A Strategic Approach to Sustainable Shrimp Production in India

THE CASE FOR IMPROVED ECONOMICS AND SUSTAINABILITY

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A STRATEGIC APPROACH TO SUSTAINABLE SHRIMP PRODUCTION IN INDIA

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HOLGER RUBEL

WENDY WOODS

DAVID PÉREZ

SHALINI UNNIKRISHNAN

ALEXANDER MEYER ZUM FELDE

SOPHIE ZIELCKE

CHARLOTTE LIDY

CAROLIN LANFER

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EXECUTIVE SUMMARY

Shrimp farming has been a huge success story for India. From 2011 through 2018, the country's farmed-shrimp industry grew by 23% and, through 2024, is expected to grow by 11%, far surpassing global growth rates of 5.6%. With such explosive growth, the country has established itself as the second-largest farmed-shrimp producer in the world, after China. Despite this extraordinary growth story, India is facing increasing challenges.

India has a very strong competitive position. International demand is high, and the potential for growth is excellent. Still, four developments threaten the industry's future profitability.

- **Low Shrimp Survival Rates and Increasing Disease Risk.** The survival rates of India's farmed shrimp are low—just 55%, which is significantly lower than the rates of many other countries. Thus far, unlike Thailand, India has not been affected by devastating diseases, but because its rapidly growing farms have low biosecurity standards, experts are predicting that India will eventually suffer from disease outbreaks.

- **Limited Value-Added Processing Capacity.** Value-added processing is a profitable business, but India's capacity is limited: 28% of its exports are sent to Vietnam for further processing. Not only is this a lost revenue opportunity, it also hinders efforts to achieve product traceability.

- **Strict Traceability Standards.** In 2018, the US Congress extended coverage of the Seafood Import Monitoring Program to shrimp, requiring stricter reporting and record keeping for shrimp imports. Given that India exports 40% of its shrimp to the US, there's pressure for India to provide traceability across its supply chain. Because most shrimp farms in India are unregistered, however, it's very difficult for the government to regulate farmed shrimp.

- **Increasing Environmental Pressure.** Shrimp farms have expanded rapidly, paying minimal attention to environmental impact.

While the Indian farmed-shrimp market continues to expand quickly, farmers need to implement significant changes in production.

- To increase profitability, expand resource efficiency, and reduce disease risk, India's shrimp industry should make immediate changes in three areas: feed, water treatment, and renewable energy.

- These changes should be viewed as just the first steps toward a much more sustainable approach to shrimp farming.

To maintain their strong ties to the US market, India's shrimp producers must offer fully traceable products.

- Regulators and retailers, pushed by consumer demands and reputational concerns, are becoming increasingly concerned about food safety and sustainability.

- India's shrimp producers are not well positioned to fulfill major importers' ever-stricter traceability requirements.

- By offering a fully traceable product, India can respond to changing consumer demands, stay ahead of tightening US import standards, and defend its leading position in the mass market.

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

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

- To protect shrimp ponds from environmental hazards, stabilize water quality, and reduce disease risk, companies should consider shifting to fully closed indoor systems. This production method allows farm operators to increase stocking densities and support a fully traceable product with low environmental impact.

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

Fast growth in recent years has masked a host of challenges that face India's farmed-shrimp market. To maintain its leadership position and strengthen ties with the US market, India's shrimp producers must quickly make the transition to traceability and sustainability.

MARKET FORCES ARE RESHAPING THE GLOBAL SHRIMP INDUSTRY

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

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

The overall industry is growing at a record pace, but not all shrimp producers are thriving. In the early years of this century, China, Thailand, and Vietnam were leaders in the shrimp farming sector—and India was only the sixth-largest shrimp producer. But the competitive landscape has shifted. Outbreaks of disease and rising labor costs have threatened this once-thriving industry, and India, which has dramatically increased its share in the global shrimp market by producing large volumes at low prices, has become the second-largest shrimp producer worldwide, after China.

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

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 aspects of unregulated shrimp production, including the use of banned chemicals, environmental degradation, and human and labor rights violations.

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

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

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

Nearly all major retail chains, supermarkets, and convenience stores around the world have pledged to increase their share of sustainably produced food—including shrimp and other seafood categories—and an increasing number of major retailers are requiring suppliers to sign contracts and carry out in-depth due diligence to ensure traceability and adherence to ecofriendly production methods 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 risks 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, the industry must establish a clear definition of what it means for food to be labeled sustainable. To put it simply, sustainable products should be produced today in ways that do not compromise the ability to produce those same products tomorrow. Products should minimize environmental degradation and the use of natural resources and should be traceable across the supply chain to provide greater transparency and accountability. For sustainability to have maximum impact, it is important for all stakeholders to understand and adhere to these fundamental principles.

To defend its current strong competitive position and to maintain exceptional growth, India needs to embrace sustainability. As changes are implemented across the supply chain, the industry must align on the definition of sustainability and establish mechanisms that will hold all actors accountable.

INDIA'S SHRIMP INDUSTRY IS THRIVING BUT IS VULNERABLE TO THREATS

INDIA, WHOSE GLOBAL COMPETITIVE position was strengthened owing to outbreaks of diseases and production issues in Thailand and Vietnam in the early years of this decade, is currently the second-largest shrimp producer in the world, with a global market share of 14%. In 2017, the country produced around 600,000 metric tons of shrimp. (See Exhibit 1.) India's production value, which is currently estimated to be more than $3 billion, has grown at a 32% CAGR since 2010.

The Basics of India's Shrimp Industry

There are two farmed-shrimp species in India: L. vannamei, also known as whiteleg shrimp, and Penaeus monodon, or P. monodon (black tiger shrimp). L. vannamei accounts for about 80% of production, growing at an 18% CAGR over the past five years. Most L. vannamei is produced in Andhra Pradesh. P. monodon has declined in importance, growing at a 5% CAGR over the past five years. Most P. monodon is produced in West Bengal. (See Exhibit 2.) The focus of this report is mainly on L. vannamei since it is the primary driver of market growth.

For the following reasons, India's farmed-shrimp industry has been thriving in recent years:

- **Strong Demand While Competitors Struggle with Disease Outbreaks.** Two important competitors, Vietnam and Thailand, have lost a lot of ground as a result of disease outbreaks.

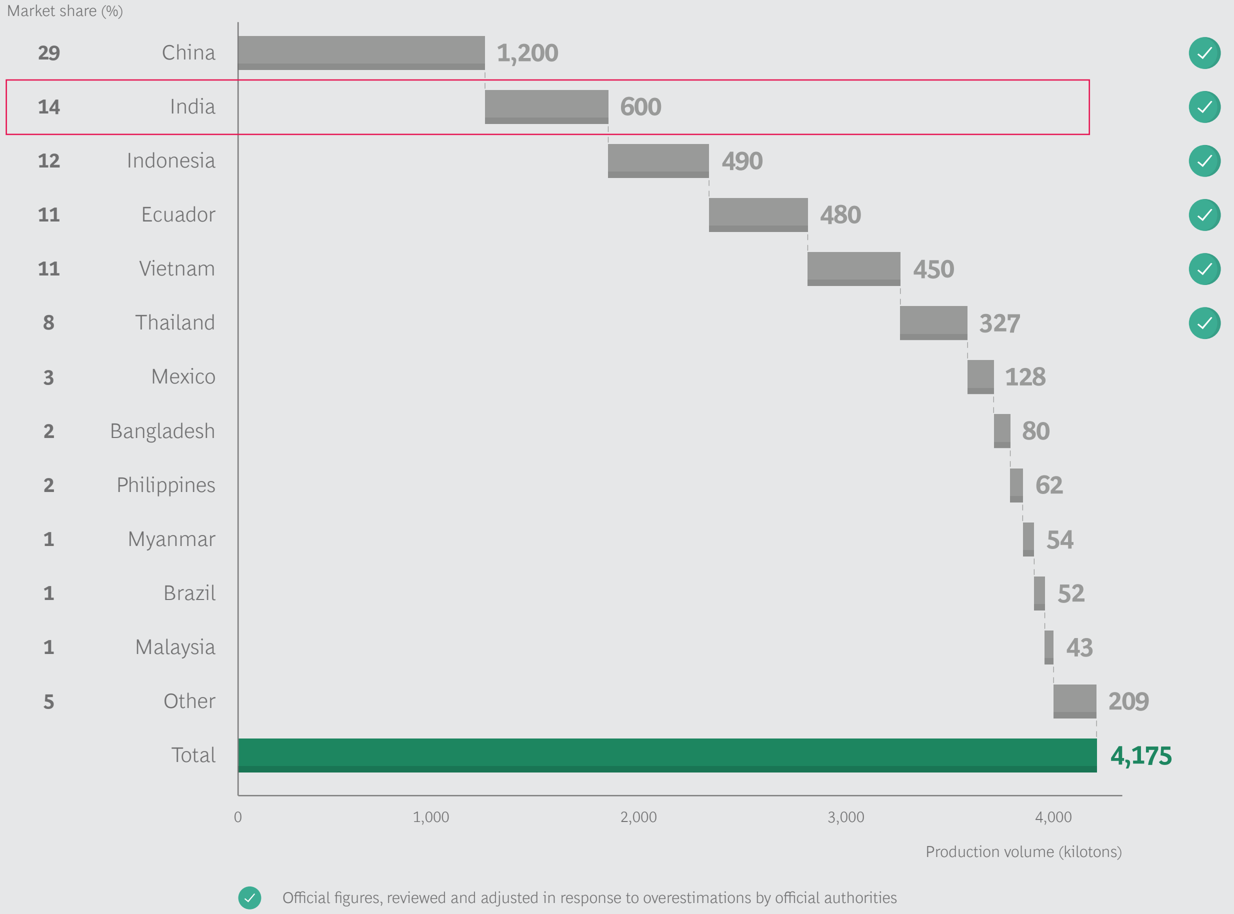
  Thailand, formerly the second-largest shrimp producer, has seen its production cut in half since 2012 owing to a series of disease outbreaks. Even though India introduced L. vannamei only in 2010, by 2014, it was able to surpass Thailand's production volume, filling the gap that opened up when other countries could not meet market demand.

- **Competitive Advantage Due to Lower Production Costs.** India's production costs are lower than those of many other countries, thanks, in part, to low labor costs and strong governmental support for the shrimp industry. The Indian government has been providing subsidies for processing facilities, offering crop and equipment insurance, and investing in broodstock facilities and local breeding programs. In the future, governmental support for shrimp farming could be linked more closely to environmental standards and regulations.

- **Abundant Land That Enabled Quick Expanding of Production.** Shrimp-farming areas have expanded rapidly, particularly in Andhra Pradesh, and, unlike in other countries, land availability

Exhibit 1 | With a 14% Market Share, India Is the World's Second-Largest Shrimp Producer

Global aquaculture production of shrimp, 2017



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

has not been a limiting factor. Most farms are not registered, and many don't adhere to governmental standards, so shrimp production has done considerable damage to the environment. Still, the government has little power to enforce regulations on unregistered farms.

