to Overcome as the Industry Shifts Toward Sustainability

Middlemen play a key role in the Vietnamese farmed-shrimp supply chain. In many cases, they serve as gatekeepers and facilitators between shrimp farmers and shrimp processors, as well as between hatcheries and farmers and among feed mills and hatcheries and farmers. They often play an important role in financing for farmers. This wide network of middlemen currently handles about 70% of all farmed shrimp produced in Vietnam.

Despite the many services that middlemen provide, they represent a major challenge for Vietnam's shift toward product traceability: they often mix shrimp batches from different farmers, making it very difficult to trace provenance. In addition, middlemen have allegedly injected shrimp with water and even illegal substances, tarnishing Vietnam's reputation as a reliable exporter and increasing the risk of entry line refusals in major markets, such as the US, the EU, and Japan.

Because middlemen play an informal role in the value chain, keep minimal records on shrimp purchased and sold, and are subject to little regulatory or company oversight, a shift in how they conduct their business will be key for the industry's successful transformation to a more traceable and sustainable supply chain. (See Exhibit 9.)

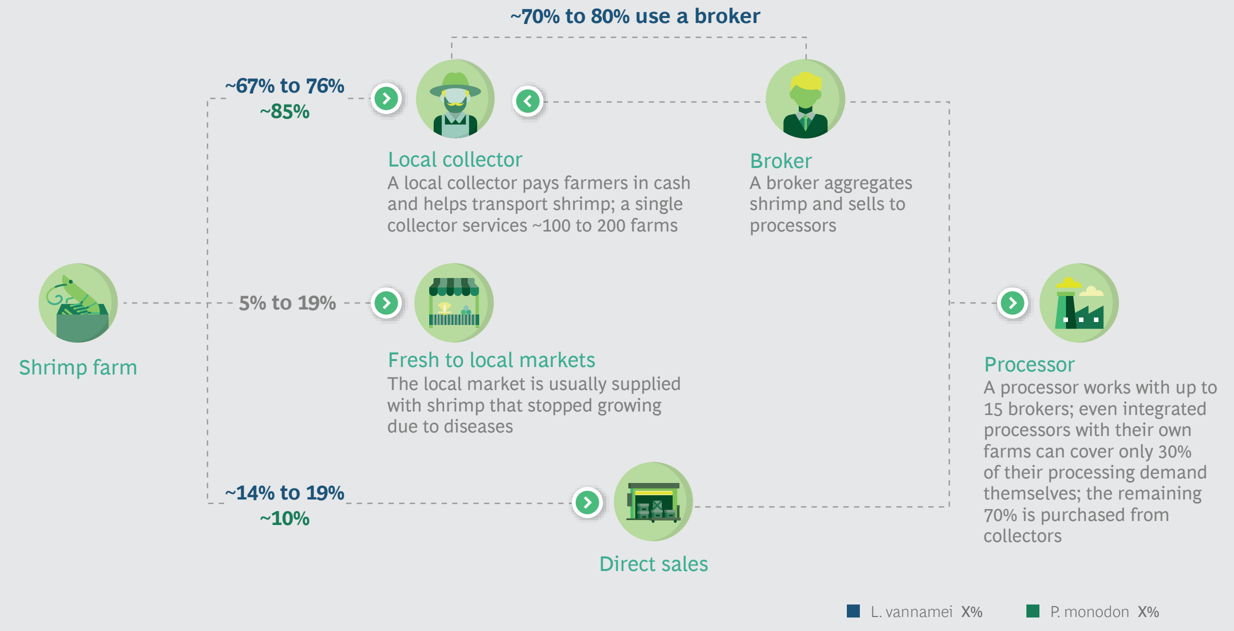
By becoming more involved in the shift toward sustainability, middlemen can stay relevant in an industry that might otherwise cut them out over time. In Vietnam, there is an urgent need for middlemen to keep strict records and stop mixing shrimp batches. These are two of the most pressing issues in the supply chain. (See the Appendix for a more detailed discussion of the business case for middlemen.)

Processors: Imperative to Improve Traceability and Reduce Import Dependency

About 70% of Vietnam's processed shrimp is exported to the EU, Japan, China, and the US. Typically, processors handle exports as well, and they are, therefore, directly affected by allegations of ethical and environmental misconduct in farmed-shrimp supply chains. Vietnam's processing is largely fragmented, and approximately 100 processors account for most of the exports. A number of large companies have the finances, expertise, and sophistication to drive the industry forward.

Vietnam is widely known for its value-added processing capabilities, and Vietnamese processors import large quantities of shrimp from

EXHIBIT 9 | Middlemen Play a Critical Role from Farm to Processing



Sources: Expert interviews; *Journal of Cleaner Production*, 2011; BCG analysis.

countries such as India for additional processing. The processed shrimp is then reexported.

Processors also serve as intermediaries between shrimp farmers and importers and sometimes even retailers, so it is in their interest to help farmers reduce disease risk and reliably produce more responsibly farmed, high-quality shrimp.

Improving the productivity of farmers also yields significant benefits for processors:

- Eliminating the reliance on imports from other shrimp-farming nations for processing and reexport
- Providing traceable, clean, and sustainably produced shrimp at sustained volumes to maintain relationships with buyers and meet export regulations
- Allowing processors to maintain market access and develop strong relationships with buyers and retailers

Processors have a responsibility and a clear incentive to engage with farmers and middlemen to implement more sustainable production methods and work toward a fully efficient, traceable, and sustainable shrimp value chain. (See the Appendix for a discussion of the business case for processors.)

True Change Is Achievable Only When Industry Players Work Together

The short-term changes of individual players outlined above offer several immediate benefits for Vietnamese shrimp producers. They would be able to create additional value of $30 million in export revenues over the next five years. Shrimp producers are currently positioned to create just $0.7 million to $2.1 million of additional value (based on exports) in one year.

Over the next five years, the industry could reduce water use by as much as 0.4%, saving up to 125 million cubic meters, preventing up to 90 million cubic meters of wastewater leakage, and reducing feed use by 3,700 metric tons per year.[12] These changes could boost EBIT margins by as much as 40% in individual cases.

Although this represents a meaningful step forward, the value created by these changes pales in comparison with the value that can be created if the industry were to set its sights higher. If Vietnam's shrimp producers were able to implement traceability and achieve growth levels on a par with India's, for example, they could add up to $300 million annually to Vietnam's shrimp industry. Short-term changes, on the other hand, would reap only about 2% of this value, or about $6 million annually.

Increasing water quality and use, using special functional feed, or switching to renewable energy options can bring about short-term gains, but true change can be achieved only when the industry works together on a larger scale. What's needed is an innovative business model focused on long-term sustainability. (See the sidebar "An Opportunity to Create Business Value and Positive Environmental Impact by Converting P. Monodon Farms.")

AN OPPORTUNITY TO CREATE BUSINESS VALUE AND POSITIVE ENVIRONMENTAL IMPACT BY CONVERTING P. MONODON FARMS

P. monodon, a shrimp species that is native to Vietnam, was traditionally farmed in mangrove areas, its natural habitat. While stocking densities on farms are much higher than in shrimp's natural habitat, it soon became evident that mangrove areas are not ideal for shrimp farming:

- **Unfavorable Pond Construction.** Low sea levels prevent construction of deep ponds and complete drainage of used water during and after farming cycles.
- **Low-Quality Soil.** Soil embankments used as natural barriers at the edges of ponds tend to decrease in size over time and eventually to breach.
- **Low-Quality Water.** Soil in mangrove areas is highly organic with high acid sulfate potential and low pH levels. Shrimp farming requires low acidity.
- **High Stress Levels That Result in Higher Risk of Disease.** Low pH levels stress shrimp and can reduce pond water nutrients, leading to serious threats to health and susceptibility to disease.
- **Higher Overall Costs.** Construction and production costs are generally higher due, for example, to initial soil reclamation before pond construction, extensive use of lime to increase water quality, and higher maintenance costs that result from soil degradation.

With lower shrimp yields and productivity losses over the years, shrimp farming in mangrove areas is not recommended. The business case for shrimp farming there is not as favorable as that for shrimp farming in supratidal areas or as favorable as the standalone value of mangrove areas.

Mangroves contribute up to about $4,000 to $8,000 per hectare per year of standalone value in terms of carbon sequestration, coastal protection, forestry, and fisheries. Over a ten-year period, this value is eight times the potential value of shrimp farming in mangrove areas. Many farmers have realized the disadvantages that mangrove areas present to shrimp farming and have abandoned these areas for supratidal areas, where they cultivate L. vannamei shrimp intensively. Some countries have stopped shrimp farming in mangroves. In Thailand, for example, P. monodon farming in mangrove areas is now prohibited by law. In Vietnam, however, P. monodon still accounts for some 70% of the total land used for shrimp farming.

