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An opportunity for the Middle East to feed the world sustainably

Energy-to-food

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EXECUTIVE SUMMARY

We live in an era of growing concern about food insecurity and the toll that agriculture imposes on the environment, including through high greenhouse gas (GHG) emissions and excessive water use. The Middle East has an opportunity to alleviate many of these problems by pursuing a new technology called precision fermentation. There are different types of precision fermentation. Our focus in this paper is on a form of precision fermentation that converts energy and a handful of ingredients to a variety of proteins and other food ingredients with little negative environmental impact (so-called energy-to-food). Middle East countries, in particular in the Gulf Cooperation Council (GCC),[1] have a natural advantage because of their ample, low-cost renewable energy.

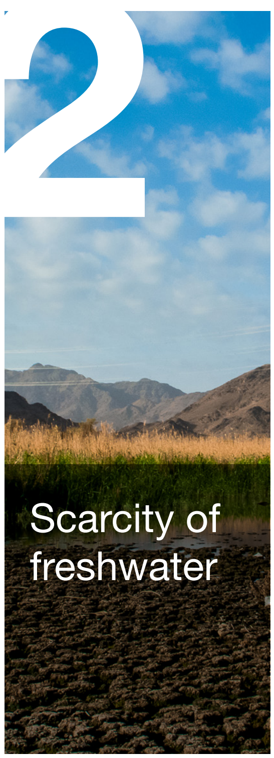
The ability to make food from energy and little else is not science fiction; soon, it will be an economically viable fact. Already, the market for alternative proteins is attracting considerable investment—one forecast predicts that it could be worth US$1.4 trillion globally by 2050.[2] Energy-to-food could allow Middle East countries that import most of their food to lead a new agricultural revolution.

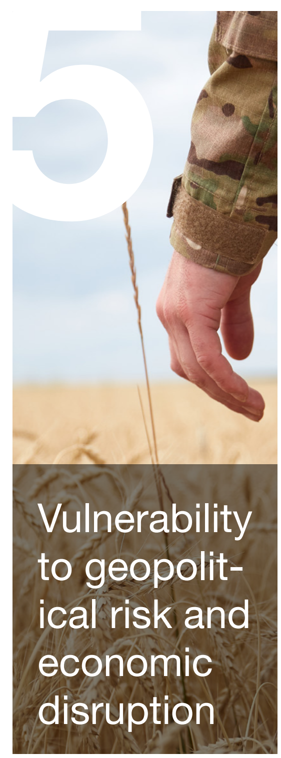
To become a market leader in this emerging sector, the region must act swiftly. Moving energy-to-food from the lab to the table requires action in six areas: research and development (R&D), investment in infrastructure, value chain development, talent, regulation and policy, and consumer awareness. Although costs are inevitable, the prize of securing global food supplies in an environmentally sustainable manner is priceless.

THE ENVIRONMENTAL COST OF FEEDING HUMANITY

The Middle East was the birthplace of the first agricultural revolution, when people began farming in settlements, which replaced hunting and gathering and allowed civilization to emerge. Agriculture then went through successive revolutions, becoming mechanized in the Industrial Revolution and then transforming again in our era with the introduction of hybridization, genetic modification, and increased use of pesticides and fertilizers. Each of these changes helped feed a growing population, albeit at increasing environmental costs such as habitat loss, greater GHG emissions, and resource depletion.

Today, agriculture needs another revolution, as it is encountering the limits of what it can provide given the available resources. Agriculture needs to feed a world population that is projected to grow to 9.7 billion people by 2050, or 1.8 billion people more than today.[3] These people will need to be fed in a sustainable manner, which requires overcoming multiple problems including scarcity of land and freshwater, GHG emissions, the high cost of nutritious food, and vulnerability to geopolitical risk and economic disruption.





Scarcity of land

We already use 50 percent of the planet's habitable land for agriculture to feed the world.[4] It is difficult to see how we can obtain more land for agriculture. By 2050, the world's agricultural production will have to increase by more than 60 percent to feed a population of almost 10 billion people.[5] That means that by 2050, even if crop and pasture yields continue increasing at today's rates, we will need to add almost 6 million square kilometers of agricultural land to meet projected food demand.[6] Such an increase would mean reducing important land use types such as forests, and that reduction has implications for climate change and air quality. To put this in context, meeting the world's food demand by 2050 would require wiping out forest areas the size of the Amazon to create agricultural land. Another problem is that livestock farming to generate animal protein has a disproportionately high impact on depleting natural resources.[7] Moreover, climate change is likely to reduce the amount of land suitable for agriculture, thereby aggravating the land use problem.

