GREEN FEED REVOLUTION

Eco-Friendly Feed Solution For Urban Agriculture

Green Feed Revolution mirrors eco-friendly feed solution by emphasizing the transformative, sustainable impact of algae- based animal feed

PBRC 9.1

Table of Contents

1. Chapter 1: Executive Summary

This section introduces an eco-friendly feed solution grounded in microalgae production, targeting sustainable urban and periurban agriculture. As part of the broader PBRC (Portable Bioreactor for Regenerative Cultivation) system, this solution focuses on producing algae-based animal feed that supports small-scale livestock, aquaculture, and poultry systems in cities and emerging periurban zones. By using compact and modular bioreactors, the PBRC feed system offers an innovative approach to closing food production loops while reducing the environmental footprint of animal husbandry.

Algae-based feed is not a new concept in industrial agriculture, but the PBRC approach brings this idea into urban settings where access to affordable, reliable, and sustainable feed is often limited. In dense urban areas, smallholder farmers and micro-producers face multiple challenges in raising livestock or fish: high input costs, fluctuating feed prices, supply chain instability, and limited space for conventional feed crop cultivation. The PBRC system addresses these barriers by enabling local production of high-quality algae biomass, cultivated on-site or in nearby locations using wastewater, captured CO_2, and renewable energy inputs where available.

This feed solution is not just a replacement for imported commercial feeds but a step forward in the redesign of localized food systems. The nutrient profile of microalgae makes it an ideal candidate for sustainable animal feed. It is rich in proteins, essential amino acids, fatty acids like omega-3, and important micronutrients. These qualities support animal health and growth while reducing the need for synthetic supplements or resource-heavy ingredients like soy and fishmeal.

One of the main drivers of this innovation is sustainability. Traditional animal feed production, especially soy and corn, is associated with deforestation, high water use, and significant greenhouse gas emissions. In contrast, PBRC-grown algae requires a fraction of the land, uses water in a closed loop, and absorbs CO_2 during cultivation. This positions algae-based feed as a tool for climate-smart agriculture, especially in cities where emissions reduction and environmental stewardship are increasingly seen as essential goals.

Cost efficiency is another core benefit. While commercial algae feed products are often expensive due to centralized production and long supply chains, the PBRC approach brings feed production directly to the point of use. By eliminating transportation costs and leveraging local waste streams as feedstock, the system can produce algae biomass at a lower cost. This makes it accessible to small-scale producers who operate within tight margins and cannot afford high-end industrial feed. Over time, locally grown feed also creates job opportunities and stimulates circular economic activity in the community.

The PBRC feed system is circular by design. It utilizes organic waste, recycles water, and feeds the resulting biomass into local animal systems. In turn, animal waste can be re-processed or composted to support urban agriculture, completing a resource loop that is both efficient and regenerative. This form of bio-integrated infrastructure fits well within larger plans for sustainable cities and food security. It turns waste into value while reducing external dependencies.

Urban agriculture initiatives often emphasize food production, but feed is just as critical. Livestock and aquaculture remain essential for dietary diversity, income generation, and resilience. Without affordable and sustainable feed, these systems are hard to scale or sustain. PBRC provides a solution that brings feed into the urban fold, aligning with rooftop farms, aquaponics systems, backyard poultry setups, and other emerging models of local food resilience.

The integration of algae-based feed into urban food systems also supports broader agri-tech and policy goals. It aligns with national and global efforts to promote sustainable intensification, reduce environmental degradation from livestock production, and increase local capacity for food production. Furthermore, the system is modular and scalable. It can be installed in a school compound, a community center, or a periurban fish farm. It adapts to various sizes and needs, making it an inclusive and flexible solution.

At the policy level, algae-based feed supports multiple Sustainable Development Goals. These include Zero Hunger, Responsible Consumption and Production, Climate Action, and Life Below Water, among others. The system's circular nature directly contributes to resource efficiency while its local production model supports food sovereignty and community development.

In conclusion, the PBRC algae-based feed solution is a forward-thinking response to the growing challenges of urban food production. It combines ecological sustainability, economic feasibility, and social inclusivity. By decentralizing feed production and rooting it in regenerative design, PBRC enables cities and communities to support healthier animals, reduce waste, and build food systems that are both resilient and future-ready. This feed module complements the food applications introduced earlier and sets the stage for integrated and circular approaches to food production in cities.