Integrated Mangrove Shrimp Farming Is Neither Economically Viable nor Environmentally Sound

Vietnam's shrimp industry is working with NGOs and several certification bodies to

AN OPPORTUNITY TO CREATE BUSINESS VALUE AND POSITIVE ENVIRONMENTAL IMPACT BY CONVERTING P. MONODON FARMS (continued)

produce certified P. monodon shrimp in integrated mangrove shrimp-farming systems, in which mangrove trees are planted alongside shrimp ponds to create a more natural habitat. In theory, these systems adhere to set mangrove-to-pond-area ratios and aim to imitate the natural habitat of P. monodon, reducing the environmental impact.

However, the positive business and environmental impact of these systems is questionable. Buyers promise price premiums to certified farms, but these premiums are achievable only when the entire market has high value. Furthermore, the output volume and production costs are similar to extensive production systems. For these reasons, the business case is rarely compelling.

The environmental benefits are also unclear. In many cases, farmers do not adhere to the mangrove-to-pond-area ratios, and that means that they are still deforesting or cutting mangroves just to replant them elsewhere. By diminishing mangrove density, shrimp farmers are unwittingly eliminating a key characteristic of healthy mangrove areas and failing to capitalize on their standalone value. This approach is therefore viable for neither businesses nor the environment.

Sustainable Intensification and Mangrove Protection Reap Business Benefits and Protect the Environment

P. monodon farms should seek alternative farming methods. One promising solution is to switch from P. monodon to intensive L. vannamei farming. In doing this, the industry could boost productivity by up to 80% without having to convert additional land or construct new ponds. L. vannamei intensive farms can be stocked up to 13 times more densely than P. monodon farms, offering up to 20 times the annual revenues and tripling average productivity per hectare. (See the exhibit below.) This move has the potential to shift industry value by as much as $2.7 billion based on export revenues.

While the shift to L. vannamei is promising, it does require considerable capital investment and technical knowledge, especially when done in the most environmentally responsible way. P. monodon farmers tend to be small-scale farmers without access to capital or expertise, so for them, there is a significant challenge to implementation.

If farms are converted in ways that do not respect the environment, the increase in productivity will be very short-lived. And although L. vannamei farming can be done intensively, it also presents some sustainability challenges—including water pollution and disease outbreaks—and farmers must address these issues directly in order to thrive.

Businesses Can Contribute to Environmental Protection

Farmers should acknowledge the value of mangrove areas and work with communities to foster awareness of the benefits of mangroves and develop opportunities to capitalize on those benefits. The growing carbon-offsetting trend can open up new economic opportunities for farmers in Vietnam to abandon extensive P. monodon shrimp farming, especially in the Mekong Delta, which was once covered with 250,000 hectares of dense mangrove forests. Farmers can have their reforestation or forest protection initiatives certified—as verified carbon standard or Gold Standard—in exchange for a defined amount of money per ton of carbon dioxide that the initiative can store.

By protecting mangroves instead of engaging in risky and expensive shrimp farming, farmers could achieve superior profit margins and secure revenues, but

AN OPPORTUNITY TO CREATE BUSINESS VALUE AND POSITIVE ENVIRONMENTAL IMPACT BY CONVERTING P. MONODON FARMS (continued)

they need to consider that the certification process is currently still complicated and costly. Nevertheless, the current carbon-offsetting trend does give shrimp farmers an economically viable alternative to deforestation and funds reforestation projects. Such initiatives should be promoted by NGOs and local communities to raise awareness and unlock the full economic potential of mangrove forests.

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 60 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.

INTEGRATED AND LARGE PLAYERS MUST ACHIEVE SIGNIFICANT CHANGE

While small, standalone players can make short-term changes that suit their business model and specific circumstances, integrated and large players are uniquely positioned to pioneer broad-based changes across the entire industry. With strong market power, access to financing, and the ability to scale, fully integrated players—which can make improvements and implement changes quickly and efficiently at every step along the supply chain—are positioned to push the industry in a new direction.

No market claims can be made in the absence of transparency and traceability. If activity along the supply chain is visible, actors' accountability 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. And retailers, eager to avoid product recalls and minimize the potential for reputational damage, want to track and trace products from pond to plate.

Vietnam has relatively few players that are fully integrated across the value chain, but this is beginning to change. Many large processors and exporters that have historically relied on reexports are expanding into the farming and hatchery business—an important step toward traceability.

With increasing power and control over critical parts of their supply chains, these integrated players can become frontrunners for traceability in the industry. On the other hand, if large Vietnamese shrimp producers do not take action, traceability will be nearly impossible, and the lack of traceability will undermine the industry's long-term future.

COLLABORATION ACROSS THE VALUE CHAIN CAN ENSURE INDUSTRY HEALTH

GIVEN THAT 70% OF Vietnam's exports—worth $2.5 billion—go to the US, the EU, Japan, and South Korea, refused shipments can have serious repercussions on the overall value chain. The US Food and Drug Administration, for example, has cited multiple problems with Vietnamese shrimp imports, including salmonella, drug contamination, and mislabeling. China, which has historically had less strict import requirements, is increasingly monitoring imports and prioritizing food safety.

Consequently, retailers and importers are pushing for full traceability, which is both a necessity and a business opportunity. Consumers demand it, and a niche segment is willing to pay a premium for sustainable products. 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."

Traceability represents a complex challenge in Vietnam. Middlemen are heavily involved in transactions—not just with farmers and processors but also with feed mills and hatcheries. Middlemen pose a major challenge as 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. In addition, the industry is quite fragmented at the farm level, with minimal data collection and little incentive to share data. Furthermore, Vietnam's reexporting business makes it very difficult to trace the provenance of shrimp.

Nevertheless, with the demand for traceability becoming the norm, the shrimp industry in Vietnam needs to act now to gain a competitive edge and ensure industry survival. Every player in the supply chain must participate and share reliable data among multiple stakeholders. Shielding supply chain data in modern value chains erodes the trust of those purchasing products and makes it appear as though companies have something to hide.

The Far-Reaching Business Benefits of Traceability

Exhibit 10 outlines traceability's important economic benefits 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

EXHIBIT 10 | 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 rewards and punishment of producers of sustainable and unsustainable products

Improved logistics
- Optimizing transportation routes 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.

volumes. Traceability can increase operational efficiency through record keeping, but that works only if farms take action accordingly.

- **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 and 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, 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.** Because some consumers are willing to pay a premium for traceable food products, traceability is 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.

Traceability Is the Key to a Bright Future for Vietnam's Farmed-Shrimp Industry

There are many ways to implement traceability in supply chains, ranging from supply chain integration to software solutions. (See Exhibit 11.)

One way is for integrated players that have full control over their supply chains to provide traceability. However, because of the heavy reliance on reexports and middlemen and the relatively small number of truly integrated players, this is easier said than done.

Another technique is to verify the country of origin through elemental profiling. This new

Exhibit 11 | 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.

technique has emerged to verify 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.[13] 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 where the shrimp was grown, verify the production technologies and methods used, or trace the trading route of the shrimp from production to point of entry.

Elemental profiling adds a layer of oversight to 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

Various technology-enabled traceability solutions, 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.

This solution is easy to use, accessible, and affordable even for the smallest farmers. However, it does not entirely solve the issue of data verification, and it relies on truthful specifications and uploaded data from all involved players.

Pairing the Internet of Things (IoT) with blockchain represents another promising technology 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.
- The 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, but this technology has not yet been used to track shrimp. Technology companies, including IBM, VeChain, Provenance Technologies, and ConsenSys, as well as the newly founded OpenSC food-tracking platform, are providing traceability for various products with less complex supply chains than that of the shrimp industry. Consistent data collection is a prerequisite for successful traceability, and its lack poses significant barriers to implementation.

As import authorities in key buying nations such as Japan advocate for more traceability in the shrimp supply chain, Vietnamese supply chain actors are feeling pressure to respond, and technology companies are innovating to provide new solutions for traceability. Te-Food, a blockchain technology provider, is planning to launch a pilot for tracking shrimp in the Mekong Delta. The company is collaborating with Vietnam's government, and the testing phase will involve about a thousand small-scale farms. This pilot is a step in the right direction, but middlemen still pose problems. The traceability pilot excludes middlemen, but because most processors in Vietnam still rely on them, shrimp from certified farms and uncertified farms can be mixed in a single batch, making it difficult to trace shrimp along the value chain. (See the sidebar "Certifications: There Are No Shortcuts to Full Traceability.")