- **Focus on High-Volume Exports with Only Basic Processing.** India's farmed-shrimp producers have focused primarily on high-volume production of low-cost, minimally processed shrimp almost exclusively for the export market. This focus allows producers to export their products quickly without the cost of additional processing and investment. However, value-added processing is far more profitable.

India is by far the largest global shrimp exporter, and shrimp is the country's largest agricultural export. Until recently, less than 5% of total production was for domestic consumption. In recent years, domestic consumption has increased to around 20% of total production—primarily fresh shrimp. Approximately 90% of processed shrimp, mostly frozen, is exported. Some 40% of shrimp is exported to the US, followed by approximately 30% to Vietnam and nearly 15% to the EU. (See Exhibit 3.) The growth rate of India's exports has slowed recently. In 2017, exports grew 31%, but in 2018 they grew only 8%.

India's Value Chain Is Complex

The value chain of India's farmed-shrimp industry comprises several interrelated steps:

Exhibit 2 | There Are Strong Regional Differences in India's Shrimp Production

Gujarat

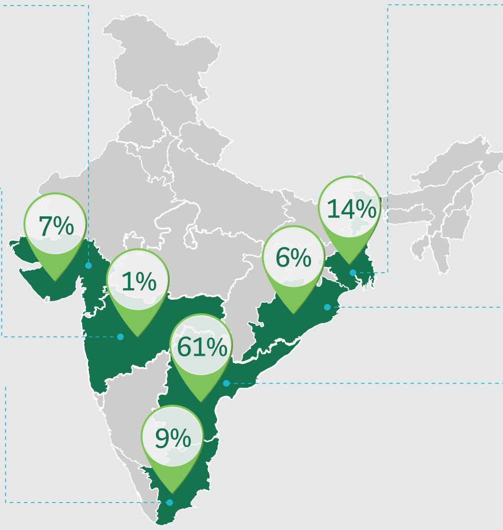
Species	Share of total production (%)
L. vannamei	8.1
P. monodon	1.5

Maharashtra

Species	Share of total production (%)
L. vannamei	1.5
P. monodon	0.01

Tamil Nadu and Puducherry

Species	Share of total production (%)
L. vannamei	11.0
P. monodon	1.4



West Bengal

Species	Share of total production (%)
L. vannamei	1.7
P. monodon	76.1

Orissa

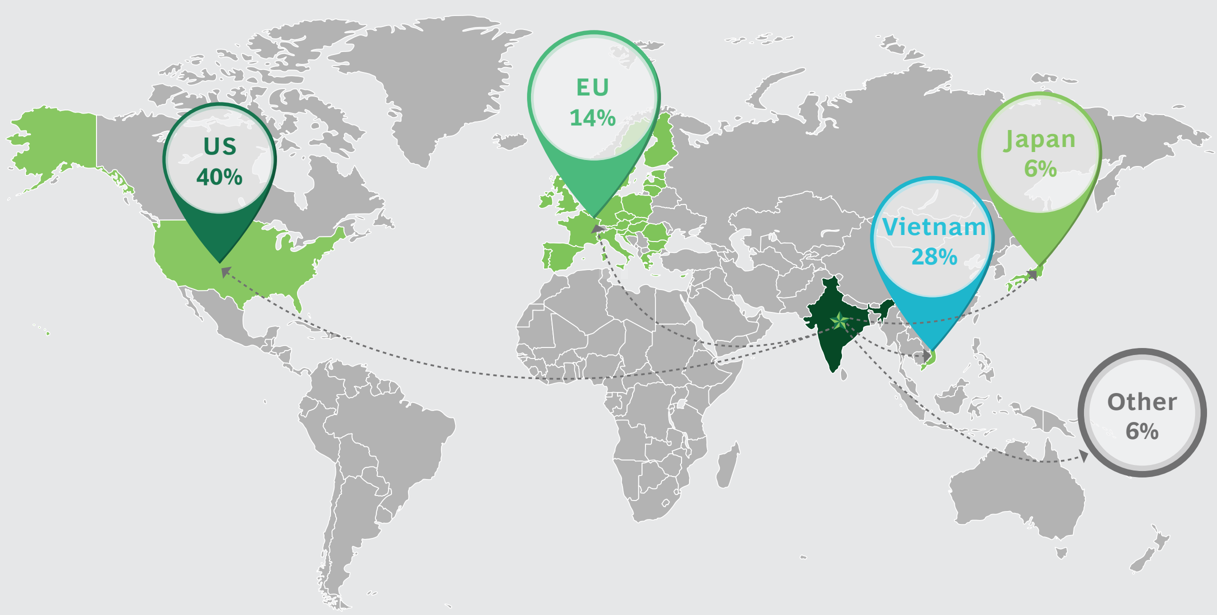
Species	Share of total production (%)
L. vannamei	4.7
P. monodon	11.3

Andhra Pradesh

Species	Share of total production (%)
L. vannamei	72.7
P. monodon	4.6

Sources: Marine Products Exports Development Authority, 2016; BCG analysis.
Note: The number on each state represents the percentage of India's total shrimp production for either L. vannamei or P. monodon; colored rows in the tables indicate the most significant markets contributing to L. vannamei or P. monodon production, respectively.

Exhibit 3 | The US Accounts for the Highest Share—40%—of India's Shrimp Exports, Followed by Vietnam, the EU, and Japan



Sources: UN Comtrade; Imarc Research; BCG analysis.
Note: This data includes all species of shrimp and is based on FY 2018 data.

EXHIBIT 4 | India's Farmed-Shrimp Supply Chain

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

feed mills, hatcheries, farmers, middlemen and commission agents, processors, exporters, and retailers. (See Exhibit 4.)

This report focuses on the first five steps:

- **Feed Mills.** Two players, Avanti Feeds and CP India, together control approximately 70% of the shrimp feed market. Several midsize companies control 20%, and the rest of the market is highly fragmented.
- **Hatcheries.** BMR Group controls 20% to 25% of the market, but the rest of the market is very fragmented. Five to seven large-scale hatcheries, including BMR Group, control around 60% of the market.
- **Farmers.** Approximately 90% of shrimp farms are managed by small or midsize players; large corporate players, including BMR Group and Devi Fisheries, control 10% of farms and shrimp farm hectares.
- **Middlemen.** These intermediaries, also called commission agents, play a role between farmers and all other segments of the value chain. Middlemen in India control about 40% of production.
- **Processors.** Generally, both the processing and the exporting are managed by one company. The market is highly fragmented. Nekkanti Sea Foods and Avanti Feeds have the largest processing capacities.

Across the value chain, there are some fully integrated players. The two largest, Avanti Feeds and CP India, own feed mills, hatcheries, farms, processors, and export facilities. In addition to these fully integrated players, various midsize downstream players—such as Devi Fisheries—own farms as well as processing and export facilities. Many smaller players, such as Nekkanti Sea Foods, focus on processing and distribution only.

INDIA

THE CASE FOR CHANGE

India's shrimp industry is currently in a strong competitive position in the global market, but three market forces are threatening its position: limited value-added processing capabilities, lack of traceability, and an intensifying need to cope with low productivity and the high risk of disease. (See Exhibit 5.)

Limited Value-Added Processing

Most of the shrimp in India undergo basic processing and are sold to other countries for additional value-added processing and reexport. Approximately 30% of India's farmed-shrimp is exported to Vietnam for further processing. Value-added shrimp products are more profitable, but India has limited value-added processing capacities. EBIT margins for frozen shrimp with minimal processing are about 8%, whereas value-added processed shrimp's EBIT margins are around 20%. This lost-revenue opportunity limits the industry's overall profits.

A few large processing companies, such as Avanti Feeds, Castle Rock Fisheries, Devi Fisheries, and Apex Frozen Foods, produce high-quality, processed shrimp and have all the certifications in place to export their products directly to food companies in the US and Europe. Avanti Feeds, for example, sells 80% to 85% of its processed shrimp to retail chains such as Walmart and restaurants such as Red Lobster, which maintain very high quality standards.

Market Demand and Traceability Regulations

In 2018, the US expanded its Seafood Import Monitoring Program (SIMP), which establishes reporting and record-keeping requirements for seafood imports, to cover shrimp. Because the US is India's most important export market, SIMP has had a major impact on the Indian shrimp industry, especially when standards have been strictly enforced. Given India's relatively low traceability standards, SIMP will likely have a negative impact.

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

The demand for traceability is fueled also by a fast-growing niche market for sustainable and traceable seafood, and some companies are beginning to capitalize on this trend. A group of companies in Ecuador, for example, established the Sustainable Shrimp Partnership to produce fully traceable shrimp while improving social and environmental performance. As first movers act on this trend toward traceability, India finds itself in a precarious position regarding its exports. It risks losing share in the global shrimp market. Giv-

EXHIBIT 5 | The Case for Change in India Is Driven by Three Factors

Source: BCG analysis.

en its still relatively weak domestic market for farmed shrimp, the shift toward traceability and sustainability affects India more than other countries, such as Indonesia, with strong domestic demand. Because most farms in India are not registered and India's government has very little control over unregistered farms, establishing traceability will be challenging. For a number of reasons, however, it's important that India shift toward traceability and sustainability now. By raising sustainability standards in the supply chain, the Indian shrimp industry can tap into new markets, build an even stronger competitive position, and become a leader in this segment.

Low Survival Rates and Increasing Disease Risk

Approximately 80% of L. vannamei farms in India are semi-intensively farmed. With survival rates of just 55%, Indian farms are significantly less productive than those in other countries—even in countries such as Thailand that have been previously ravaged by disease. India has thus far been spared a major disease outbreak, but its rapidly growing farms have low biosecurity standards and therefore disease risk is high. Industry experts expect that Indian farmers will face a major disease outbreak eventually.

With more than 100,000 shrimp farms in operation, more than 90% of them family owned and only 1% registered with the Coastal Aquaculture Authority, India will find it difficult to implement change quickly. But improved survival rates can boost production by 300,000 metric tons of shrimp (equal to 50% of production volume in 2017) and create production value of $1.5 billion annually.

Despite these challenges, India's shrimp producers are reluctant to change their methods: the industry is currently profitable, and the supply chain costs remain low. While it's true that India continues to dominate the global export market, growth rates are slowing, and inaction poses a high risk.

The following are the risks of inaction for the industry overall:

- Reputational damage due to contaminated shrimp and unsustainable practices could affect profitability for years.
- Import refusals and loss of market access could threaten up to $2 billion in exports (from a total of $4.9 billion).

The following are the risks of inaction for producers:

- Farms that do not comply with stricter environmental standards that are being more strongly enforced by local authorities could be shut down.
- Producers that fall behind in sustainability and traceability could lose market share and access.
- Producers that use unsustainable methods will become less productive over time, resulting in operational and financial losses.

SHRIMP PRODUCERS CAN CREATE IMMEDIATE ECONOMIC VALUE

Three imperatives inform the future of India's farmed-shrimp industry:

- Pursue immediate change to alter current practices on an individual level, increasing efficiency and productivity while improving profit margins.
- Collaborate to achieve product traceability.
- Shift to indoor shrimp farming by investing in closed-containment indoor facilities that reduce contamination, increase output, minimize environmental footprint, and improve accountability. (See Exhibit 6.)

