

Single-Cell Protein (SCP) as Strategic Investment and Emergency Reserve for Saudi Arabia

A concise technical-policy paper — rationale, techno-economic sketch, resilience role in blockade scenarios, implementation roadmap, risks, and references.

Abstract

Single-cell protein (SCP) — microbial biomass produced in controlled fermentation — is a high-density, low-land, low-water source of protein that can be produced domestically in energy-rich, water-poor states. For an import-dependent arid state such as Saudi Arabia, SCP is not a panacea but is a strategically valuable layer: a domestic, scalable protein source that (1) reduces dependence on global agricultural supply chains, (2) provides a rapid nutritional buffer during sea or land blockades, and (3) creates a commercial product line that keeps production capacities active and financially viable. This paper quantifies key cost drivers in local currency (SAR), evaluates resilience value in blockade scenarios, and proposes a pragmatic implementation strategy.

1. Technology overview — what SCP is and production routes

SCP refers to protein-rich microbial biomass produced from bacteria, yeast, fungi, or microalgae. Viable production pathways include:

Gas fermentation ($\text{H}_2 + \text{CO}_2$ or $\text{CH}_4 + \text{O}_2$) using hydrogen-oxidizing or methanotrophic microbes (projects: Solar Foods, Calysta).

Methane/biogas fermentation using methanotrophs (lower feedstock cost if natural gas or biogas is cheap).

Heterotrophic fermentation on sugars or industrial waste streams (cheaper microbes, but dependent on carbohydrate feedstocks).

Photoautotrophic microalgae (high capital; water and light intensive).

Each route trades off energy vs feedstock dependency: gas/ H_2 routes are energy-intensive but land/water-light, while sugar routes rely on agricultural feedstock. For the Saudi context, the energy-rich / land/water-poor profile favors gas-based or hydrogen-oxidizing SCP for strategic reserve use. (See GFI fermentation review and Solar Foods materials.)

2. Why SCP is strategically attractive for an arid, import-dependent country

1. Decouples protein from arable land and freshwater. SCP requires reactors, energy, and feed gas — not hectares of irrigated grain. This directly addresses Saudi Arabia's water constraint and limited capacity for cereal self-sufficiency.

2. Rapid scale and modularity. Industrial fermentation plants can be built modularly and scaled more predictably than land-based agriculture. Demonstration plants (2024–2025) show industry moving from pilot to industrial scale.

3. Commercial + reserve dual role. Selling a fraction of output finances operations, maintains supply chains, and builds public acceptance; stockpiling the remainder creates a domestic emergency buffer (protein concentrate/flour). This “sell some, store most” model preserves operational readiness and avoids idle facilities.

4. Complement to caloric reserves. SCP supplies protein and essential micronutrients (e.g., B-vitamins when fortified) even while grain imports supply calories. In blockades, calories (grains, oils) are the immediate hunger solution; SCP preserves muscle mass and immune function, reducing long-term morbidity. (See methane-SCP cost and nutrition discussions.)

3. Techno-economic sketch — realistic cost ranges and local SAR math

> NOTE ON EXCHANGE: 1 USD = 3.75 SAR (fixed peg). All currency conversions use this rate.

Published cost anchors

Peer-review literature and techno-economic assessments for methane SCP report retail cost scenarios in the range roughly USD 1.54 to USD 5.16 per kg (dry SCP) under different

assumptions; wholesale/plant-gate numbers are lower. Converting those USD figures to SAR gives an approximate 5.78 to 19.35 SAR/kg (dry) retail range.

Calculation example: $1.54 \text{ USD/kg} \times 3.75 = 5.78 \text{ SAR/kg}$; $5.16 \text{ USD/kg} \times 3.75 = 19.35 \text{ SAR/kg}$. (All arithmetic exact to two decimals.)

Emerging industrial producers (e.g., Solar Foods) have published projected production ranges in EUR and company investor materials suggesting early commercial prices in the EUR 13–25/kg range (translating ~48.75–93.75 SAR/kg at 1 EUR \approx 4.25 SAR — note EUR \leftrightarrow SAR can vary) for ready-to-market consumer goods in 2025–2027; these are for consumer-facing formulations, not wholesale protein concentrate.