The Vietnamese government and a handful of companies have begun to make traceability a priority, but there is much more work to be done. Traceability requires action at every link along the supply chain, and the various parts of the industry must work together to implement these far-reaching changes. If traceability can be achieved, Vietnam will not merely survive—it will thrive in the decades ahead.

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 a positive impact on certain production or supply chain elements, but many do not address environmental and social issues in 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. In many cases, the lack of traceability of certified supply chains renders 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 seafood—farmed and caught—was certified, and this number is expected to climb by about 5% annually through 2025. A small proportion of customers will pay premiums that can be as high as 40% in specialty stores for shrimp certified as sustainably produced and fully traceable.

Certification standards and practices are problematic for the following reasons:

- Certification standards vary, and each certifying organization establishes minimum or maximum limits for such concerns as antibiotics and chemicals, land use, and water pollution. 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 infrequent-

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

ly—at most twice a year. Furthermore, only a subset of farms in collectives is checked and audited, 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 time 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, 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 from the nonsustainably produced shrimp.

Certifications aim to provide transparency on sustainability and production standards, but implementation is close to impossible in Vietnam'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 what has worked for the Vietnamese shrimp industry in the past—providing certified products without proof of traceability detached from certification—will not succeed. More holistic approaches to supply chain integrity are necessary. Over the long term, indoor farming is poised to disrupt the entire industry.

LONG TERM, INDOOR FARMING WILL DISRUPT THE ENTIRE INDUSTRY

In addition to the collective effort to establish technology-enabled traceability within the supply chain, large Vietnamese shrimp producers could overhaul shrimp production at its very core. One of the most promising opportunities is the shift to high-intensity, high-volume shrimp farming in closed systems. Closed-loop systems provide a significant improvement over today's production methods and an important shift toward sustainable intensification. The effect of closed-loop systems can be further accelerated by moving them indoors.

Viet Uc is building indoor facilities in Vietnam, investing about $44 million in intensive indoor farms that cover about 315 hectares in the Mekong Delta. The company has built one of the largest hatcheries in the world. Its capacity of about 15 billion PL per year allows the company to have total control over broodstock. It has also built a feed mill and shrimp-processing plant, and all of these facilities are under one roof. With this vertical integration, Viet Uc controls production from start to finish and can provide full traceability and sustainability over the entire supply chain.

The company expects to produce 120 to 130 metric tons of shrimp per hectare per year, significantly outperforming the standard 18 to 50 metric tons per hectare of intensive outdoor shrimp farms. This huge boost in productivity could be a game changer in Vietnam, given its relatively low overall farming productivity.

Similarly, Charoen Pokphand Group (CP), in Thailand, has invested in indoor farms and plans to shift all production to indoor ponds over the next five to ten years.

Because of the high capital investment, scale, and new construction required, in the short term, indoor farms will be financially viable only for large-scale integrated players. As Viet Uc is already proving with indoor farming, an integrated player can build 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. This approach offers closed-loop-system and indoor-farming advantages.

Closed-loop-system advantages include the following:

- 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 advantages include the following:

- Traceability as long as the entire production process is integrated and the shrimp are not sold to processors by middlemen
- Lower costs and fewer logistics requirements 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 the construction in highlands
- More sophisticated, automated, and monitored control over inputs and no use of antibiotics
- Disease risk mitigation through a cleaner environment
- Avoidance of external contamination
- Opportunity to increase control over social responsibility and ensure ethical conduct

The business case for indoor farming is still evolving. The investment costs of up to $200,000 per hectare of pond area and operational costs of up to about $4.37 per kilogram (compared with conventional farming costs: about $3.30 per kilogram of shrimp) for large indoor farms in Southeast Asia are high, 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 12.)

Although indoor farming is complex and scaling up requires a certain level of expertise, it promises to be the future of shrimp farming.

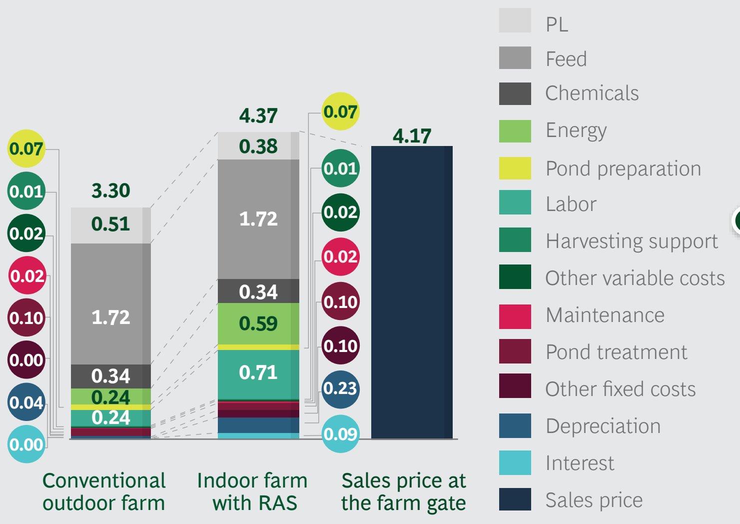
Throughout the history of shrimp farming, industry players have moved from extensive systems—characterized by low stocking densities and high land use levels per kilogram of shrimp produced—to more intensified systems.[14] With the shift toward intensification, stocking densities and farm output per hectare increase and the need for land and water per kilogram of shrimp output potentially decreases. In turn, total energy use (and per unit energy use at the rates achieved today) increases. And when farms are not well managed, disease risk also increases. Indoor farms can mitigate disease risk and wastewater discharge, and a transition to renewable energy can reduce energy costs.

Vietnam's farm productivity has been relatively low, not only because of its reliance upon extensive P. monodon shrimp farming but also because compared with other countries, L. vannamei intensive farming has lower output than average. Shrimp production systems and intensification levels vary significantly in Vietnam, but overall productivity remains low enough to cause concern. (See Exhibit 13.)

Solutions for small to midsize players in Vietnam are needed to holistically and inclusively improve farm efficiency and productivity. One step in the right direction would be to implement closed-loop systems, such as RAS. When combined with removable covers on ponds, which add protection from external contaminants, even small to midsize players can create "indoor" closed systems with better control and higher productivity, supporting the long-term industry shift to lower-impact indoor farms.

EXHIBIT 12 | In Vietnam, Indoor-Farming Production Costs Are About $1.10 Higher per Kilogram of Shrimp

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 rate (from 60% to 70%)

Feed and chemical costs are stable

Energy consumption and costs climb by a factor of 2.5 with RAS and the increased use of technology solutions and automation

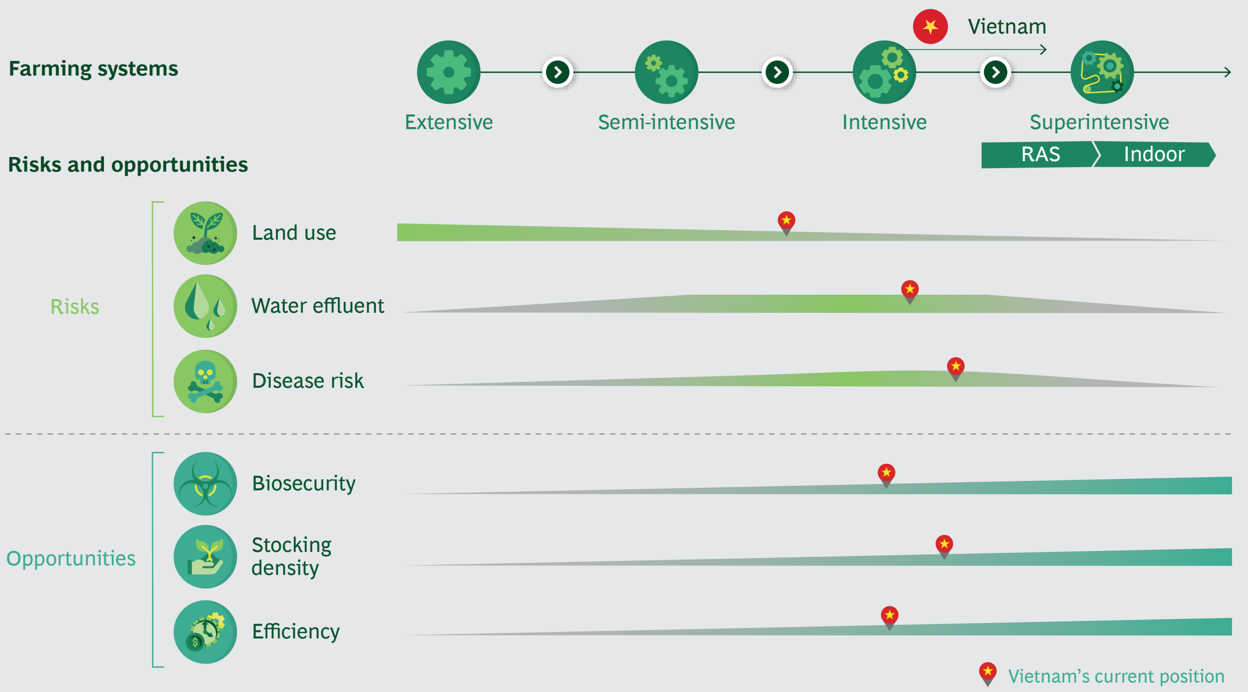
Labor costs increase significantly owing to a shift from low-skill to high-skill labor despite the overall reduction in the amount of labor required