The shift to traceability, transparency, and indoor farming offers the highest potential for successfully defending the currently strong competitive position of India's shrimp industry, but this will require considerable capital investment, extensive expertise, and time. In the meantime, there are several immediate changes that actors along the value chain, particularly feed mills and farmers, can implement to significantly improve financial performance and resource efficiency and create environmental benefits.

In this section, we briefly review how each player in India's farmed-shrimp value chain can benefit from these short-term improvements. (See Exhibits 7 and 8.)

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

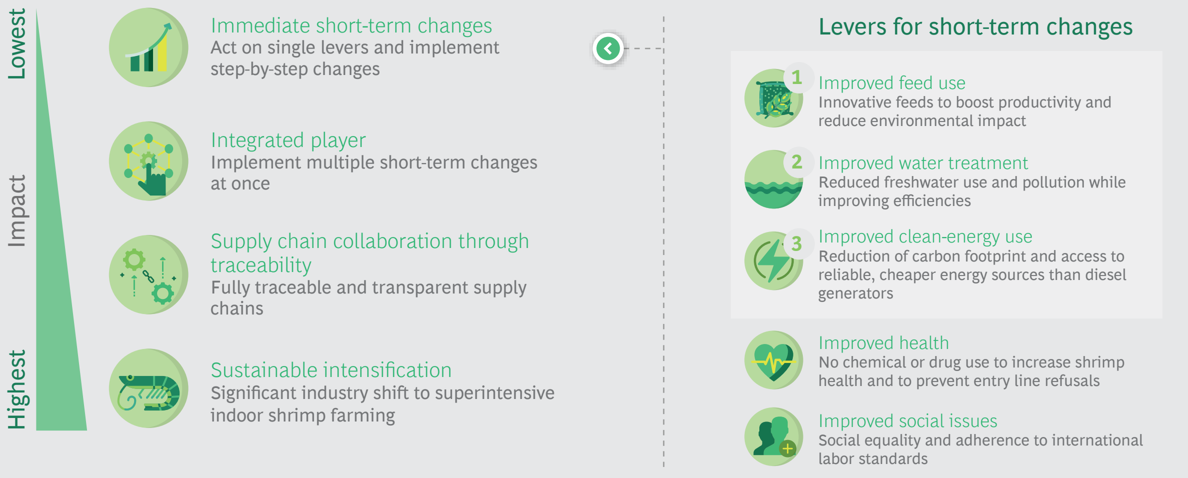
The feed market in India is expected to grow at 11% per year through 2022, in line with India's overall shrimp market. While some large corporate farms buy feed directly from feed mills, the vast majority of farmers—90%—use a well-established dealer network. Feed dealers often supply farmers with materials and credit, and they even link them to processors, acting like middlemen or commission agents.

Feed mills have an opportunity to expand their portfolios to include functional feed—basic feed that has been enhanced with additives, such as proteins, vitamins, or probiotics (but never antibiotics), to achieve a specific outcome. It is not uncommon for feed mills to improve basic feed with additives, but functional feed is slightly different from improved basic feed: it is used in specific circumstances to achieve a specific outcome, usually includes more additives, and is therefore defined as its own feed category.

Two types of functional feed have high potential.

Growth Enhancement Functional Feed. This is used to increase shrimp growth rates and allow farmers to sell larger shrimp at a potentially higher price or to accelerate

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.

growth cycles and, therefore, farm throughput. It offers a positive business case for feed mills, potentially increasing EBIT margins by 130% per kilogram of shrimp feed sold. This increase in profitability is achieved by charging a premium of as much as 20%, offsetting the additional production costs.

However, when farmers invest in growth enhancement functional feed, their feed conversion ratio (FCR) is drastically reduced.[1] The immediate demand for feed may drop, reducing revenues by up to 16% per kilogram of shrimp produced, but this decline can be offset by other factors, including the ability to charge higher prices for functional feed and an overall uptick in demand for feed (as shrimp grow faster and demand increases).

Health Enhancement Functional Feed. This type of feed can enhance shrimp health and disease resistance, and it also offers several benefits for feed mills, not the least of which is that feed mills can charge premiums of up to 50%. Production and feed ingredient costs will likely increase by 10% to 20%, but these costs are typically offset by the revenue boost.

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

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

Feed mills are responsible also for careful consideration of the production of the feed's ingredients. Worldwide, the demand for fish

EXHIBIT 7 | Current Average Economics per Value Chain Step

	Feed mills	Hatcheries	Farmers	Middlemen	Processors	Local market / Exporters	National retailers / International retailers
Costs	$1.00 per kilogram of feed	$2.18 per 1,000 PL	$3.75 per kilogram of shrimp		$6.99 per kilogram of shrimp		
Price	$1.09 per kilogram of feed	$4.53 per 1,000 PL	$4.83 per kilogram of shrimp		$7.61 per kilogram of frozen shrimp, the price at the factory gate	$8.30 per kilogram of frozen shrimp for export, including freight and insurance	
EBIT margins %	~8	~50	~22 Example for base-case scenario **Long-term margin ~20% EBIT**	~10 Works on a commission-based model	~10 Frozen shrimp products dominate the market[1] **Value-added margin ~20% EBIT**		

Source: BCG analysis.
Note: Based on an exchange rate of 1 Indian rupee = $0.0151; PL = post-larvae shrimp.
[1]Frozen shrimp constitutes more than 80% of all shrimp exports.

EXHIBIT 8 | The Economics of Short-Term Improvements

	Status quo	Feed	Water	Combination
Feed mill level	EBIT margin: ~8%	**Growth enhancement** EBIT margin: Up to 19% — Increase: 130% **Health enhancement** EBIT margin: Up to 30% — Increase: 260%	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 19% — Increase: 130% Potential revenue loss through improved farm efficiency, with a similar increase in farming output
Farm level	EBIT margin: ~22%	**Growth enhancement** EBIT margin: Up to 30% — Increase: 32% **Health enhancement** EBIT margin of up to 23% even during disease outbreaks versus 11% with basic feed	**Biofloc** EBIT margin: Up to 29% — Increase: 30% **RAS** EBIT margin: Up to 27% — Increase: 22%	**Growth enhancement with biofloc and energy** Positive, but further studies are required **Growth enhancement with RAS and energy** EBIT margin: Up to 36% — Increase: 61%

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

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

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

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

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

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.

Although our analysis did not reveal many opportunities for hatcheries to implement short-term changes in feeding techniques or water treatment systems, hatcheries that offer high-quality PL with benefits such as specific pathogen-free (SPF) broodstock can charge premiums for their products.

Many hatcheries in India still rely on imported broodstock from the US. However, the Indian government is strongly investing in and supporting the development of local breeding programs. SPF shrimp broodstock is now being produced locally by the Rajiv Gandhi Centre for Aquaculture and more broodstock centers are planned. Local broodstock can lower shipping costs and reduce mortality rates during transit. Also, a shift to domestic broodstock can help the Indian shrimp industry become more independent and significantly reduce the potential spread of diseases from foreign countries.

Individual hatcheries should focus on improving quality by domesticating broodstock and implementing selective breeding practices to compete more effectively against the significant market power of integrated players. Because developing better PL involves genetic testing and investments in R&D, implementation might be rather difficult for small hatcheries. Institutions and players with the necessary means should, therefore, continue to support small hatcheries in these efforts. (See the Appendix for a discussion of the business case for hatcheries.)

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

The farming market in India is highly fragmented. With many unregistered farms located in geographically diverse regions, circumstances vary strongly and profit volatility remains high. Profit margins vary significantly. With a good crop, farmers can expect margins of 22% to 25% per kilogram of shrimp sold, but farming carries high risk owing to outbreaks of disease and crop failures; therefore, the average margins over a period of two to three years is more likely to be around 20%.

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

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

Key Opportunity 1: Functional feed can increase profits by up to about 32%, and only minimal training is required. India's farmers have much to gain by using growth enhancement and health enhancement functional feed on their shrimp farms—if they use them in a specialized manner to address specific challenges.

Growth enhancement functional feed has the potential to accelerate shrimp growth rates or to produce larger shrimp. Farmers are likely to opt for growth enhancement functional feed when global shrimp prices rise and they want to take advantage of the opportunity. Under these circumstances, it can be beneficial to use growth enhancement feed during the second half of the growth cycle to boost growth rates and reduce FCR. When growth enhancement functional feed is managed properly, FCR can be reduced by a total of 15%, and the larger shrimp can be sold for up to 6% more, significantly improving EBIT margins. This approach, which drastically reduces quantities of feed needed per kilogram of shrimp produced, compensates for the higher feed price—up to 20% per kilogram. Farmers who manage to sell larger shrimp at higher market prices can achieve EBIT margins of up to 30%, representing increases of as much as 32% over average EBIT margins. If global shrimp prices increase, fast-growing shrimp could allow for an additional production cycle, significantly increasing farming output.

Health enhancement functional feed, which can cost up to 50% more than basic feed, appears quite expensive when the consideration is a single use per kilogram of shrimp produced. However, should farmers anticipate disease outbreaks, health enhancement feed can achieve an EBIT margin of up to 23% because the feed drastically increases survival rates during disease outbreaks.

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

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

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

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

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

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

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

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

In a best-case scenario, farmers benefit from an EBIT increase of up to 30%, resulting in an EBIT margin of about 29% per kilogram of shrimp sold. At worst, if farmers are not able to fully benefit from the advantages of biofloc, they still achieve a small increase in EBIT, leading to an EBIT margin of about 26%. The increase in EBIT margins is a result of decreased costs for feed and chemicals combined with the potential to grow shrimp faster or larger within a given period of time because of the high protein content of biofloc.

With this opportunity, large farms tend to have an advantage over small farms, because they have better access to knowledge and expertise—imperatives for the successful use of biofloc. However, as it can be difficult to scale this method, small farms have the advantage of being positioned to apply the method on a limited scale.

For farmers with the right equipment—such as aerators and monitoring equipment—as well as access to the necessary training and knowledge to maintain biofloc in ponds, this approach is a promising option. Used properly, it can reduce water pollution and prevent eutrophication of natural ecosystems by reusing water. In some cases, however, its incorrect application can have an adverse effect on the heterotrophic pond environment by adding excessive waste material to the water, possibly reducing shrimp survival rates. (See the Appendix for additional information on biofloc.)

RAS are sophisticated filtering systems that treat water so that it can be reused in the same location.[2] Such closed-loop systems offer two significant benefits: no unfiltered wastewater is discharged into the local environment, and demand for “new” water is reduced. In an ideal case, no water exchange is required. Moreover, these systems can improve farm and resource efficiency and boost productivity, as they reduce the need for production inputs such as chemicals, feed, and fertilizers, and therefore can lead to higher EBIT margins for farmers. RAS can be basic biofilters or more sophisticated water recirculating systems and can vary in effectiveness, investment and operating costs, and environmental impact.