Scarcity of freshwater

Today, agriculture accounts for 70 percent of freshwater withdrawal and more than 90 percent of freshwater consumption.[8] Water availability is already under stress; two-thirds of the world's population is affected by shortages.[9] According to estimates from the United Nations' Food and Agriculture Organization, the world can increase the amount of water it needs to withdraw for agriculture by only 10 percent by 2050. As a result, there will have to be significant agricultural productivity gains to accommodate the estimated 60 percent increase in agricultural production required by then.[10]

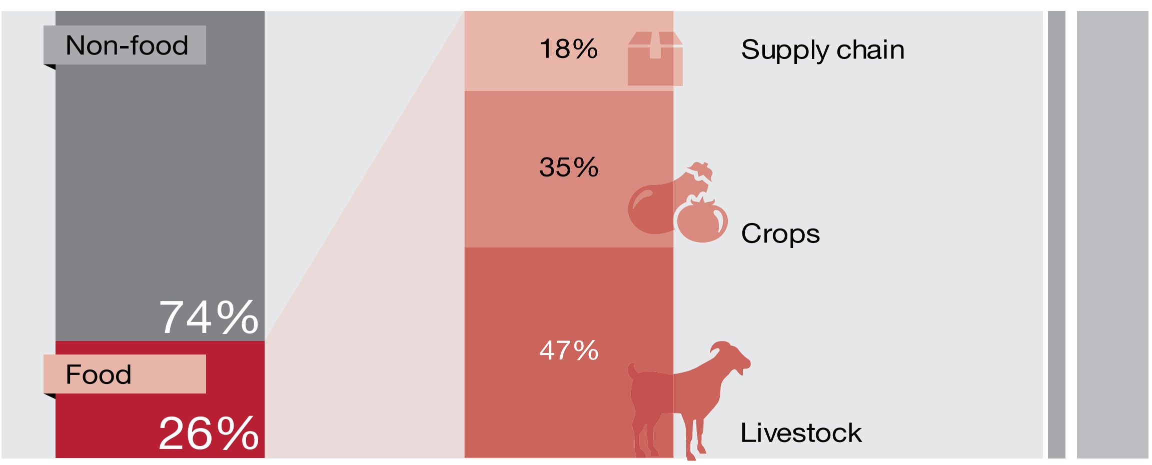
GHG emissions

The food industry contributes between one-quarter and one-third of global GHG emissions, according to various estimates (*see Exhibit 1*).[11] These emissions are expected to increase by 2050 as the demand for food grows. However, GHG emissions from food production actually need to decrease by about 11 gigatons per year to limit global warming to 2 degrees Celsius above preindustrial levels, according to the Paris Agreement.[12]

EXHIBIT 1

Food production accounts for about one-quarter of global GHG emissions

Contribution to global GHG emissions (2018)



Note: GHG = greenhouse gas.
Source: J. Poore and T. Nemecek, "Reducing food's environmental impacts through producers and consumers," Science 360, pp. 987–992 (2018), June 1, 2018 (https://www.science.org/doi/10.1126/science.aaq0216); Hannah Ritchie, *Food production is responsible for one-quarter of the world's greenhouse gas emissions*, Our World in Data, November 6, 2019 (https://ourworldindata.org/food-ghg-emissions); Strategy& analysis

Affordability of nutritious food

Despite all the use of land and freshwater, good-quality food is unaffordable for much of the world's population. Some 3 billion people today, almost 40 percent of the global population, cannot afford healthy diets.[13] People in the developing world, in particular, are eating mostly starchy food because it carries about one-fifth the cost of foods making up a healthy diet.[14]

Vulnerability to geopolitical risk and economic disruption

Our global food production system is closely intertwined with the global trade system. The disruption of global supply chains by geopolitical events and economic shocks can severely hamper food availability, especially for countries dependent on food imports. One study on the decoupling of agricultural production and consumption found that by 2050 as much as half of the world's population could become reliant upon non-domestic food sources.[15]