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 10 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 13 | Farming Systems for L. Vannamei: Intensification Mitigates Environmental Impact While Boosting Productivity and Quality



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

THE TIME TO ACT IS NOW

The Vietnamese shrimp-farming industry is under immense pressure to develop more sustainable practices. As one of the former leading nations in shrimp farming, Vietnam has an opportunity to make progress at many levels: by implementing short-term changes, fostering traceability, and innovating in the space of indoor shrimp farming to increase efficiency without further land conversion.

Shrimp is becoming an ever more important source of protein around the world, shifting from being a luxury product consumed in predominantly Western markets to being a mass-market product that is increasingly available and sought after in developing countries. Vietnam faces a significant business opportunity as well as the responsibility to farm shrimp in a manner that protects resources, conserves the environment, and benefits all actors along the supply chain without violating labor laws and human rights or risking the health of consumers.

Vietnamese players must respond, not only improving production at an individual level but also lifting the industry from import dependency and mitigating the risk of future import refusals due to contaminated shrimp.

By embracing this approach, Vietnam can reverse its downward trend, produce high-quality and safe products, and preserve natural resources. If the industry navigates these transitions successfully, 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, 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 improvement systems, 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 14.)

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 shrimp faster and larger.

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 shrimp 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 cycles per year, improves biomass and productivity.

Health enhancement functional feed aims to improve shrimp survival and 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 14 | Functional Feed: The Impact, Costs, Requirements, and Results

	FOCUS	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 sales 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 36% higher for farmers	✓ Loss from disease 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 Treatment and 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 in terms of sophistication, levels of water reuse, and cost. Many systems use microbes to regulate water quality and imitate natural water conditions. Exhibit 15 provides an overview of commonly used closed-loop and microbial systems.

Two approaches to improve water quality during shrimp production—biofloc and RAS—have been modeled in detailed scenarios, but the capital investment and operating costs can present challenges. (See Exhibit 16a.)

With biofloc, carbohydrates are added to water, increasing the carbon-to-nitrogen ratio. The nitrogenous waste blends with other bacteria, algae, and fungi, creating a biofloc that improves water quality while reducing FCR, as it can also be used as a feed source for shrimp. (See Exhibit 16b.)

Biofloc can have positive environmental impact. It leads to a statistically relevant decrease—as much as 73%—in nitrite levels in pond water to 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 15 | Overview of Water Quality Enhancement and Closed-Loop Systems

Nonexhaustive

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 animal
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 animal
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 animal

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

RAS offer significant advantages for farmers:

- The various filter and water treatments improve the 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 broad implementation:

Exhibit 16a | Capital Investment and Operating Costs Are the Main Concerns in Method Selection

	FOCUS		
	Water treatment: biofloc system Inserting bacteria or chemicals to reduce water pollution	**Water recycling: RAS** Treating water to allow for water reuse within farms	**Integrated aquaculture: integrated multitrophic system** 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 16b | 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

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

- Installation of the necessary filters and treatments 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 require higher energy use).

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

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

- Sophisticated recirculating aquaculture systems that include significant alterations to the production facilities and 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

The shrimp-farming industry has an opportunity to reduce its environmental footprint and avoid disruptions in its energy supply by shifting toward 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 17.)

There are three types of solar energy available to shrimp producers: PV cells that can be installed on the ground in close proximity to ponds, 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 from $1.7 million per megawatt to $1.9 million per megawatt, including storage costs. Farm size, location, 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.

EXHIBIT 17 | 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.

APPENDIX

MARKET DYNAMICS AND THE ENVIRONMENTAL IMPACT OF IMMEDIATE CHANGE

To calculate the business case for each player in the Vietnamese shrimp value chain, the base case (today's average) was derived from BCG knowledge, proprietary data, and industry expertise and 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 player along the value chain, we also analyzed the overall market structure and the environmental impact of immediate change.

Feed Mills

Market Dynamics. The feed industry in Vietnam is dominated by large international players. Overall feed use for the aquaculture industry is growing rapidly and expected to reach a market size of 4.3 million metric tons in 2019 as compared with 3.3 million metric tons in 2017. Shrimp feed is estimated at 550,000 metric tons, valued at $600 million in 2017.

The major players in Vietnam—Grobest Industrial Viêt Nam, CP, Uni-President Enterprises, and Thang Long—represent about 85% of the market. The rest of the market comprises small to midsize local and international players with small operations in Vietnam.

The feed market is dominated by basic feed. Only 5% to 10% is certified and/or functional feed. The share of certified feed varies significantly, depending on overall shrimp market prices. When, owing to low overall shrimp market prices, farmers are struggling to sell their shrimp at a profit, they are reluctant to purchase the more expensive feed.

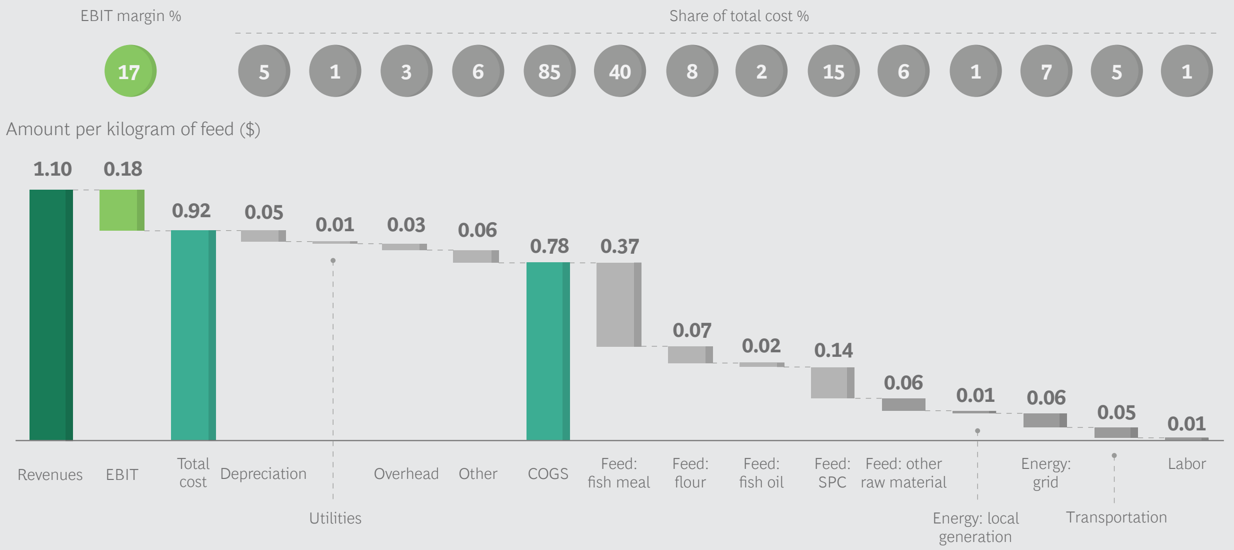
However, functional feed has significant potential in Vietnam, where the farming industry must deal with low survival rates and high FCR. Feed mills should promote the various benefits of enhanced feed types to help farmers understand the business value.

Business Case. A feed mill selling basic feed currently sells its products for about $1.10 per kilogram, with an EBIT margin of about 17%. Exhibit 18 shows the average economics of today's feed mills.

Growth Enhancement Functional Feed. Feed mills can achieve EBIT margins of up to about 26% on sales of functional feed. This is up to about 58% higher than current EBIT margins per kilogram of product sold. However, as functional feed increases farm efficiency, revenues per kilogram of shrimp produced for feed mills could decrease.