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

For producers that can afford the investment, sophisticated RAS—some costing $150,000 per hectare—can potentially increase EBIT margins by up to 22% per kilogram of shrimp produced, resulting in an overall EBIT margin of about 27%. This increase assumes that farmers can reduce fixed costs by 50% and variable costs by 15%, owing to higher stocking densities, reduced labor costs because of automation, and reduced pond preparation costs. The margin increase will counterbalance the capital investment that results in the fourfold increase in deprecation per kilogram of shrimp, as well as the higher costs for the electricity needed to support the use of the filters and constant aeration.

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

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

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

Key Opportunity 3: Solar energy can reduce local energy generation costs. In India, energy represents a major cost sink for farmers. Shrimp farms located in remote areas are faced with frequent energy outages, so they often have to resort to using diesel generators, which are expensive (accounting for up to 20% of total costs) and sources of pollution. Cost estimates vary for farmers depending on their access to the grid network and the frequency of power outages, but many farmers have to deal with this problem. For these farms, renewable solar energy represents a reliable, economic, and clean alternative.

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

Although on the basis of the cost per megawatt hour, solar energy is more expensive than grid energy, it is significantly less costly than diesel. Replacing diesel generators with solar energy can yield a 12% EBIT increase per kilogram of shrimp, resulting in a total EBIT margin of about 25%. This said, the initial investment for PV systems requires significant capex investments—up to $26,000 per hectare depending on the system, or about $15,000 not including battery use. Small farms in remote areas might not be able to afford this. But as batteries and solar power become less costly, this option could eventually be more affordable for remote farms as well as grid users.[3] (See the Appendix for a more detailed discussion on the business case for solar energy.)

Key Opportunity 4: Combining functional feed, water treatment systems, and solar energy could maximize economic benefits and environmental impact. Producers that seek to maximize the effect of immediate, short-term change can combine growth enhancement functional feed, closed-loop systems such as RAS, and solar energy. If farmers implement these correctly, combining these three strategies can achieve EBIT margins of up to 36%—an increase of 61% compared with today's average. This is an improvement of as much as 20% compared with the standalone use of functional feed, up to 33% compared with standalone use of RAS, and up to 44% compared with a standalone solar energy solution.

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

Another option is to combine growth enhancement functional feed with biofloc and solar energy. The combination of growth enhancement functional feed and biofloc affects the same production parameters, and its efficacy is difficult to predict. However, it is likely superior to standalone options.

While these combined approaches have promise, they also require farming expertise and changes in production and farm management. They are, therefore, not likely to be widely adopted unless farmers receive guidance from key partners across the value chain, including representatives from feed mills and processors, as well as technology providers for sophisticated systems such as RAS. Without knowledge sharing across the industry, these techniques will very rarely be used. (See the Appendix for a detailed discussion of combining functional feed, water treatment systems, and solar energy.)

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

Middlemen, also known as commission agents, play a key role in India's farmed-shrimp supply chain. (See Exhibit 9.) They frequently serve as gatekeepers and facilitators between shrimp farmers and processors, in many cases, providing raw materials and financing for farmers and helping processors sort, preprocess, and transport shrimp. In some cases, farmers are heavily dependent on middlemen because the farmers are in debt or they have strong family ties.

Middlemen play an informal role in the value chain, keep minimal records on shrimp purchased and sold, and act with little regulatory or company oversight. A shift in how middlemen conduct their business will be key to the industry's successful transformation to a more traceable and sustainable supply chain.

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

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

Shrimp processing in India is highly fragmented. The majority of processors focus on basic shrimp processing, and large quantities are exported to Vietnam for further, value-added processing. If India's processors were to upgrade their facilities to provide value-added processing, they would achieve significantly higher sales prices for shrimp.

Most processors handle exports as well, and that means that they have a clear incentive to help mitigate risk in the supply chain. When importing countries establish new regula-

Exhibit 9 | Middlemen Play a Critical Role from Farmers to Processors

Sources: *Indian Journal of Pure & Applied Biosciences*; expert interviews; BCG analysis.
Note: Some middlemen in India are called commission agents. This value chain analysis focuses on farmed shrimp in the Navsari district of Gujarat. Data is for 2017.

tions, such as SIMP in the US, processors and exporters must translate these requirements into actions.

Around 40% of production volume reaches processors directly from farmers, so there is an opportunity to encourage the production of high-quality, responsibly farmed shrimp and to reduce disease risks to ensure a stable shrimp supply. Processors stand to benefit when farmers produce sustainable shrimp, because they can obtain a price premium. Due to the fragmented market, this is especially critical for large standalone processors that face stiff competition from integrated players with more control over their supply chain, as well as players in other shrimp-producing markets that are already at the forefront of traceability.

Nevertheless, around 40% of shrimp production in India is managed by commission agents—an added challenge to achieving traceability. Processors can step up and deliver the much-needed transparency that middlemen typically fail to provide. (See the Appendix for a more detailed discussion of the business case for processors.)

Immediate Change Is Limited—Disruptive Transformation Is Needed

The short-term changes outlined above offer several immediate benefits for Indian shrimp producers, but because the changes are implemented on an individual basis, they do not promote the kind of wide-ranging change that's needed to secure the industry's future.

If India attains its projected growth rate of 11% per year over the next five years, the total value of the Indian shrimp market will reach $6.53 billion by 2024 (up from $3.06 billion in 2017). Compared with the global growth rate at just 5.6% per year, this would be a massive gain for India. However, this value cannot be achieved unless India's shrimp producers look beyond short-term, immediate gains and focus instead on developing an innovative business model focused on long-term, inclusive sustainability.

INTEGRATED PLAYERS MUST SUPPORT THE SHIFT TO TRACEABILITY

Standalone players can make short-term changes that help their business thrive, but integrated players are uniquely positioned to leverage changes on a grand scale. India's two largest integrated players—Avanti Feeds and CP India—own their own feed mills, hatcheries, and processing facilities, and they manage their exports. In addition, they either own farms or they contract with individual farmers and closely supervise farm management and shrimp quality.

But even integrated players such as Avanti Feeds and CP India have limited control over certain steps in the supply chain. Avanti Feeds is the second-largest processor with approximately 40% of the market share in feed, but the company has little direct influence over hatcheries and farms. CP India has some 30% of the feed market, a significant share of hatcheries, but less influence over farms and processing. Nevertheless, these players are well positioned to support the shift toward traceability.

As these integrated players shift toward more environmentally sound production, they also must think carefully about how changes will play out at each step along the value chain. For example, when integrated players use growth enhancement functional feed, their feed mills will likely experience a 16% decline in feed sales, but if their farms adopt RAS and solar energy at the same time, farmers can achieve a 61% increase in their profit margins and a fourfold increase in stocking densities. These dramatic improvements in the farming segment could, as a result, more than compensate for the losses in feed mills and support a virtuous cycle: higher farming output encourages additional shrimp farming, which increases the overall demand for feed.

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

Two major shifts in the industry are already observable in some countries, and these will significantly transform the global shrimp market: full traceability and closed-loop systems.

Traceability is key. No market claims can be made in the absence of transparency and traceability. With traceability, supply chain actions become visible, and actors can be held accountable for their actions. This, in turn, creates an incentive for sustainable and responsible production. Importers and regulators, as well as a niche consumer segment, are pushing for this at the global level. Retailers, too, want to track and trace products from pond to plate so that they can avoid product recalls and minimize the potential for reputational damage. With more than 100,000 farms, this will not be easy to achieve in India, but integrated players are positioned well to achieve full product traceability and become leaders of the rest of the industry.

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

PRODUCERS CAN STAY AHEAD OF STRICT EXPORT STANDARDS

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

As noted, regulators are requiring greater transparency as a precondition for shrimp import approvals, and they have repeatedly refused shrimp imports that fail to provide clean, contamination-free products. From 2014 through March 2019, 396 lines of entry from India were rejected at the US border, largely due to salmonella. (In all, 1,300 shrimp imports were refused by the US.) Rejections may increase even more now that the SIMP program requires stricter data reporting and record keeping.

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

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

The Far-Reaching Business Benefits of Traceability

Exhibit 10 outlines the following advantages and potential economic benefits of traceability for all players across the value chain:

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

- **Sustainable Production.** With traceability, retailers can punish producers for their unsustainable practices by refraining from buying, and retailers along with consum-

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 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

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, respectively

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

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

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.

ers 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, no-go areas such as protected mangrove forests.

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

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

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

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

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

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

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

Traceability Can Be Managed with Different Levels of Effectiveness and Maturity

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

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

Another technique is to verify the country of origin through elemental profiling. This new technique has emerged to provide a check on traceability claims. The procedure involves the analysis of a set of elements that make up a material or a species. Analysts can identify the country of origin of imported shrimp with up to 98% accuracy.[4] 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 were grown, verify the production technologies and methods applied during production, or trace the trading route of the shrimp from production to point of entry.

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

Technology-Enabled Traceability Offers a Promising Path Forward

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

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.

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.

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

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

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

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

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

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

LONG TERM, INDOOR FARMS WILL TRANSFORM INDIA'S SHRIMP INDUSTRY

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

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

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

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

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

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

With higher levels of intensification, stocking densities and farm output per hectare have grown, and the amount of land required to produce a kilogram of shrimp has typically decreased. In turn, there will be increases in the risk of disease, total energy use, and per unit energy use. The disease risk can be mitigated by closed-containment farm operations and indoor systems. (See Exhibit 12.)

To continue competing on a global level in the future, closed-loop and indoor farming represent the next step for India. In addition, it makes it possible for companies to mitigate the increasing environmental hazards and risks the shrimp industry faces.