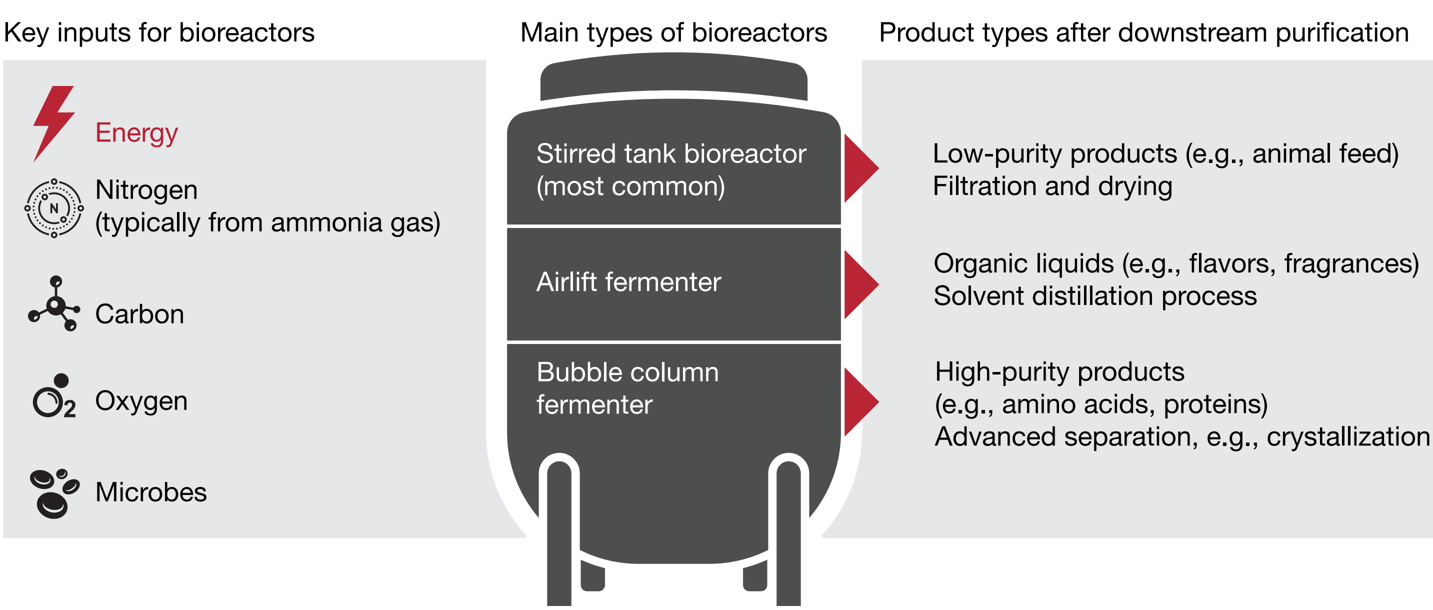
PRECISION FERMENTATION TO TRANSFORM ENERGY INTO FOOD

New technology may offer a solution to these wide-ranging problems. Energy-to-food, precision fermentation that uses energy to make food, can alleviate many of the pressures on land and freshwater, while lessening the impact on the environment. The importance of energy in this form of precision fermentation means it presents an opportunity for the Middle East, and the GCC in particular, given that these countries possess abundant low-cost renewable energy sources.

Energy-to-food is a promising technological advance that can make a variety of proteins and other food ingredients.[16] Startups are already developing a diverse range of food options including meat, eggs, dairy, and even oils. The science behind energy-to-food depends on bioreactors. These provide a uniform environment to conduct a chemical reaction that involves organisms or biochemically active substances derived from such organisms. The process is energy intensive and requires few other inputs: nitrogen, carbon, oxygen, and microbes (*see Exhibit 2*). The energy-to-food process mostly relies on gases (such as CO_2 and the other gases in air) and water as the sources of carbon and oxygen. That distinguishes it from other types of precision fermentation, which use inputs such as sugar that impose a cost on the environment, albeit a lower cost than traditional farming.