Problem Statement & Context

Urban agriculture is gaining attention as cities seek to boost local food production, reduce transportation costs, and make use of unused spaces. However, scaling urban farming faces multiple challenges. One of the major constraints is land scarcity. Urban spaces are densely built, leaving limited room for traditional agricultural expansion. Rooftops, vertical farms, and converted spaces offer some relief, but these are often small-scale and come with design and maintenance costs that deter widespread adoption.

Alongside land issues, urban agriculture must manage inputs like feed, water, and nutrients. Among these, animal feed stands out as a critical bottleneck. Most urban farms that include livestock or aquaculture systems still rely on conventional feed sources such as soy and fishmeal. These products are not only expensive to transport but are also unsustainable in the long run. Soy production contributes to deforestation, while fishmeal depletes marine ecosystems. Both create significant carbon footprints before even reaching the urban farm. As cities aim to develop more resilient, closed-loop food systems, continuing to rely on such feed sources undermines the core goals of sustainability and circularity.

Feed sourcing in cities is further constrained by the low availability of local alternatives. The lack of scalable, locally produced feed options forces urban farmers into dependency on global supply chains. These supply chains are vulnerable to price shocks, trade disruptions, and climate-driven variability. In many cities, especially in low and middle-income countries, animal feed can account for more than half the cost of urban livestock operations. This hampers profitability and makes local meat or fish production financially unviable.

Meanwhile, urban centers continue to generate enormous volumes of organic waste, much of which goes unutilized. Household food scraps, spent grains from breweries, vegetable market waste, and restaurant discards typically end up in landfills or incinerators. This not only creates methane emissions but also represents a massive missed opportunity to convert urban biomass into useful inputs. Few cities have robust systems for organic waste recovery or transformation. Recycling rates remain low, and the infrastructure for waste-to-feed conversion is underdeveloped or entirely absent.

Even where interest exists, regulatory gaps, lack of public-private collaboration, and a shortage of technical expertise hinder progress. Municipal authorities often lack the capacity to support feed innovation. At the same time, most private actors are hesitant to invest in pilot-scale urban feed systems due to perceived risks and uncertain returns.

Urban agriculture also demands climate-resilient solutions. Feed systems must operate efficiently despite temperature extremes, water shortages, and pollution. Many conventional feed crops are water-intensive and require large tracts of land unsuitable for cities. Moreover, the growing unpredictability of climate patterns is beginning to impact global feed supply chains. In this context, a resilient, locally controllable feed production system becomes not just desirable but essential.

Currently, there are gaps in local feed ecosystems in nearly every urban context. Few if any cities have the capacity to produce even a fraction of their own animal feed. Where pilot programs exist, they tend to be fragmented, underfunded, or limited in technical scope. There is a clear need for scalable, adaptable feed systems that can integrate with urban infrastructure, use minimal space and water, and turn local waste into high-value inputs.

The algae-based feed systems proposed under PBRC aim to address these pain points. By converting urban CO_2, wastewater, and food waste into nutrient-rich feed, these systems can help close urban nutrient loops. Algae can grow rapidly in photobioreactors, requiring only sunlight, carbon dioxide, and basic nutrients. These reactors can be set up on rooftops, in basements, or in modular container units. This makes them highly adaptable to dense urban environments.

Such systems also offer high protein yields per square meter, outperforming traditional crops like soy or corn. They do not require arable land and can be operated year-round. Moreover, the nutritional content of algae can be tailored based on animal needs, making it suitable for poultry, aquaculture, and even insect farming. By customizing algae strains and cultivation conditions, PBRC can produce targeted feed solutions without compromising safety or performance.

Waste from local food processing facilities, municipal compost programs, or brewery by-products can serve as feedstock for algae cultivation, depending on regulatory frameworks. This not only reduces pressure on landfills but also contributes to the city’s circular economy goals.

Such an approach aligns with the UN's Sustainable Development Goals, especially those related to Zero Hunger, Responsible Consumption, and Climate Action.

Another advantage lies in cost-efficiency. Once the photobioreactor systems are in place, operational costs can be significantly lower than importing feed. Algae's rapid growth and high conversion efficiency mean less input is needed to generate equivalent nutritional output. This reduces dependency on volatile global markets and enhances local resilience.