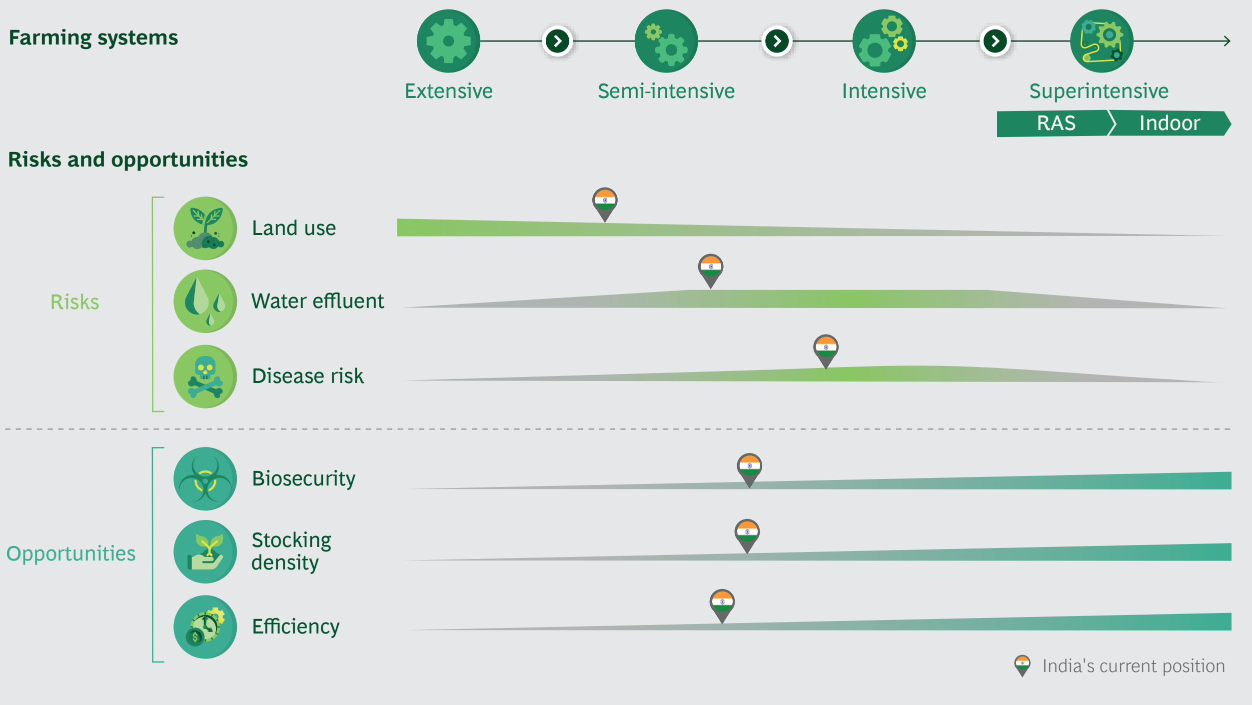
The closed-loop system offers the following clear advantages:

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

Indoor farming offers several advantages:

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

EXHIBIT 12 | India's L. Vannamei Production System



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

The business case for indoor farming is still evolving. The investment costs—up to $200,000 per hectare of pond area—are high compared with current costs for construction of about $6,000 per hectare of pond area for conventional outdoor ponds. 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.

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

INDIA'S SHRIMP INDUSTRY MUST TRANSFORM WHILE TIMES ARE STILL GOOD

SOME 3 BILLION PEOPLE rely on wild-caught seafood and aquaculture products as their primary sources of protein, and it is becoming an increasingly important source of protein around the world.

Indian producers are already feeling the pressure from policymakers to provide traceability, and because of their strong competitive position and reputation as reliable sources of shrimp, they have an excellent opportunity to be among the frontrunners in traceability and sustainability. With India's comparably low domestic demand and strong export focus, the push for traceability is particularly critical for the industry's lasting success and will eventually become the new norm in global shrimp supply chains.

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

India must respond. Other Asian countries, such as Thailand and Vietnam, have little choice but to take immediate action to save their struggling shrimp industries. Therefore, they have already taken steps toward closed-loop indoor intensification. Despite these early initiatives, there is not yet a clear winner in the sustainable and traceable market segment.

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

APPENDIX

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

APPENDIX

FUNCTIONAL FEED, WATER IMPROVEMENT SYSTEMS, AND SOLAR ENERGY

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

Details on Functional Feed

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

Growth enhancement functional feed is a complete feed (rather than an isolated compound) that is designed to promote specific physiological effects that allow farmers to grow larger shrimp faster and more efficiently.

Many varieties of functional feed are available on the market, and companies are competing to develop the most effective products. We define growth enhancement functional feed as feed that includes a variety of additives—such as special proteins, vitamins, and probiotics—that promote faster growth.

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

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

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

Health enhancement functional feed aims to improve shrimp survival and to increase productivity by optimizing the shrimp's digestive efficiency.

This type of feed is especially useful for mitigating risk when the threat of disease is high.

For example, phytobiotic additives can promote better health:

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

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

	FOCUS				
	Growth enhancement functional feed	Health enhancement functional feed	Transportation and storage	Feeding method and technology	Farming system and management
Operational impact	Potential for FCR improvement Possibility of larger shrimp	Avoidance of crop loss at times of high risk of disease	Appropriate storage important to maintain feed quality	Method and technology relevant to FCR and survival rate	Critical for overall operational success and controlling risk of disease
Cost impact	Higher feed costs; less feed required	Higher feed costs; crop loss avoided	Minor cost factor	Possibility of high investment costs for new technology Potential impact on labor	High impact on costs based on efficiency and risk management
Requirements and assumptions	Larger shrimp; higher 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 margins are 32% higher for farmers	✓ Loss from diseases avoided; higher revenues	✕ No significant impact on farmers' P&L	+ Support for successful introduction of new feeds	+ Critical for FCR, survival, and risks on farms

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

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

Details on Water Improvement Systems—Biofloc and RAS

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

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

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

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

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

RAS offers significant advantages for farmers:

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

Nonexhaustive

Zero water discharge

- Low-to-no water discharge
- Better than conventional systems
- Emphasis on microbial manipulation
- Use of microbial loop system to remove toxic nitrogen compound
- Microbial consortia added regularly to the system
- Microbial component kept dominant in the system
- Need for additional compartment for separated microbial cultivation

Biofloc

- Low-to-no water discharge
- Better than conventional systems
- Addition of carbon source to enhance heterotrophic bacteria consortium
- Emphasis on the system's carbon-to-nitrogen ratio
- Conversion of "waste" nitrogen to highly concentrated total suspended solid (microbial biomass) that can act as high-protein feed for cultured animal
- Optimal aeration and biofloc ingredient mix required

Periphyton

- Low-to-no water discharge
- Better than conventional systems
- Need for organic substrate such as bamboo for periphyton attachment
- Organic input such as manure and chemical fertilizers to trigger periphyton growth
- Occasional need for additional carbon source to maintain the carbon-to-nitrogen ratio
- Periphyton acts as toxic nitrogen removal system and food source for cultured animals

Biofilm

- Low water discharge
- Better than conventional systems
- Use of formed biofilm to remove toxic nitrogen compound during culture period
- No control of microbial consortia
- A potential food source for cultured animals

Defined biofilm

- Need for additional reactor and attachment substrate
- Defined microbial consortia in biofilm (predominantly nitrifying bacteria)
- Main purpose: removal of toxic nitrogen substance from the system
- Applicable in the system or in an external unit such as a biofilter

RAS

- No water discharge
- Involvement of many treatment processes, including physical and chemical treatments
- Microbial compartment in the biofilter
- Biofilter has defined microbial consortia
- Isolated, clear-water system
- Main purpose: biologically secured and hygienic aquaculture product
- Higher investment and operational costs than for other systems

Green-water technique

- Low water discharge
- Use of batch system
- Use of primarily autotrophic microalgae as microbial component in the system
- Utilization of chemical fertilizer and organic waste to trigger phytoplankton growth
- No control of the system's microbe community
- Main purpose: to provide natural food for cultured animals

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

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

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

- Installation of the necessary filters and treatment tools imposes high upfront

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

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

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

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

Input: carbohydrates

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

Chemical reaction

Increases the carbon-to-nitrogen ratio

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

Stimulates heterophobic microbial growth

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

Shrimp use biofloc as a feed source

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

Improved water quality

The reduction of nitrogen improves the water quality

Reduced FCR

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

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

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 (some of which requires higher energy use).

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

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

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

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

Details on Solar Energy

Farmers in remote locations with no grid access or intermittent grid access can reduce their environmental footprint and avoid disruptions in 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 16.)

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 and with a tracking system, PV cells that can be installed above the surface of ponds, and PV cells with a tracking system that can be installed above ponds.

Each option has different implications in terms of land use, water evaporation, electricity production, and investment costs, which range for ground-mounted PV systems from $1 million per megawatt to $1.7 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 16 | Evaluation of Four Types of Renewable Energy Sources for Shrimp Farming

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

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

APPENDIX

MARKET DYNAMICS AND ENVIRONMENTAL IMPACT OF IMMEDIATE CHANGE

To calculate the business case for each step along India's shrimp value chain, the base case (today's average) was derived from BCG knowledge, proprietary data, and industry expertise and was subsequently validated in expert interviews and with secondary research.

The analysis then identified key parameters affected by changes to current operations and estimated their business impact. Each business case calculation is displayed as a relative delta to today's average, the base case. For each step along the value chain, we also analyzed the overall market structure and the environmental impact of immediate change.

Feed Mills

Market Dynamics. In 2017, the shrimp feed industry in India produced about 862,000 metric tons. Production is expected to grow at about 11% per year. Most feed players are located in Andhra Pradesh, where they have easy access to farmers and lower transportation costs. (See Exhibit 17.)

The feed market is dominated by two players, Avanti Feeds and CP India, with a combined market share of around 70%. Approximately 90% of the feed reaches the farmer through a well-established dealer network. Dealers often provide smaller farmers with credit. Direct sales are common only to large corporate farmers.

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

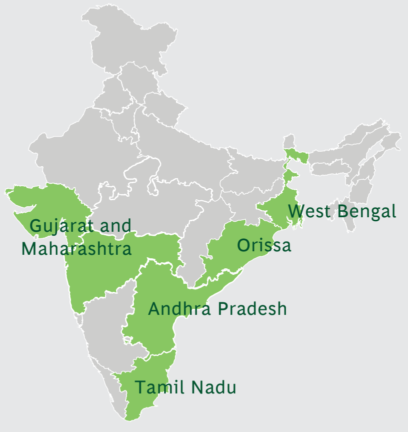
Growth Enhancement Functional Feed. The use of growth enhancement functional feed enables higher efficiency in shrimp farming: demand falls when farmers use functional feed, and revenues could decline by as much as 16% owing to lower feed mill sales.

However, there is the possibility of increasing today's EBIT margins by 130%, and, as farmers will not use functional feed continuously, the impact on feed mill revenues is expected to be marginal.