Ideally, improved growth and sales potential for farmers would lead to an increase in volume and utilization. This, in turn, would fur-

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.

ther increase demand for functional feed. Additionally, as functional feed will not be used by farms on a regular basis, there is little risk of decreased revenues for feed mills, but the opportunity to boost profit margins through the extended product portfolio is significant. (See Exhibit 19.)

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% for growth enhancement functional feed.
- 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 FCR of about 1.1 compared with about 1.3 for basic feed.

Health Enhancement Functional Feed. This type of feed offers an even better business case for feed mills: superior profit margins of about 36%, increasing today's average margins by a multiple of 2.2.

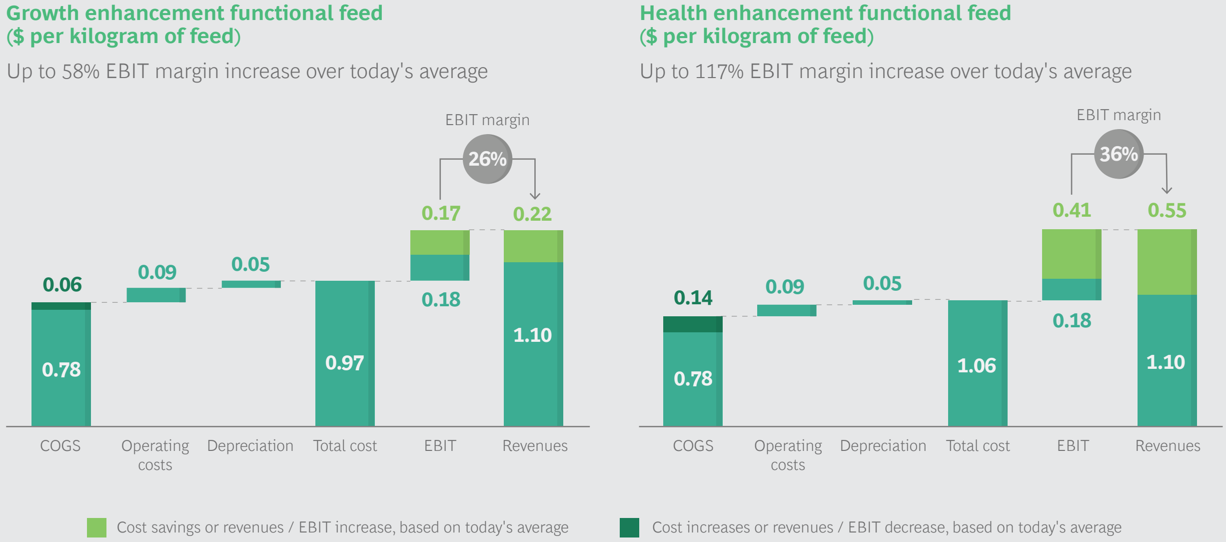
The following are the assumptions on which we based the business case calculations for health enhancement functional feed for feed mills:

- Costs for ingredients and production on a per kilogram basis increases by 10% to 20%, with about 15% assumed as the basis of the business case calculation.
- The health enhancement functional feed imparts the possibility of charging price premiums of 50% or more.
- The price premium is justified by a significantly improved disease survival rate from below 20% to between 70% and 80% during disease outbreaks.

Environmental Impact. The overall impact on the environment is limited, but feed mills enable positive change at the farm level. Individual players can position themselves on the forefront of innovations, sharing best practices in Vietnam with other countries:

- Land use is reduced by up to 15% owing to increased feed efficiency; the use of resources is improved, and there is less waste because the survival rate is higher and shrimp loss is minimal. (See Exhibit 20.)

EXHIBIT 19 | Feed Mills Can More Than Double Their Margins



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

- Water pollution is reduced owing to more efficient feed and less feed waste in water bodies. Also, there is less use of antibiotics and less reliance on fish meal and fish oil. The goal is to replace all fish meal use with plant-based nutrients.

- 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 environmental implications, as soybean production is causing widespread deforestation.

Hatcheries

Market Dynamics. The overall demand for PL, which are crucial inputs for shrimp production, stands at about 120 billion PL per year (assuming full capacity and perfect survival rates).

The largest producer of PL, with about 20% of the market, is Viet Uc. A single hatchery can produce about 15 billion PL per year. CP's market share is 15%. Overall, however, the hatchery market is highly fragmented with a large number of backyard hatcheries run by families. In total, there are some 2,500 hatcheries, of which 600 are estimated to produce PL for L. vannamei shrimp.

PL survival rates are very low, whether grown domestically or imported—at great expense—from the US, Singapore, and Thailand. About 80% of PL market sales are controlled by agents or distributors who charge farmers additional premiums of up to 20%.

Quality and survival of PL are major concerns for hatchery owners and farmers, who depend upon PL as a crucial input. PL survival rates are about 35% to 40%, so hatcheries should improve their management to increase PL survival, potentially increasing shrimp production multifold.

Business Case. Exhibit 21 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.

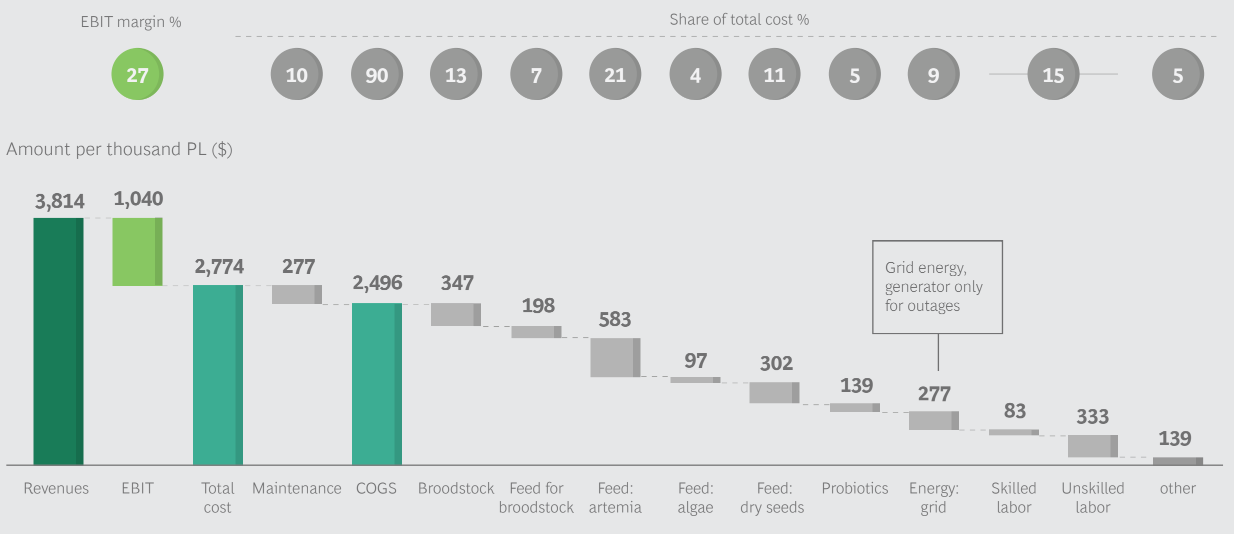
Environmental Impact. Despite their informal organization in the supply chain, hatcheries are a focal point for intervention because of the relevance of high-quality, healthy PL for the entire supply chain. Increasing the survival rates and quality of PL would impact the business model of hatcheries significantly since they have low survival rates overall. Higher survival rates would reduce waste and improve reputation, allowing

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 water body	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 water body	Replacement of antibiotics with probiotics; health improvements through, for example, 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 | 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.

hatcheries to charge higher prices for good-quality PL. Water treatment and antipollution measures could further reduce the environmental impact of hatcheries. 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 shrimp-farming market in Vietnam is widely fragmented. A handful of large-scale farms, including BIM Foods, Minh Phu Seafood, Quoc Viet Foods, Viet Uc, and CP (including their contracted farms), account for approximately 35% of farming output. About 65% of farming output comes from some 220,000 small-scale farms raising L. vannamei and P. monodon.

In 2017, the estimated production stood at 450,000 metric tons; about 60% (or 270,000 metric tons) was L. vannamei. Hundreds of commercial farms and more than 90% of the large-scale farms located mainly in the Mekong Delta and central Vietnam produce L. vannamei intensively.

Viet Uc is advancing fully indoor superintensive production methods, integrating farms, feed, hatcheries, and processing to produce fully traceable, clean, and healthy shrimp. But most farmers in Vietnam are poor, and they purchase shrimp feed and PL from traders and informal shops without knowing their origin.