EXHIBIT 2

Precision fermentation requires substantial inputs of energy but little else



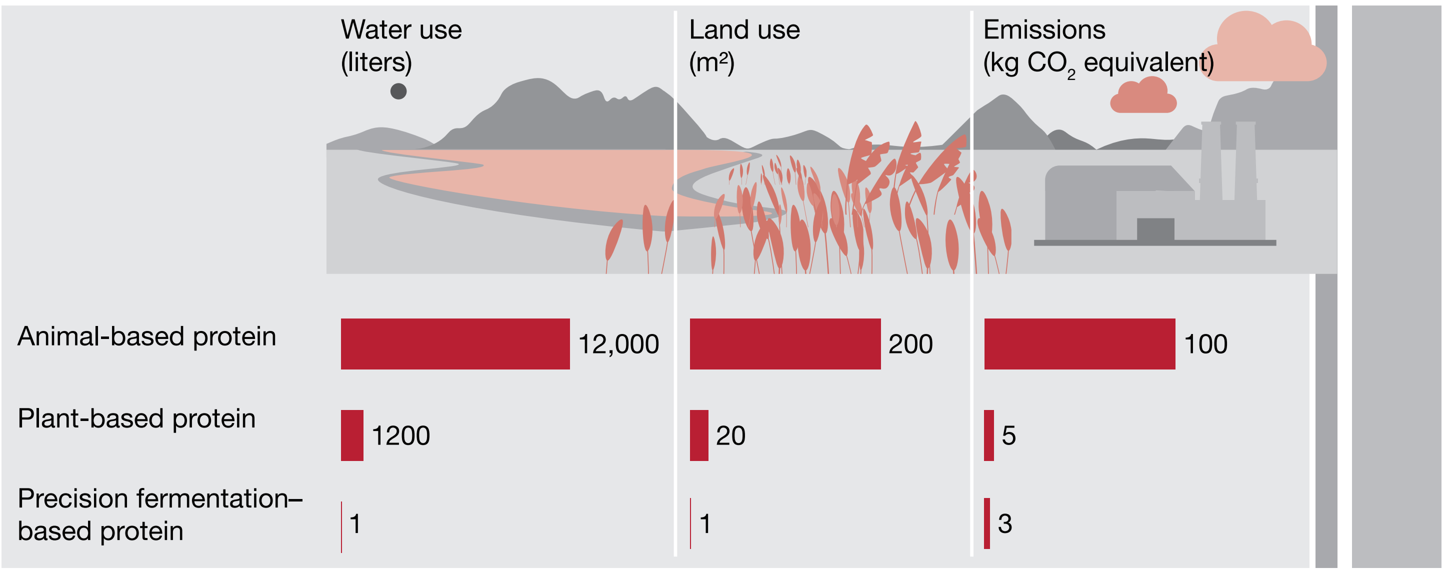
Source: Strategy& analysis

The environmental impact of energy-to-food is minimal, as it requires very little land or water compared with traditional agriculture, such as animal- and plant-based proteins. It also emits fewer GHG emissions (*see Exhibit 3*).[17]

EXHIBIT 3

Precision fermentation proteins use less water and land than other proteins and generate fewer emissions