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

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

Exhibit 17 | About 60% of India's Shrimp Feed Comes from Andhra Pradesh

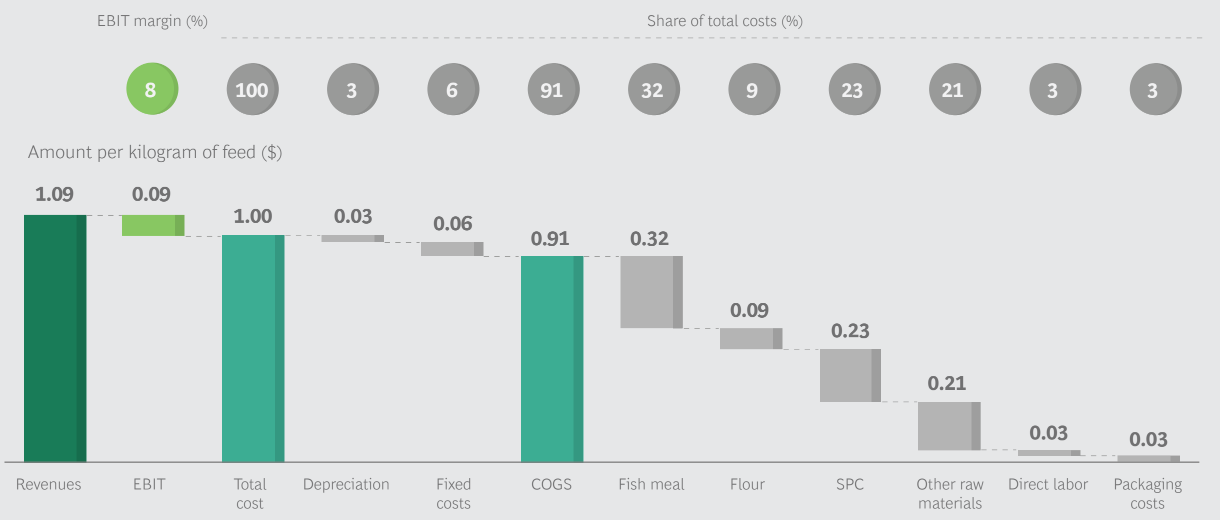


Shrimp feed volume in 2017, by region

Region	Volume, 2017 (kilotons)	Market share (%)	CAGR, 2013–2017 (%)	CAGR 2018–2022E (%)
Andhra Pradesh	514	60	19	9–10
Gujarat and Maharashtra	80	9	41	16–18
West Bengal	133	15	17	8–9
Orissa	53	6	30	4–5
Tamil Nadu	74	9	21	8–9
Others	8	1	6	1–2
Total	862	100	20	11

Sources: Marine Products Exports Development Authority; expert interviews; BCG analysis.
Note: Figures are based on 2017 numbers.

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



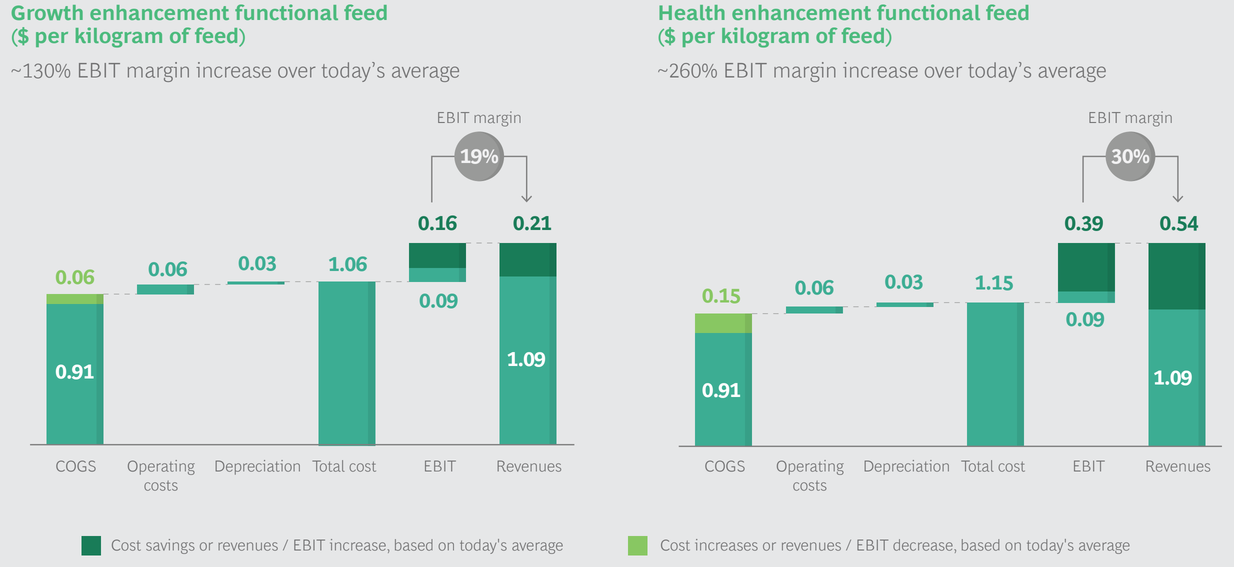
Source: BCG analysis.
Note: COGS = cost of goods sold; SPC = soy protein concentrate. Because of rounding, not all numbers add up to the totals shown.

Health Enhancement Functional Feed. Feed mills can charge a premium price of up to 50%. The premiums result in a profit margin increase of 260% compared with today's average EBIT margin. (See Exhibit 19.) The following are the assumptions on which we based the business case calculations for health enhancement functional feed for feed mills:

- Revenues per kilogram of feed sold increase because feed mills can charge a price premium of up to 50%.
- Production and input costs increase about 15% per kilogram of feed produced.
- The disease survival rate increases from a range of 20% to 30% to a range of 70% to 75%. (This is particularly relevant for farmers who deal with high risk of disease.)

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

Exhibit 19 | Feed Mills Can Increase Margins



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

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

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

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

Hatcheries

Market Dynamics. The PL market in India has been growing at around 26% in recent years and has reached more than 50 billion PL in 2017. India has more than 300 L. vannamei shrimp hatcheries.

Almost all hatcheries are located on the East Coast of India, primarily in Andhra Pradesh, while only around 15 hatcheries are located on the West Coast.

The market is very fragmented with the biggest player, BMR Group, having 20% to 25% market share. L. vannamei broodstock is sourced primarily from the US, but local Indian broodstock is increasingly common.

High-quality PL is essential for preventing disease, and therefore the relationships between hatcheries and farmers are crucial. In addition, the hatchery sector is regulated to prevent nationwide outbreaks of diseases and ensure a stable supply of PL.

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 contributes to better results for the industry overall.

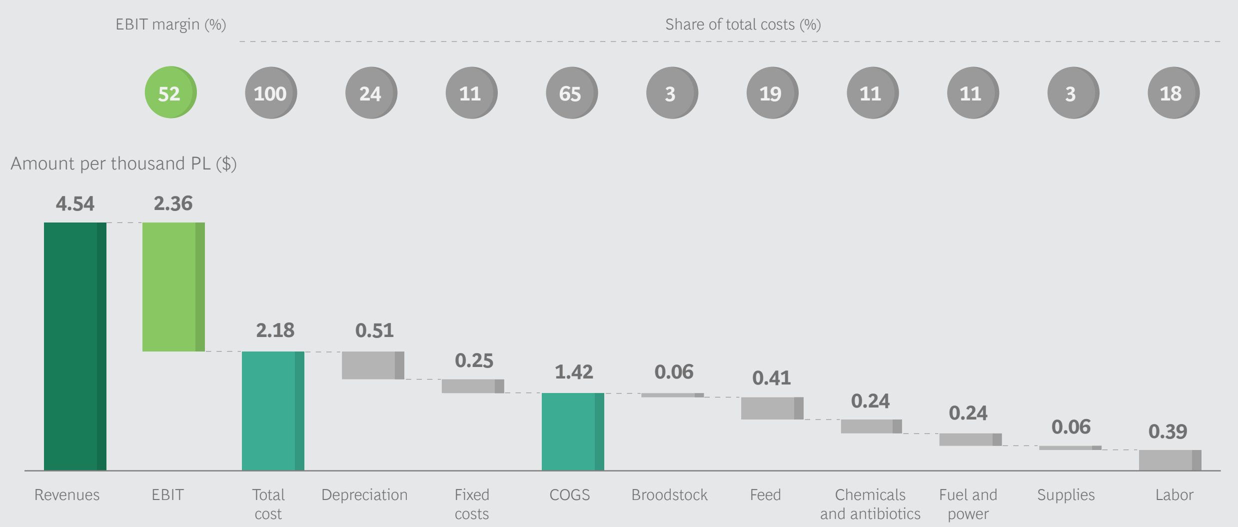
Environmental Impact. The hatcheries have only limited impact, and water treatment and antipollution measures could further reduce their impact. Better PL quality leads to better survival for shrimp, reducing the impact of failed production on farms. This is a key driver for future value.

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

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

Source: BCG analysis.

Exhibit 21 | 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.

Farmers

Market Dynamics. The farming market in India is very fragmented. Large corporate players, such as BMR Group and Devi Fisheries, control only 10% of the farms and 10% of the area under culture. Approximately 90% of the farms are managed by small or midsize players, and most are family-run operations. While there are more than 100,000 L. vannamei farms in India, only around 1% of farms are officially registered with the Coastal Aquaculture Authority. The majority of L. vannamei farms are located in Andhra Pradesh, which is responsible for some 70%

of L. vannamei production. P. monodon farms are mainly in West Bengal.

Approximately 80% of Indian farms are semi-intensively farmed, with stocking densities of about 30 PL per square meter, and survival rates have been relatively low (around 55%). Many of these farms are clustered together. Only some 15% of farms operate intensively with high stocking densities.

Middlemen, or commission agents, in India still play a significant role in the lives of individual farmers: 40% of farmed shrimp is distributed to processors through commission agents. Approximately 40% of farmers have direct agreements with processors who sell feed to farmers and buy back their harvested shrimp in return. Less than 20% of shrimp is sold at the farm gate directly for local markets without further processing.

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

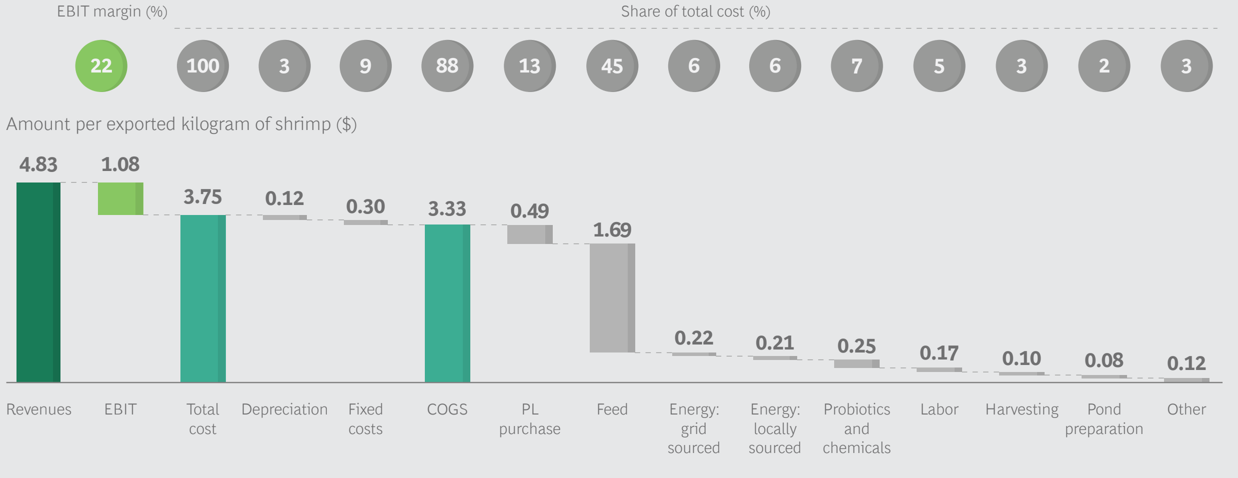
Functional Feed. The use of growth enhancement functional feed can lead to EBIT margins of up to 30% at the farm level, representing an increase of up to 32% in EBIT margins over today's average. (See Exhibit 23.)