The shrimp survival rates in Vietnam remain relatively low at 60%—compared with 65% in disease-plagued Thailand—and yields are lower than in neighboring countries ranging from 7 to 15 metric tons per crop from only two or three crops per year.

Although farm gate prices vary significantly, a price of $4.17 per kilogram—at 80 pieces per kilogram—of L. vannamei was assumed with an EBIT margin of 21%.

The farming process has become increasingly technical, with innovations in aeration and oxygenation, water pumps, feeding machines, and tanks. Because investing in these innovations can be costly, they are used primarily on the larger farms, but they can greatly reduce risk and increase survival rates.

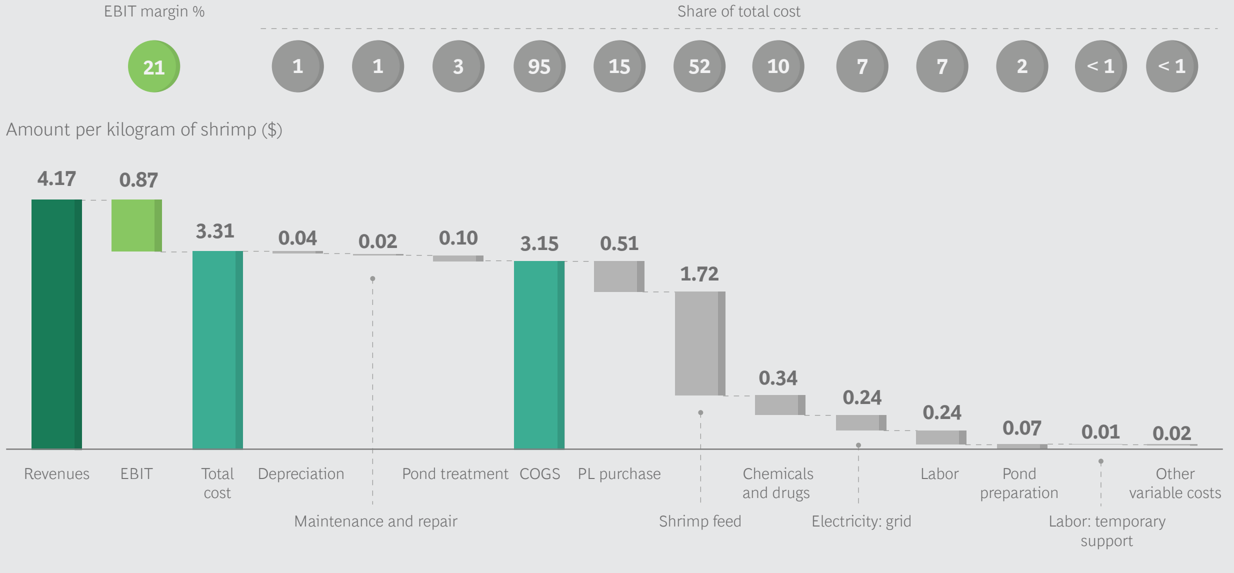
Business Case. Exhibit 22 shows the average economics of today's farmers. We explored the impact of a number of factors related to farm economics and environmental impact, individually and in combination: functional feed, biofloc, RAS, and solar energy.

Growth Enhancement Functional Feed. Farmers can achieve EBIT margins of about 28% per kilogram of shrimp sold when using growth enhancement functional feed. This is a relative increase of 36% and an increase of $0.39 per kilogram in absolute terms. (See Exhibit 23.)

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

- The margin increase is driven by the ability to charge a sales price that is 6% higher for larger shrimp.

EXHIBIT 22 | The Average Economics of Farmers



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.

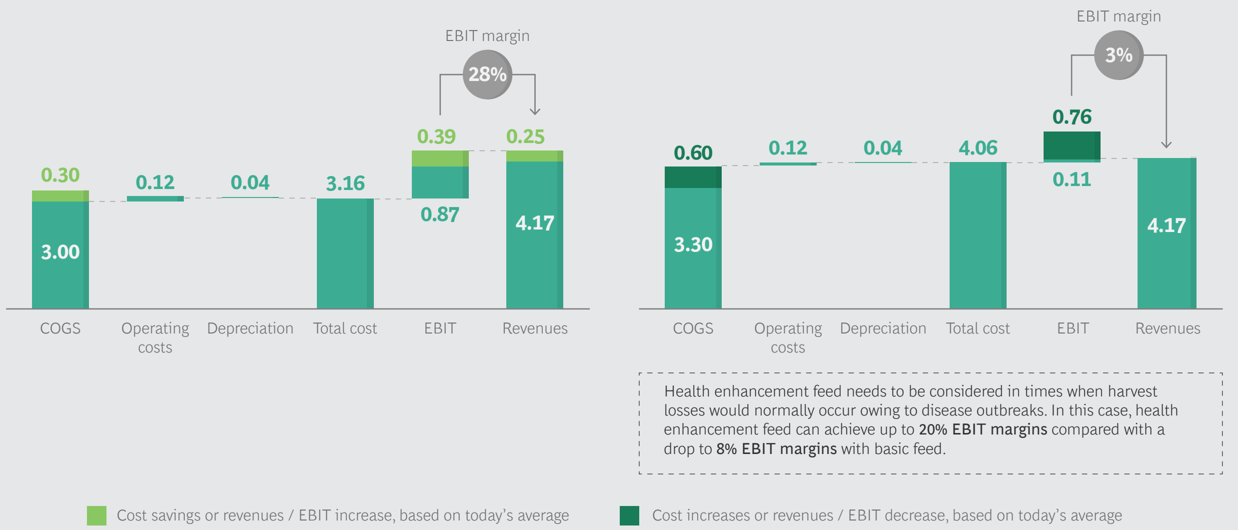
Exhibit 23 | Growth Enhancement Functional Feed with an EBIT Margin Increase of up to 36%

Growth enhancement functional feed ($ per kilogram of shrimp)

Up to 36% EBIT margin increase over today's average

Health enhancement functional feed ($ per kilogram of shrimp)

Up to 88% EBIT margin loss from today's average



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

- The high price for functional feed is compensated for by a reduction of up to 15% in FCR due to the higher nutritional value of functional feed, which is used for the second half of the growth cycle.

Health Enhancement Functional Feed. Measured on a profit per kilogram basis, health enhancement functional feed is not a profitable alternative to conventional feed. The 50% higher price of shrimp feed reduces the EBIT margin to 3%—a drop of 88% from 21%, today's EBIT margin. However, if disease outbreaks are anticipated, an EBIT margin of up to 21% can be achieved—compared with 8%, today's average—assuming that 20% of the harvest is affected by disease.

By preventing disease outbreaks, health enhancement functional feed yields superior revenues and profits in the long term with survival rates of about 73% (compared with 60% with basic feed). During times of a disease outbreak, survival rates can increase from less than 20% to about 70% to 80%. Health enhancement functional feed serves as a risk management tool for farmers with a clear financial incentive, but achieving benefits requires long-term planning, management, and foresight.

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

- Feed is sold at a premium of up to 50% over basic feed.
- No change in FCR, but survival rates rise from 20% to about 70% to 80%.
- Scenario 1. With basic feed for the entire production, about 80% of crops are successful with a 60% survival rate, and 20% of crops hit by disease have a survival rate of only 20%.
- Scenario 2. With 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 73%.

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.