Per kilogram of protein produced



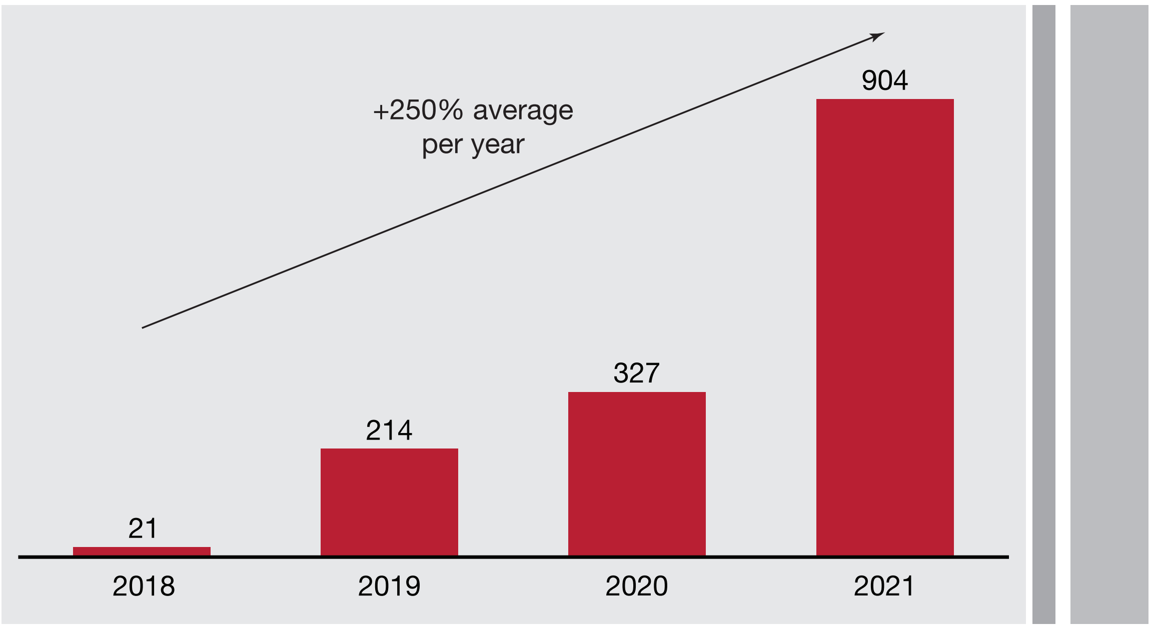
Source: Strategy& analysis

Interest in precision fermentation is growing rapidly. Invested capital in precision fermentation companies has increased at an annual rate of 250 percent since 2018 (*see Exhibit 4*). Although most of the investment is occurring in Europe and the U.S., precision fermentation startups are emerging in other countries, such as China, India, and Israel.

EXHIBIT 4

Investment in precision fermentation is rising

Investments in precision fermentation companies (US$ millions)



Source: Audrey Gyr, *State of the Industry Report: Fermentation*, Good Food Institute, 2022 (https://gfi.org/resource/fermentation-state-of-the-industry-report/).

The challenges of converting energy-to-food at scale

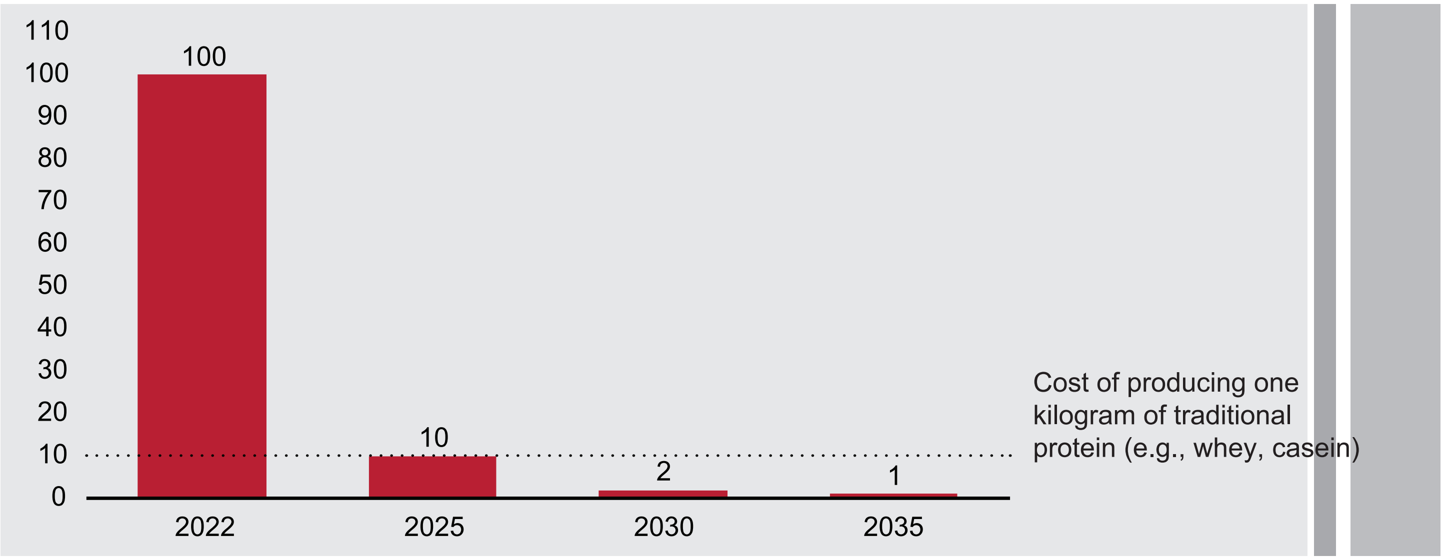
For all the promise energy-to-food offers, moving from lab to table means overcoming three connected challenges: cost, consumer acceptance, and scale.