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

- Shrimp that grow faster or to a larger size within the same timeframe can achieve price premiums of up to 6%.
- Growth enhancement functional feed lowers FCR by 30% in general, but because it is used during only half of the growth cycle, the FCR would be lowered by 15%, compensating for the 20% increase in feed prices.
- There is no need for a larger investment, but it is assumed that farmers can pay higher feed costs up front.

The use of health enhancement functional feed if used continuously is not economically viable for farmers: it would result in a steep decrease in EBIT and possibly negative EBIT margins caused by sharp increases—as much as 50%—in feed costs. However, if disease outbreaks are anticipated, it would be possible to achieve an EBIT margin as high as 23%, compared with 11%, when disease hits while basic feed is being used. This assumes that 20% of crops are affected by disease and treated with health enhancement feed. Health enhancement feed serves as a risk management tool for farmers. Although it offers a clear financial incentive, its benefits

EXHIBIT 22 | The Average Economics of Farms



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.

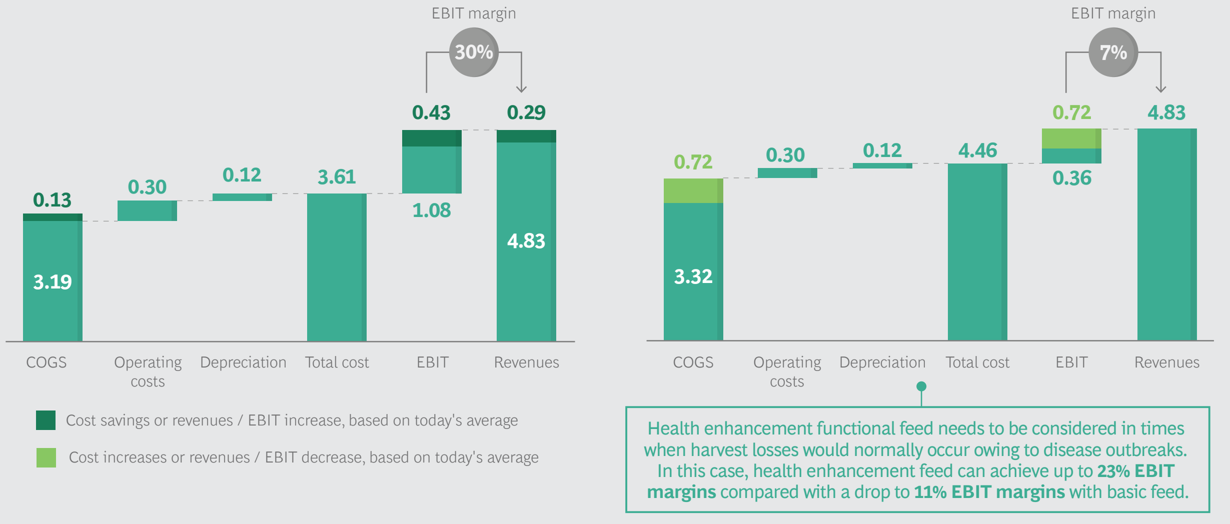
EXHIBIT 23 | Growth Enhancement Functional Feed Has an EBIT Margin Increase of up to 32%

Growth enhancement functional feed ($ per kilogram of shrimp)

Up to 32% EBIT margin increase over today's average

Health enhancement functional feed ($ per kilogram of shrimp)

~66% 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.

can be achieved only with long-term planning, management, and foresight.

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

- Feed is sold at a premium of up to 50% above the price of conventional feed.
- There is no change in FCR, but survival rates rise from a range of 20% to 30% to a range of 70% to 75%.
- Scenario 1. Using basic feed for the entire production, about 80% of the crops are successful with a 55% survival rate, and 20% of crops hit by disease have a survival rate of only 20%.
- Scenario 2. Using basic feed two-thirds of the time, successful crops have a 55% survival rate, and using health enhancement functional feed one-third of the time to avoid disease achieves a survival rate as high as 74%.

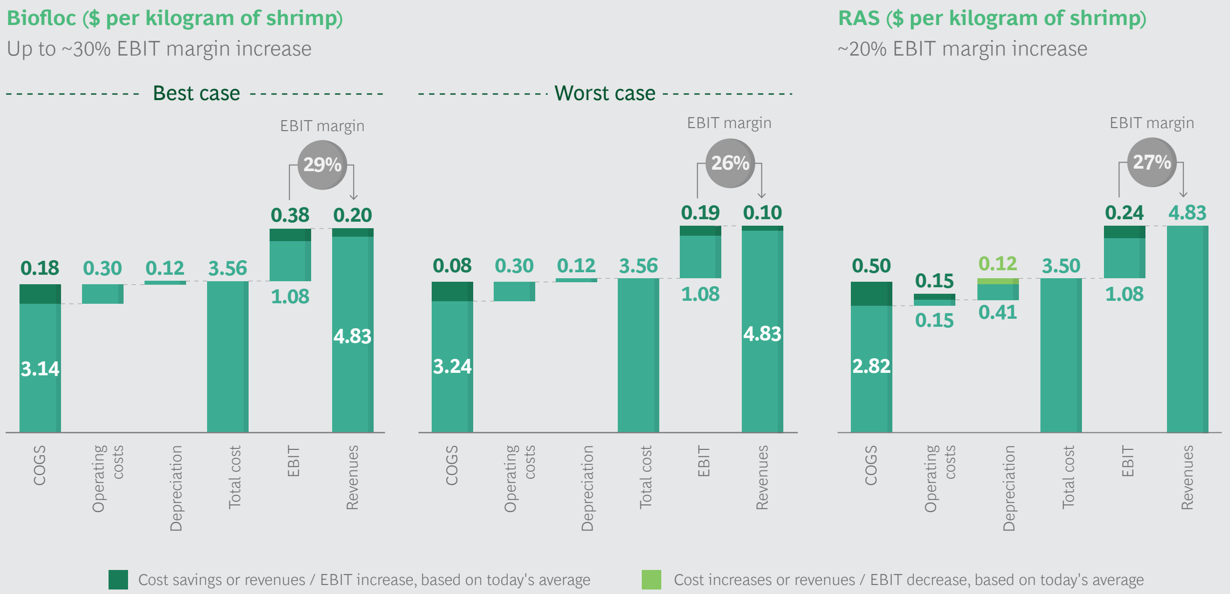
Environmental Impact. If farmers increase their efficiency, less feed will pollute the water, and the use of growth enhancement feed can indirectly reduce the impact of overfishing and lead to a positive environmental impact.

Biofloc and RAS. The business case for using biofloc depends on a farm's technical management, which influences prices, costs, and production parameters such as FCR and growth cycles. In the best-case scenario, farmers achieve EBIT margins as high as 29%, increasing margins as much as 30%. Even in the worst-case scenario, margins increase slightly, leading to overall EBIT margins of 26%. If farmers are knowledgeable and consistently monitor the system, they can expect to achieve the best-case scenario. (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 costs for skilled labor increase 5% to 10% owing to the need for higher controls and constant supervision.
- FCR decreases by 25% because biofloc can be used partly as a feed source.

EXHIBIT 24 | Biofloc Can Increase EBIT Margins by as Much as 30%, While RAS Can Increase Them by as Much as 22%



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

- The costs for chemicals decrease by 3% to 7% owing to water quality improvement through biofloc use.
- The additional cost for cornmeal as a carbohydrate source ranges from $0.23 to $0.36 per kilogram. (For a kilogram of shrimp, approximately 0.6 kilograms of cornmeal is a required biofloc ingredient.)
- The survival rate is similar to that of a system without biofloc.
- Due to the protein content in biofloc, the growth rate increases by as much as 27%, allowing farmers to benefit from a 2% to 4% higher sales price for larger shrimp.

Farms that use RAS can see EBIT margins rise by up to 22% per kilogram at the farm gate, achieving EBIT margins as high as 27%. Additionally, overall revenues are boosted owing to higher stocking densities and, consequently, yields.

Assumptions for business case calculations for RAS include the following:

- Stocking densities could increase fourfold, owing to better water quality and improved monitoring of water conditions.
- Investment costs of $150,000 per hectare, depreciated over ten years, could lead to an expected yearly yield of 30,000 kilograms per hectare (based on increased stocking densities).
- The risk of disease is lower due to superior water quality and higher biosecurity, leading to improved survival rates.
- Variable costs decrease by 15%, reflecting increased energy and maintenance costs, reduced labor costs due to higher automation and stocking densities, lower chemical requirements, and less disease risk.
- Higher stocking densities lead to a 50% decrease in fixed costs.

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

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

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

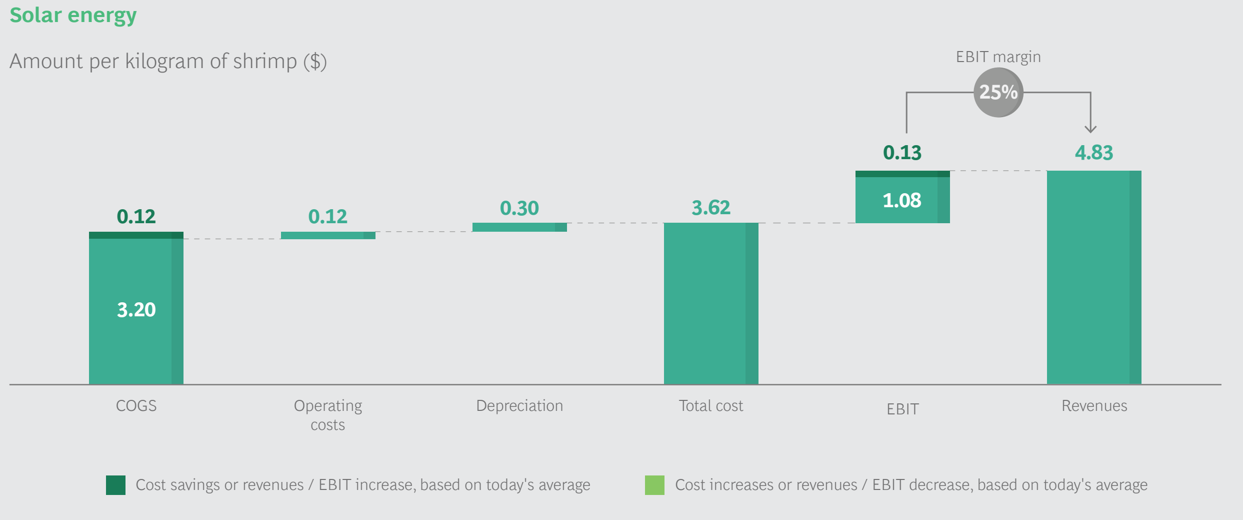
Although on the basis of the cost per megawatt hour, solar energy is more expensive than grid energy, it is significantly less costly than diesel. Replacing diesel generators with solar energy can yield an increase of up to 12% in EBIT margins. This said, the initial investment for PV systems requires significant investments—up to $15,000 to $25,000 per hectare, depending on the system and if battery storage is required—which small farms in remote areas may not be able to afford.[5] But as the costs of batteries and solar power continue to decrease, this option could eventually become more affordable for remote farms as well as grid users.