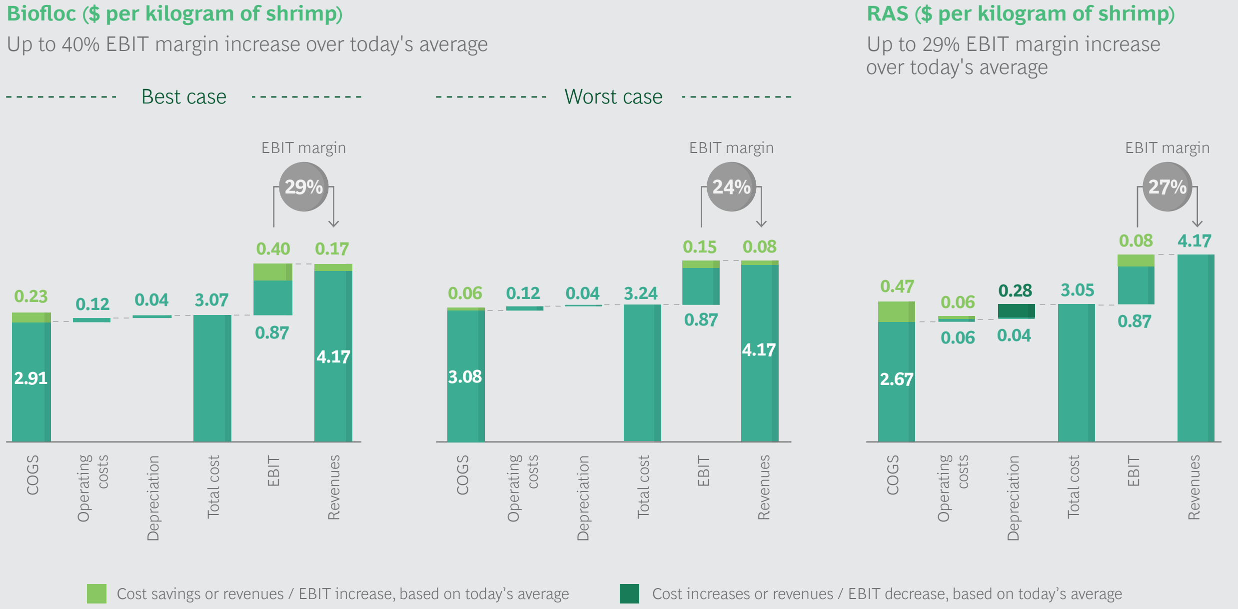
Biofloc and RAS. The business case for using biofloc depends on the farm's technical management, which influences prices, costs, and production parameters (such as FCR and growth cycles).

In the best case, biofloc can yield EBIT margins of up to about 29%, a relative increase of up to about 40% over today's average. In the worst case, biofloc yields EBIT margins of up to about 24%, an increase of about 15% over today's average, or it can even lead to a decline in EBIT margins. Results vary depending on the farm's technical management, which influences prices, costs, and parameters such as FCR and growth cycles. If farmers are knowledgeable and consistently monitor the system, they can expect to achieve the best-case scenario. If the application of biofloc fails, EBIT margins could drop significantly. (See Exhibit 24.)

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.
- The cost of skilled labor rises 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 3% to 7% as water quality improves through biofloc use.
- The additional cost for cornmeal as a carbohydrate source ranges from about \$0.28 to \$0.44 per kilogram. To produce a kilogram of shrimp, approximately 0.65 kilograms of cornmeal is a required biofloc ingredient.
- In the worst-case scenario, variable costs stagnate or decrease by 2%, and in the best case, costs decrease by as much as 7%.
- Because of the protein content in biofloc, the growth rate increases by as much as 27%, raising the sales price of the larger shrimp by 2% to 4%.

EXHIBIT 24 | Biofloc Can Increase EBIT Margins by as Much as 40%, While RAS Can Increase Them by as Much as 29%



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.

Farms that use RAS can achieve EBIT margins as high as 27% per kilogram of shrimp produced, increasing today's average EBIT margins by up to 29%.

Assumptions for the business case calculations for RAS for farms include the following:

- The possibility of a twofold increase in stocking densities due to better water quality and monitoring of water conditions
- Investment costs of $150,000 per hectare, depreciated over ten years and leading to an expected yearly yield of 50,000 kilograms per hectare (based on increased stocking densities)
- A 15% decrease in variable costs, 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
- A 50% decrease in fixed costs due to higher stocking densities

When considering RAS, farmers should keep in mind that indoor intensive farming will be the key to long-term survival and success in the industry—and RAS represents a first preparative step.

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 reduces the use of new intake water (except to make up for seepage and evaporation), but because energy consumption is higher, there is the risk of higher air pollution. Still, the use of RAS has the potential to reduce land use because the increase in stocking densities allows for higher output per hectare.

Combined Options: Growth Enhancement Functional Feed and RAS. The combination of growth enhancement functional feed and RAS yields EBIT margins of up to 34%, increasing EBIT margins by as much as about 61% over today's average. When compared with the standalone functional feed and RAS cases, the combined case offers up to about 21% and about 26% higher EBIT margins, respectively. (See Exhibit 25.)

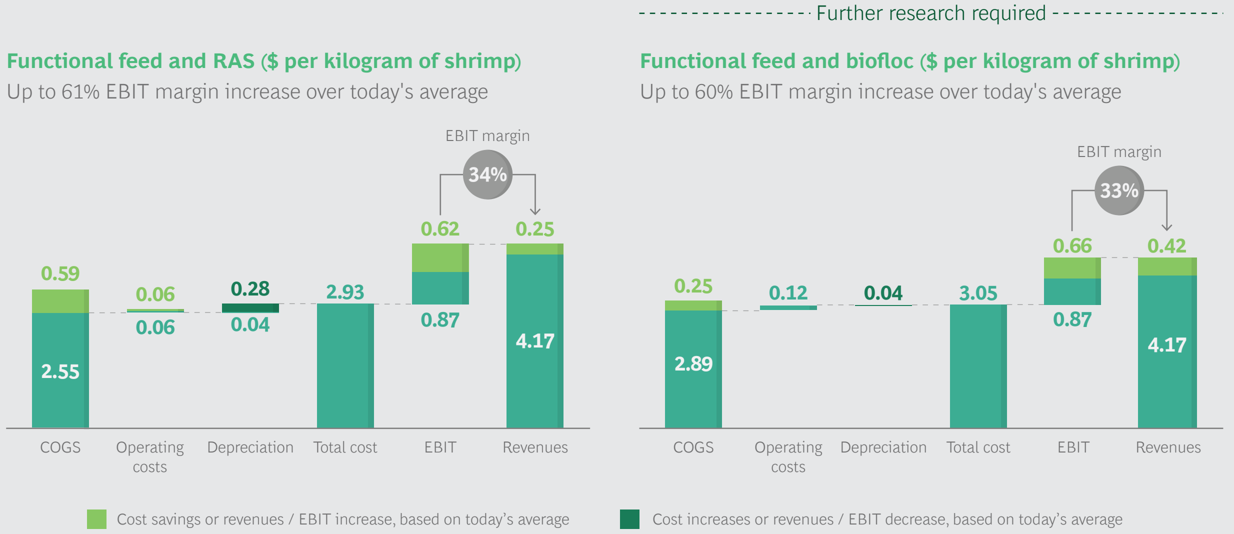
The assumptions for business case calculations for the combined use of growth enhancement functional feed and RAS for farms include the following:

- Assumptions are comparable to standalone solutions, as both methods affect different variables.
- Doubled stocking density is possible owing to higher water quality and improved monitoring of water conditions.
- Reduction of FCR by 15% is due to the use of functional feed during half of the production cycle.
- A 6% increase in the sales price of shrimp due to larger shrimp size is 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).
- Variable costs decrease by as much as about 19% based on RAS use.
- A 50% decrease in fixed costs is due to RAS.
- Investment costs of $150,000 per hectare are depreciated over ten years with an expected yearly yield of 50,000 kilograms per hectare—double today's average.

Combined Options: Growth Enhancement Functional Feed and Biofloc. The combination of functional feed and biofloc is likely to offer a better business case than standalone options, as both affect the same production parameters.

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

Exhibit 25 | A Combined Solution Can Increase EBIT Margin by as Much as 61%, 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 improves up to 32%, as the functional feed and biofloc can reduce FCR. This is compared with a 15% reduction through the use of growth enhancement functional feed and a 25% reduction through biofloc. (The effect on 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 leads to even higher prices achievable in the market if global shrimp prices are correspondingly high.)

- Additional assumptions for biofloc (averaged best and worst cases) include a skilled labor increase of 8%, an energy increase of 30%, a chemical decrease of 5%, and the price for cornmeal as a carbohydrate source at approximately $0.36 per kilogram with 0.65 kilograms of cornmeal needed per kilogram of shrimp produced.

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

Solar Energy. When farmers rely on a generator for backup energy, EBIT margins are reduced by more than 20% to 17% owing to high fuel costs of about $224 per megawatt hour. When solar energy is used instead of diesel generators, EBIT margins could rise about 20%, which is a drop of up to about 6% in EBIT margins when compared with today's average (assuming a stable grid energy supply). (See Exhibit 26.)