First, energy-to-food needs to become cost-effective. Today, protein from any form of precision fermentation is about 10 times as expensive to produce as protein from sources such as whey and casein.[18] As the technology matures, the cost should come down (*see Exhibit 5*). However, the speed at which it becomes economically viable will depend on market adoption and the ability to scale production.[19]

EXHIBIT 5

The cost of manufacturing proteins using precision fermentation is projected to fall sharply

Cost of precision fermentation–based protein (US$ per kilogram)



Source: Catherine Tubb and Tony Seba, *Rethinking Food and Agriculture 2020-2030: The Second Domestication of Plants and Animals, the Disruption of the Cow, and the Collapse of Industrial Livestock Farming*, Rethinkx, September 2019 (https://www.rethinkx.com/food-and-agriculture-executive-summary); Strategy& analysis

Second, there has to be consumer acceptance of energy-to-food proteins. Food is a highly personal and sometimes fraught issue; people's preferences are often influenced by culture, religion, and tradition. Marketing can increase acceptance, especially among younger consumers who want meatless products and who can influence others. People need to understand the health benefits of energy-to-food, and explore whether ingredients are culturally and religiously acceptable.

Significant changes can be greeted with suspicion. Take, for example, the regulatory debate over genetically modified organisms (GMOs), which affects precision fermentation–based proteins. The U.S. considers precision fermentation–based proteins to be non-GMO, whereas the European Union treats them as GMOs. That matters because U.S. regulations are more accepting of GMO products, whereas many European countries have banned GMO products. Ultimately, there is a need for broad agreement within the international regulatory and scientific community.

Encouragingly, plant-based protein products have made some inroads in recent years that could provide valuable lessons for precision fermentation products. Plant-based meat sales in the U.S. have grown rapidly, rising almost 75 percent over the past three years to total $1.4 billion in 2021. Companies are providing consumers with more options with respect to product types, making them available at various price points, and these products are more widely available in stores than they were a few years ago.[20]

The third challenge is that energy-to-food needs to build scale, which can come only with lower cost and initial consumer acceptance. Energy-to-food can attract the substantial investment required only if it can show that it is a commercially viable option. Investors need to see that consumers are interested and can afford the product.