Energy as the dominant operating cost

Hydrogen/CO₂ or H₂-oxidizing SCP routes have high electricity / hydrogen energy demand. Independent estimates place energy consumption in the range of \approx 65–85 kWh per kg of dry protein for hydrogen-based routes (estimate range used in recent energy-cost studies).

Saudi industrial electricity tariffs (indicative) are around SAR 0.20–0.26 per kWh for industrial users in 2025; using SAR 0.20/kWh as a conservative industrial price yields energy cost \approx 13–17 SAR per kg ($65 \times 0.20 = 13.0 \text{ SAR/kg}$; $85 \times 0.20 = 17.0 \text{ SAR/kg}$).

Putting feedstock + energy together (order-of-magnitude)

If energy cost is \sim 13–17 SAR/kg and other OPEX (nutrients, labor, maintenance, gas compression) add another \sim 5–10 SAR/kg, you reach \sim 18–27 SAR/kg plant-gate for hydrogen-based SCP in many realistic near-term scenarios (this aligns reasonably with higher end published retail projections once packaging/marketing/processing are added). Published methane SCP wholesale/retail scenarios (USD 1.5–5.2/kg) convert to \sim 5.8–19.5 SAR/kg retail, depending on whether energy and feedstock are cheap/subsidized.

Interpretation: for strategic reserve planning, budget planning should assume plant-gate SCP concentrate will cost on the order of \sim 15–30 SAR per kg in near-to-mid term under typical assumptions — lower if natural gas or industrial by-product feedstocks are available cheaply, higher if relying on renewable hydrogen at current costs.

4. Storage, shelf life, and reserve format — how to stockpile SCP for emergencies

Practical reserve design principles:

Store dry, stabilized formats: protein flour, milled textured protein, or extruded blocks have much longer shelf lives (years if packaged under low-oxygen conditions with moisture control and antioxidants). Wet biomass is perishable and requires refrigeration — avoid for strategic stockpiles. (Literature & industry practice favor dried, fortified concentrates.)

Fortification and blending: SCP is protein-dense but not a complete caloric source. Reserve packages should be blended with long-shelf staples (rice, wheat flour, vegetable oil, legume flour) to provide calories + protein. A reserve product might be a fortified biscuit or emergency ration providing ~400–500 kcal and 20–30 g protein per bar.

Volume & mass planning: dry SCP density varies with processing; assume 1 kg dry SCP yields ~3–4 kg of blended emergency food when combined with bulking calories. Stockpiling target example: a 3-month protein buffer for 10 million people at 30 g/day protein (excessive — illustrative) would imply enormous tonnages; realistic national targets focus on key groups (military, hospitals, children) and staggered stockpiles.

5. Role in blockade / supply-shock scenarios

Consider three blockade cases:

A. Partial blockade (one maritime front blocked)

Imports reroute via the unaffected coast, land corridors, or airlift for high-value items. Impact: price spikes, temporary shortages in perishable and specialty items.

SCP role: small domestic plants and stockpiles cushion the protein shortfall for targeted groups; commercial sales continue to fund operations.

B. Dual maritime blockade + temporary land disruption

Imports constrained, airlift capacity limited by cost. Strategic reserves of grain and oils are primary. SCP provides protein preservation and reduces health burden by preventing sarcopenia and infection risk among vulnerable populations. Because SCP production is domestic, it bypasses blocked maritime logistics as long as energy and feedstock (e.g., domestic natural gas, electricity, or stored hydrogen) remain available.

C. Full systemic crisis (ports blocked, borders closed, energy infrastructure attacked)

This is an extreme scenario implying multi-domain conflict. SCP production requires continuous energy and possibly feedstock imports; thus, if energy systems fail, SCP stops quickly. However, stored, shelf-stable SCP reserves remain valuable because they were produced before the crisis. Therefore, SCP's strategic value is highest when production, commercialization, and stockpiling are combined pre-crisis. (Literature supports SCP as a complementary buffer rather than a standalone famine cure.)

6. Business model: "Sell some — store most" (why this is financially sensical)

Commercial sales (food ingredients, aquaculture feed, specialty foods) create revenue to cover fixed costs and workforce continuity.

Government procurement: state offtake contracts for emergency reserves provide demand certainty and enable investment in capacity.

Dual supply chains: one stream channels product to commercial markets (retail, feed), the other to strategic reserve stockpiles packaged to military/humanitarian specs.

This model avoids idle capacity, keeps technical skills current, and reduces per-kg costs through economies of scale.