The total EBIT margin can be as high as 25% when solar energy is combined with grid energy, representing an increase of up to 12% EBIT margin compared with today's average. (See Exhibit 25.)

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

- A levelized cost of energy for solar options, including batteries, is estimated to be higher than for grid energy but significantly lower than for diesel generator use.
- The shift to solar energy is relevant and applicable only for farms in remote areas with high diesel generator use.

Exhibit 25 | The Use of Solar Energy Generates a 12% Increase in EBIT Margins



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

- A levelized cost of energy for solar is $119 per megawatt hour for a ground-mounted PV system with the tracking option.

- The grid energy price is $83 per megawatt hour, and the diesel energy price is $300 per megawatt hour.

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

Combined Options: Growth Enhancement Functional Feed, RAS, and Solar Energy. The combination of growth enhancement functional feed, RAS, and solar energy yields EBIT margins as high as 36%, representing an increase of 61% over the base case. (See Exhibit 26.)

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

- The assumptions are comparable to standalone solutions, as the three methods affect different variables.

- Doubled stocking density is possible due to better water quality and improved monitoring of water conditions.

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

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

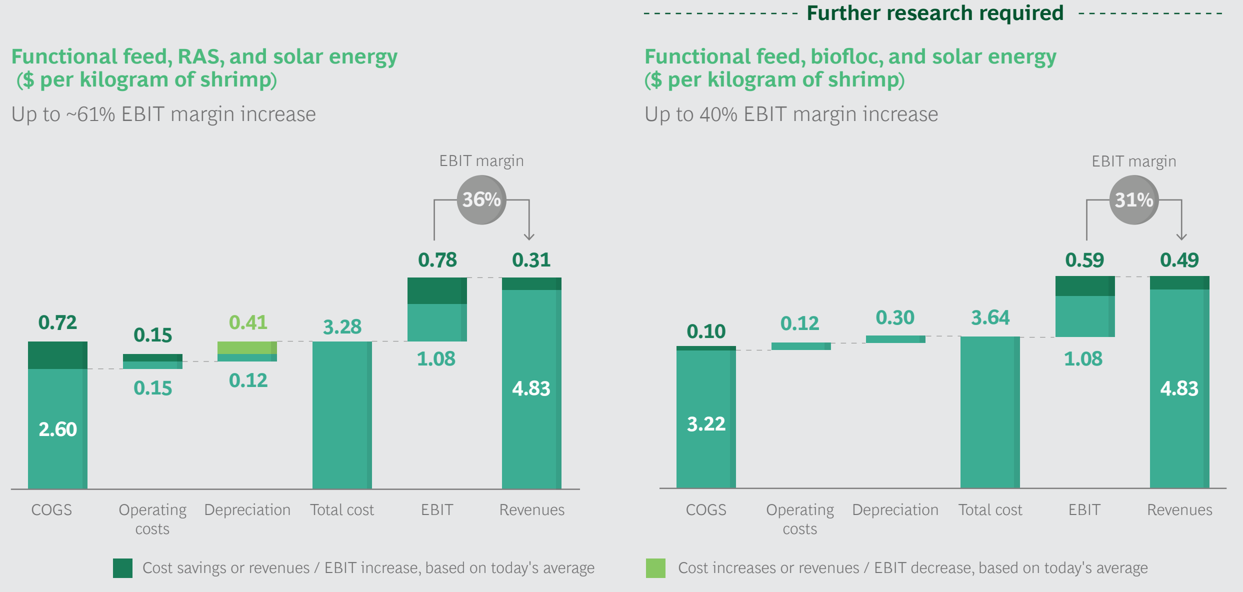
- For half the growth cycle, there is a 20% increase in the feed sales price, and additional feed mill costs are incurred.

- A 15% decrease in overall variable costs is the result of the combination of a cost increase that is due to the use of functional feed and a decrease in the cost per kilogram that is due to the use of RAS and solar energy.

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

- Investment costs of $150,000 per hectare are depreciated over ten years with an expected yearly yield of 30,000 kilograms per hectare.

Exhibit 26 | A Combined Solution Can Increase EBIT Margins by About 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.

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

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

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

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

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

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

Middlemen

Market Dynamics. Middlemen handle business interactions between the fragmented farmers and processors. There are great differences in the role and activity of middlemen across the country, but generally such commission agents provide the link between farmers and processors. Their operating model also differs by region and state, but many operate on a commission basis and achieve EBIT margins of around 10%. Farmers choose middlemen for various reasons: to ensure transportation of shrimp to processors, to outsource sales risks, and to provide financing.

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

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

Environmental Impact. Middlemen can decrease their environmental footprint by ensuring that no drugs or other illegal substances are injected into shrimp, that shrimp is not farmed in mangrove areas, and by providing guidance to farmers on best practices.

Processors and Exporters

Market Dynamics. Shrimp processors in India are highly fragmented, with more than 400 processors. Larger and integrated players such as Nekkanti Sea Foods and Avanti Feeds have the largest processing capacities. The Indian shrimp and seafood processing industry, which is regionally very fragmented, is located mainly in port cities.

There are various types of processing, such as shrimp with or without heads and shrimp with or without tails. The type of processing depends on the preferences of export countries. With limited value-added processing facilities in India, 60% of Indian shrimp is block frozen after basic processing (for example, headless shrimp without shells), and 40% receives more value-added processing (for example, ready-to-eat cooked shrimp). Basic frozen shrimp achieve EBIT margins of around 8%, whereas value-added processing achieves EBIT margins of some 20%. (See Exhibit 27.)

Business Case. Exhibit 28 illustrates the average economics of today's processors.

Because processors are at the intersection of buyers and retailers, they are directly affected if retailers refuse, owing to environmental concerns, to buy Indian shrimp or if retailers want better traceability and sustainable supply chains and are willing to pay a premium.

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

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

EXHIBIT 27 | Profitability of Frozen Shrimp Compared with Prepared Shrimp

Frozen shrimp

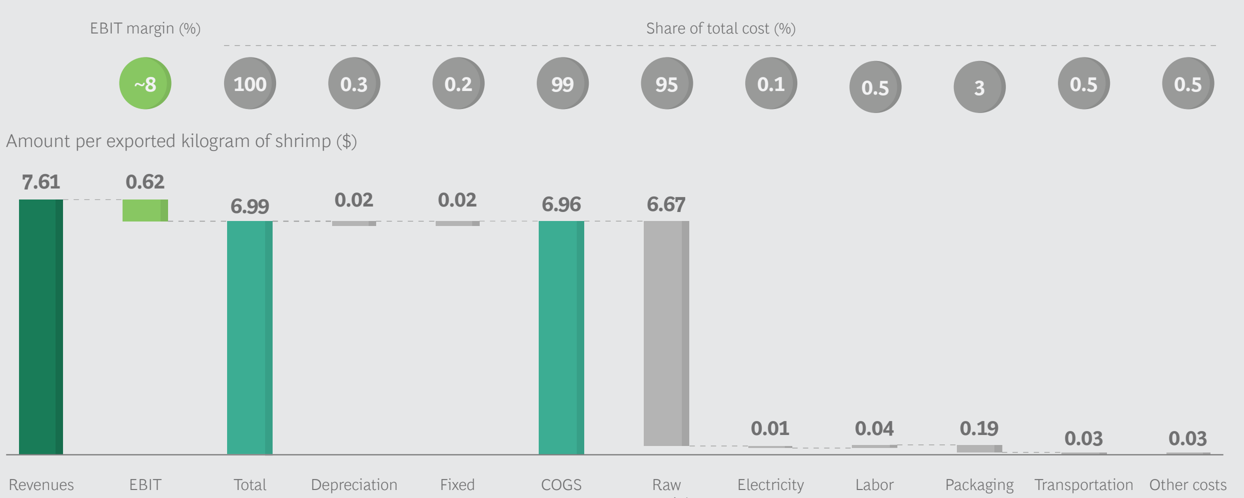
- Subjected to block freezing and blast freezing
- Volume share: ~60%
- EBIT margins: ~8%
- Typical products: headless, shell on; peeled, deveined, and tail on; peeled, deveined, and head on; shell on

Prepared shrimp

- Subjected to value added processing
- Volume share: ~40%
- EBIT Margins: ~20%
- Typical products: cooked, breaded, and sushi

Sources: Equirus; Imarc Research; Export Genius; news articles; BCG analysis.

EXHIBIT 28 | Today's Average Economics of Processors



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

NOTES

1. FCR indicates how much feed is needed for the production of 1 kilogram of shrimp.

2. RAS provide farmers with a way to reuse water on the farm, thus dramatically reducing freshwater intake as well as wastewater discharge into the environment.

3. Based on energy use per hectare of shrimp produced per year: approximately 30 tons of shrimp with electricity requirements of about 125 megawatts per year.

4. 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.

5. This is based on the energy use per hectare of shrimp produced per year: 30 tons of shrimp with electricity requirements of 125 megawatt hours per year.

NOTE TO THE READER

About the Authors

Holger Rubel is a managing director and senior partner in the Frankfurt office of Boston Consulting Group, the global topic leader for green energy, and an expert on total societal impact and sustainability. **Wendy Woods** is a managing director and senior partner in the firm's Boston office and the global leader of the Social Impact practice. **David Pérez** is a managing director and partner in BCG's Stockholm office and the global leader on aquaculture topics. **Shalini Unnikrishnan** is a managing director and partner in the firm's Chicago office and an expert on total societal impact and sustainability. **Alexander Meyer zum Felde** is an associate director in BCG's Hamburg office who focuses on total societal impact and sustainability and circular economy. **Sophie Zielcke** is a project leader in the firm's Berlin office who works on total societal impact and sustainability as well as the agriculture topic. **Charlotte Lidy** is a consultant in BCG's New York office who works on total societal impact and sustainability. **Carolin Lanfer** is an associate in the firm's Cologne office who works on total societal impact and sustainability.

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For Further Contact

If you would like to discuss the themes and content of this report, please contact one of the authors:

Holger Rubel
Managing Director and Senior Partner
BCG Frankfurt
+49 69 915020
rubel.holger@bcg.com

Wendy Woods
Managing Director and Senior Partner
BCG Boston
+1 617 973 1200
woods.wendy@bcg.com

David Pérez
Managing Director and Partner
BCG Stockholm
+46 8 402 44 00
perez.david@bcg.com

Shalini Unnikrishnan
Managing Director and Partner
BCG Chicago
+1 312 993 3300
unnikrishnan.shalini@bcg.com

Alexander Meyer zum Felde
Associate Director
BCG Hamburg
+49 40 309960
meyer.zum.felde.alexander@bcg.com

Sophie Zielcke
Project Leader
BCG Berlin
+49 30 2887 10
zielcke.sophie@bcg.com

Charlotte Lidy
Consultant
BCG New York
+1 212 446 2800
lidy.charlotte@bcg.com

Carolin Lanfer
Associate
BCG Cologne
+49 221 550050
lanfer.carolin@bcg.com

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