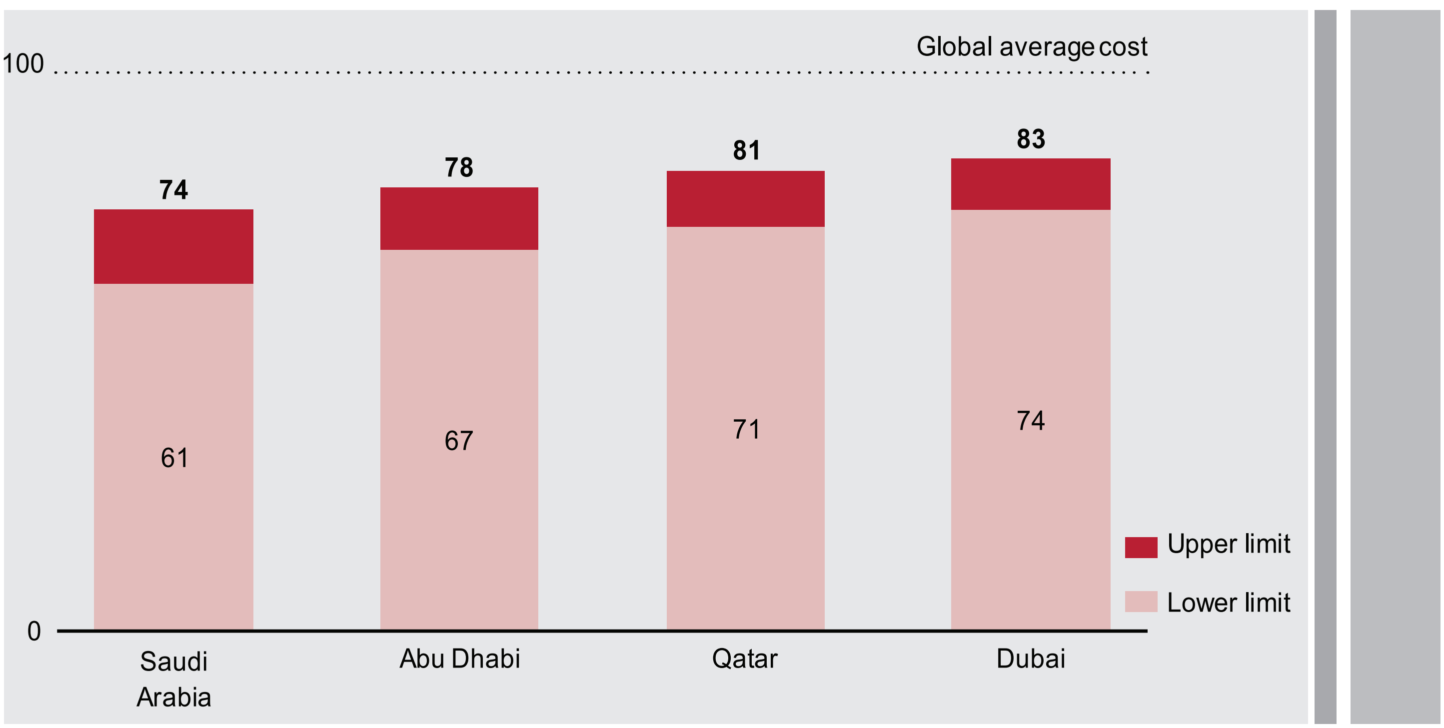
THE POTENTIAL FOR THE GCC TO FEED HUMANITY

The GCC is uniquely positioned for success in pursuing energy-to-food because it possesses the world's lowest levelized cost of renewables. Energy makes up 40 to 60 percent of the expense of producing energy-to-food proteins. Assuming GCC producers incur non-energy-related costs similar to the global average, their energy-to-food proteins will be significantly cheaper than those created anywhere else in the world (*see Exhibit 6*).

EXHIBIT 6

GCC countries have a cost advantage in the energy-to-food sector

Cost of precision fermentation compared to global average in select GCC areas (indexed to 100)



Source: Strategy& analysis

GCC countries also have significant reasons to pursue energy-to-food.

Improved food security

Energy-to-food would free GCC countries from dependence upon foreign food suppliers. Currently, 85 percent of the GCC's domestic food needs are met from imports.[21] That is mainly due to the region's inability to grow certain foods that depend on particular soil and climate conditions. If they were released from such constraints, GCC countries could become significant food exporters.

Market opportunity

GCC countries could grab a large slice of the growing demand for alternative proteins. According to Credit Suisse, the global market for alternative proteins is expected to reach $1.4 trillion by 2050.[22] If precision fermentation were to account for 20 to 25 percent of the alternative proteins market, the value would be $280 billion to $350 billion. If GCC countries were able to grab only 20 percent of that market, they would have energy-to-food sales worth $56 billion to $70 billion by 2050. For comparison, Saudi Arabia's crude oil exports in 2020 were worth just over $110 billion.[23]

Contribution to net zero

Reducing emissions from agriculture and food imports would help the GCC countries meet their net-zero goals. Oman and the UAE are aiming for net zero by 2050. Bahrain and Saudi Arabia have announced a 2060 target date. Energy-to-food could replace considerable production of animal protein. If 25 percent of GCC consumers were to switch from animal protein to energy-to-food protein, that would constitute 3 to 5 percent of the GCC's total GHG reduction target.

> "The GCC is uniquely positioned for success in pursuing energy-to-food because it possesses the world's lowest levelized cost of renewables.

A BOLD APPROACH TO MARKET LEADERSHIP

The GCC countries should engage in a bold and concerted effort to become the market leaders in energy-to-food. If they are successful, using renewable energy to feed the world could become a prestige project that highlights the region's technological prowess and its ability to take the lead in sustainability. It would also promote regional economic diversification. If it is to succeed, the ambition of this undertaking will need to be accompanied by significant resource allocation. GCC countries need to act in six areas: R&D, investment in infrastructure, value chain development, talent, regulation and policy, and consumer awareness.