7. Implementation roadmap and recommended targets for Saudi Arabia

Phase 1 (0–3 years): pilots and policy

Fund 1–2 demonstration industrial plants (5–20 t dry SCP/month) employing hydrogen or methane routes near industrial energy clusters (e.g., NEOM, Jubail, Ras Al Khair). Use public R&D grants and public-private partnerships. Leverage petrochemical by-products where possible to reduce feedstock cost.

Phase 2 (3–7 years): scale and commercial integration

Scale to multiple 100 t/month trains. Secure offtake agreements with food processors and aquaculture. Begin active stockpiling program: target initial strategic reserve of 1,000–5,000 tonnes dry SCP (a modest buffer focused on critical sectors). At ~20 SAR/kg, 1,000 tonnes ≈ 20 million SAR; 5,000 tonnes ≈ 100 million SAR (product value basis; procurement cost should be modeled precisely).

Example simple math: $1,000,000 \text{ kg} \times 20 \text{ SAR/kg} = 20,000,000 \text{ SAR}$.

Phase 3 (7–15 years): resilience integration

Integrate SCP into national emergency plans, military rations, and regional humanitarian stockpiles. Invest in renewable hydrogen to lower energy cost per kg over time.

8. Risks and mitigations

1. Energy disruption risk. Mitigation: pair plants with on-site generation (gas turbines, captive solar + electrolyzers) and maintain fuel/hydrogen buffers.

2. Feedstock dependency. Mitigation: design plants to accept multiple carbon/nitrogen feedstocks (methanol, biogas, $\text{CO}_2 + \text{H}_2$) and secure strategic feedstock contracts.

3. Cultural acceptance. Mitigation: phase in SCP as ingredient (protein-enriched flour, meat analog components) and fund consumer education and ISO/FSQA certifications.

4. Economic risk (capex and scale). Mitigation: public-private partnerships, government offtake guarantees for reserve procurement, and initial targeting of institutional markets (aquaculture, pet food, hospital nutrition) to expedite break-even.

5. Regulatory and safety. Mitigation: adopt international food-safety standards, invest in GRAS/Novel Food approvals as needed.

9. Conclusion — realistic, unvarnished judgment

SCP is a smart strategic investment for an energy-rich, water-poor country. It aligns with Saudi strengths (cheap energy, capital, logistics) while reducing vulnerability to agricultural import shocks.

It is not the single answer to national food security — calories from cereals/oils remain essential — but SCP is one of the highest-value domestic resilience layers available: provides protein, is scalable, and can be stocked in shelf-stable formats.

Practically, expect near-term plant-gate protein costs on the order of ~15–30 SAR/kg depending on technology choices, energy pricing, and feedstock. Energy is the dominant cost — policies that lower electricity/hydrogen prices (or that provide access to cheap natural gas or renewables) materially improve economics.

References (selected, load-bearing)

1. Martínez, J.B.G., et al., Methane Single Cell Protein: Potential to Secure a Global Protein Supply (2022). Contains techno-economic scenarios for methane SCP (USD/kg retail and wholesale scenarios).
2. Solar Foods, Investments Plan and Impact for Industrial-Scale Solein® Production (Investor materials, March 2025). Industrial projections for Solein commercial pricing and capacity development.
3. Good Food Institute, State of the Industry Report — Fermentation (2023/2024). Review of fermentation-based alternative proteins and scaling issues.
4. Energy cost study (Oct 2024): Energy Costs of Bacterial Food Manufacture — estimate energy intensities for hydrogen-based SCP at ~65–85 kWh/kg. (Technical note informing energy cost calculations.)
5. Saudi electricity tariff reporting and industrial electricity price references (2025) — indicative industrial tariffs ~ SAR 0.20–0.26/kWh. Used to compute energy cost per kg.

Annex: Simple cost arithmetic examples (all figures illustrative, order-of-magnitude)

Published methane SCP retail low scenario: USD 1.54/kg $\rightarrow 1.54 \times 3.75 = 5.78$ SAR/kg.

Published methane SCP retail high scenario: USD 5.16/kg $\rightarrow 5.16 \times 3.75 = 19.35$ SAR/kg.

Energy cost example (hydrogen route): 65–85 kWh/kg \times SAR 0.20/kWh = 13–17 SAR/kg energy cost.