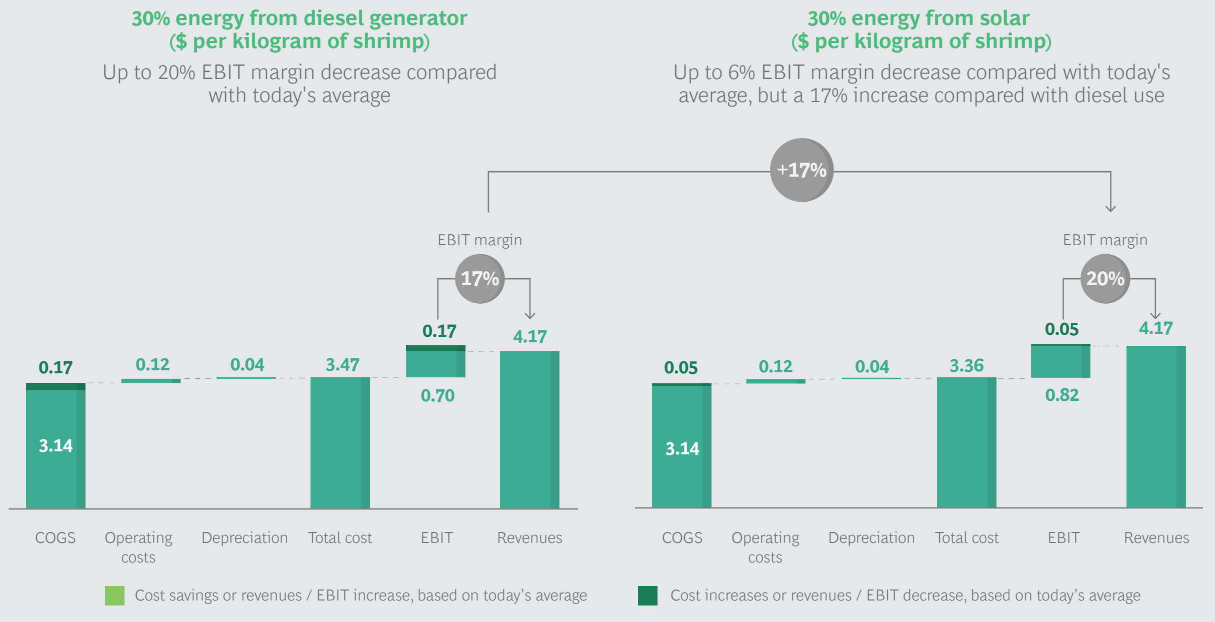
Assumptions for business case calculations for solar energy include the following:[15]

- A levelized cost of energy for solar options, including batteries, is currently estimated to be higher than grid energy but significantly lower than diesel generator use.

- Electricity is 70% from the grid and 30% diesel generated.

- An average levelized cost of energy for solar of ground-mounted tracking, floating tracking, and floating PV systems is $115 per megawatt hour.

Exhibit 26 | The Use of Solar Energy Trumps Diesel Results for EBIT by as Much as 17%



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

- The grid energy price is $65 per megawatt hour, and the diesel price is $224 per megawatt hour.

- This is applicable only for players in remote areas or in areas with unreliable grid energy.

Farmers who are exposed to frequent electricity outages should consider implementing renewable energy sources, which offer a better business case than generators. This would also decrease carbon dioxide emissions and the environmental footprint associated with them.

Environmental Impact. Farmers are the key lever for transforming the entire supply chain in terms of profitability, volume, and shrimp quality. Farmers can make a positive contribution to the environment and ensure the sustainable, long-term survival of operations: their livelihoods depend on it. Solar energy results in lower carbon emissions than do diesel generators and grid-sourced energy. However, construction of solar panels can, in some cases, affect land use.

Middlemen

Market Dynamics. In Vietnam, middlemen play a crucial role in the supply chain. A single middleman may be responsible for connecting some 100 farmers at one time with processors, and they handle about 70% of all shrimp produced. Often multiple layers of middlemen aggregate shrimp from various farms, which prevents full transparency on the shrimp's provenance.

Middlemen buy and resell shrimp, earning low profit margins of 0.5% to 3%, depending on their position within the value chain and the services added.

For the Vietnamese supply chain to maintain a strong connection with the Western and Japanese export markets, it should find ways to operate without middlemen so the shrimp can be traced more reliably.

Business Case. No quantitative business case was assessed, but middlemen can play a key role in moving the industry toward traceability. Currently, it's difficult to trace and track shrimp in Vietnam because, in many cases, middlemen mix and sort shrimp from multiple farms. Exhibit 27 illustrates the average margins of middlemen.

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. There are about 500 processors in Vietnam. Approximately 200 processors have a license to export to the EU, but only about 100 handle major exports to Western markets.

About 70% of farmed shrimp is processed for export, and approximately 160,000 to 210,000 metric tons of these exports were at one time imported from other countries—such as India and Ecuador—and then reprocessed for export. About 30% of processing is value added—for example, the shrimp are cooked or breaded—and the remainder is simple processing.

Exports tend to be more formalized than other steps in the value chain. They are managed primarily by major companies that were once state owned but have been privatized.

Processors typically achieve profit margins of about 10%, depending on the type of processing and shrimp.

Business Case. Exhibit 28 illustrates the average economics of today's processors. No quantitative business case was assessed, but as processors exist at the intersection of buyers and retailers, they are directly affected if retailers refuse to buy Vietnamese shrimp owing to social or environmental concerns or if retailers want better traceability and sustainability and are willing to pay a premium price. This opportunity currently exists only for a niche market, because the mainstream market competes on price. If processors enable the upstream supply chain, they can yield high benefits, including sustained access to larger quantities of high-quality shrimp, market access, and good relationships with buyer markets.

Environmental Impact. Processors in Vietnam have a decent amount of market power in the supply chain: they buy shrimp in large quantities from farmers and pass on the market price for shrimp. With their direct connection to export markets, processors also have to comply with regulations and retailer and importer demands directly. This provides

EXHIBIT 27 | The Average Economics of Middlemen

Eample of L. vannamei

Value ($ per kilogram)	Purchasing price	Transportation	Labor costs	Ice	Depreciation	Other costs	Total cost	Sales price: collector	Sales price: wholesale
Unit value	4.17	0.02	0.03	0.08	0.01	0.04	4.35	4.37	4.48
Share of the total(%)	~96	<1	~1	~2	<1	~1	100	~0.5	2.5

Margins earned by collectors and wholesalers

Sources: *Journal of Food and Agriculture*; BCG analysis.
Note: L. vannamei = Litopenaeus vannamei. Because of rounding, not all numbers add up to the totals shown.

EXHIBIT 28 | The 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. Production output of 1 kilogram of frozen shrimp requires at least 1.3 kilograms of raw shrimp.

a strong incentive to support the shift toward traceability along the entire supply chain. If processors support traceability, this will reduce land use as well as water and energy consumption.

NOTES

1. This estimate, based on data of the Food and Agriculture Organization of the United Nations (FAO), has been adjusted for production losses due to disease and harvest losses.
2. Vietnam's government has set a national action plan for the development of the shrimp industry through 2030. The plan, which sets growth targets of 1.3 million metric tons of shrimp output and $12 billion in export value, includes the creation of a high-tech shrimp industry and a large-scale ecofriendly shrimp-farming area.
3. The export value is based on data from the Vietnam Association of Seafood Exporters and Producers and FAO.
4. The business case analysis and recommendations in this report are focused mainly on L. vannamei, as it is considered the major species in shrimp farming. P. monodon production has been declining since the early years of this century. However, general issues and trends are also relevant for P. monodon production.
5. For example, in 2018, Vietnam and the EU finalized the terms of a free trade agreement that is expected to be ratified in 2019.
6. This takes into account only L. vannamei production. Including P. monodon production, the average output level is reduced to about 0.7 metric tons per hectare for the entire industry. Calculations are based on the total farmed-shrimp output and total land use, including water treatment systems, facilities, and buildings—not just pond area.
7. This assumes a growth rate of about 4.3%, which was derived from an average of past and current growth rates. There are no official forecasts for production.
8. Southern Shrimp Alliance, 2018.
9. Carboxymethyl cellulose powder is a gelling agent that is sometimes used as a laxative. This information is from several sources, including *Viêt Nam News*, *SeafoodSource News*, and Southern Shrimp Alliance.
10. FCR indicates how much feed is needed for the production of 1 kilogram of shrimp.
11. RAS provide the ability to reuse water on the farm, thereby dramatically reducing freshwater intake as well as wastewater discharge into the environment.
12. The effects on the feed market, as well as the impact on land and fish use, should be examined separately.
13. 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.
14. PL stocked per square meter in brackish water for the production of shrimp.
15. Further assumptions for the calculation of levelized energy costs: fuel costs are $0.72 per liter, the weighted average cost of capital is 9%, the capital expenditure for ground mounted PV is $1.7 million per megawatt hour, the operating expenditure is 2% of capital expenditure, and the mean capacity factor for solar irradiation is about 15%.

NOTE TO THE READER

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