R&D

A major R&D focus is essential if energy-to-food proteins are to achieve cost parity with traditional proteins. Governments will need to invest in R&D initially to accelerate the maturity of this technology. Private-sector investment will then need to follow. Although there is rising interest in precision fermentation generally, the industry lags behind other sectors. In particular, there must be more investment in early-stage, high-risk innovation. For comparison, although $14 billion has been invested globally in 1,000 food systems–focused startups since 2010, that is barely one-tenth of the $145 billion put into healthcare startups in the same period.[24]

If they are to address this disparity, governments need to take the lead in funding R&D to accelerate the energy-to-food industry. It is instructive to draw parallels with the growth of the biopharma industry in the U.S. in the 1980s and 1990s. To get the industry going, the U.S. government provided annual R&D funding for healthcare of $6 billion in 1980 that steadily increased to more than $13 billion in 1998 before stabilizing.[25] R&D efforts need to focus on improving the overall yields of the precision fermentation process, identifying novel microbial strains, pinpointing more cost-efficient and sustainable feedstock, creating artificial intelligence and machine-learning algorithms to enhance the speed of the process, and developing more efficient bioreactor design.

Investment in infrastructure

Companies need bioreactors for precision fermentation. Commercial bioreactors can cost up to $500 million for a capacity of 1 million liters. Currently, the world has just over 60 million liters of bioreactor capacity for contract manufacturing, although it is used for applications besides food.[26] In a scenario in which alternative proteins make up 10 percent of total protein consumption by 2030 and precision fermentation–based proteins make up 25 percent of the alternative proteins market, the world would need more than 4 billion liters of bioreactor capacity for precision fermentation. The total required investment would exceed $2 trillion globally—although the cost is expected to come down as the technology matures and becomes more efficient. The public and private sectors need to combine their efforts to ensure sufficient investment goes to developing the critical infrastructure.

Value chain development

GCC governments will need to develop the whole value chain if their countries are to become major players in energy-to-food. They will need to secure access to the required raw materials and feedstock, such as nitrogen.

Talent

GCC countries need the necessary talent to conduct R&D and commercialization. That means acquiring top-notch talent in fields such as molecular biology, chemical engineering, strain engineering, data science, product development, and plant design. The field also requires clinicians, nutritionists, and policy experts. GCC countries should provide a compelling value proposition and vision of the future to attract the best global talent, while also developing the talent pool in the Middle East.

Regulation and policy

GCC governments must have effective regulatory practices to ensure the quality and safety of energy-to-food proteins. They can also use a range of policy mechanisms to promote the sector, encouraging businesses to move from conventional proteins to energy-to-food. For example, they could mitigate the cost of switching to energy-to-food by providing incentives for investment in renewable energy R&D.

Consumer awareness

Public- and private-sector stakeholders should educate consumers about the environmental and nutritional benefits of energy-to-food proteins. Consumers will need to know that these products are beneficial and safe. Producers will have to develop protein products that are affordable and enjoyable to consume. In particular, producers will need to ensure that their products comply with religious norms so that their proteins are *halal* (permissible) for Muslims to consume in the domestic GCC market. Producers must also demonstrate similar consideration for cultural and religious concerns in other markets.

CONCLUSION

Energy-to-food precision fermentation is a consumer, commercial, investment, and scientific challenge. GCC countries in particular are well positioned to rise to this challenge, to lead a new agricultural revolution. The reward for those countries that succeed is considerable: independence from food imports, large-scale exports of an innovative product, lower emissions, and the achievement of feeding people around the world.

ENDNOTES

1. The GCC countries are Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.

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12. Tim Searchinger, Richard Waite, Craig Hanson, and Janet Ranganathan, *Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050*, World Resources Institute, July 2019 (https://research.wri.org/sites/default/files/2019-07/WRR_Food_Full_Report_0.pdf).

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17. Ibid.

18. Strategy& analysis and data from Statista (https://www.statista.com/statistics/657103/global-crude-oil-exporter-value-by-country/).

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