However, successful deployment depends on strong policy support and cross-sector collaboration. Cities will need enabling regulations, technical guidance, and perhaps subsidies to encourage early adopters. Integrating algae-based feed into existing urban food systems will also require partnerships with waste management companies, urban farms, and innovation hubs.

In summary, urban agriculture faces a serious feed problem that current systems are ill-equipped to solve.

The conventional feed supply is environmentally and economically unsustainable, and the urban waste problem continues to grow. There is a clear mismatch between urban needs and current solutions. Algae-based feed systems provide a novel, climate-smart, and scalable answer to this challenge. They close resource loops, support local economies, and reduce the ecological burden of feeding urban populations. The gaps in current production ecosystems can be filled with this approach, positioning it as a vital innovation in the future of urban food security.

Description of the Solution

The proposed algae-based feed solution is a modular, sustainable system that uses microalgae to produce high-quality animal and aquaculture feed. It addresses the feed demands of urban and periurban farms while contributing to broader waste management, resource recovery, and low-emission goals.

Chapter 2: What is the Algae-Based Feed Solution?

The solution centers around cultivating selected strains of nutrient-rich algae in controlled environments that integrate seamlessly with the urban ecosystem. These algae are then harvested, processed, and transformed into feed for livestock (e.g., poultry, pigs) and aquatic species (e.g., tilapia, catfish). The system uses minimal land, relies on renewable inputs, and offers a low-emission, high-yield alternative to conventional feed production.

This model supports localized feed production that minimizes transport needs, supports closed-loop systems, and utilizes urban resources that would otherwise go to waste. Its flexibility allows it to be implemented on rooftops, inside repurposed buildings, or integrated into periurban greenhouses and farming cooperatives.

How It Works: Inputs, Processing, Output

The algae-based feed system relies on a few essential inputs: wastewater, carbon dioxide, sunlight or artificial lighting, and selected nutrients.

1. **Inputs**

    - **Wastewater**: Treated greywater or agricultural runoff is used as a nutrient base. This reduces freshwater use and provides essential minerals like nitrogen and phosphorus.

    - **Carbon Dioxide**: CO_2 is sourced from nearby buildings or biogas digesters. Algae absorb CO_2 during photosynthesis, turning it into biomass.

    - **Nutrients**: Depending on the algae strain, micronutrients such as iron or magnesium may be added to optimize growth.

- **Light**: Solar energy is used when possible, supplemented by LEDs when needed for consistent growth cycles.

2. **Processing**

    - **Cultivation**: Algae are grown in photobioreactors or open tanks. The design is modular and scalable, ranging from rooftop setups to warehouse installations.

    - **Harvesting**: Once the algae reach optimal density, they are separated from the liquid medium using filtration or centrifugation methods.

    - **Drying**: Biomass is then dried using solar drying racks, low-temperature air drying, or energy-efficient dehumidifiers.

    - **Milling**: Dried algae are milled into a fine powder suitable for mixing into feed pellets or used directly as a protein supplement.

- **Formulation**: Algae powder is blended with other feed ingredients or fortified to meet species-specific nutritional requirements.

3. **Output**

    - The final product is a protein-rich feed supplement, free from antibiotics or growth hormones, suitable for poultry, fish, pigs, or rabbits. It can be packaged and distributed locally or used on-site.

Chapter 3: Types of Algae Used

The most commonly used algae strains include:

- **Spirulina (Arthrospira platensis)**: High in protein (up to 70%), essential amino acids, and antioxidants. It supports immune function in livestock and improves feed conversion ratios.
- **Chlorella vulgaris**: A single-cell green algae rich in chlorophyll, iron, and essential fatty acids. It enhances digestive health and growth in aquaculture.
- **Scenedesmus and Nannochloropsis**: Often used in aquafeed for their omega-3 content and favorable lipid profiles.

Strain selection depends on the animal type, the environmental conditions, and the specific nutrient profile required. For instance, fish farming operations may favor strains high in polyunsaturated fatty acids, while poultry might benefit from protein-dense spirulina.

Nutritional Profile and Benefits

Algae offer several nutritional advantages over conventional feed ingredients:

- **High Protein Content**: Most microalgae contain 40–70% protein, making them comparable to fishmeal or soybean meal.
- **Vitamins and Minerals**: Algae are naturally rich in vitamin B12, iron, potassium, calcium, and magnesium.
- **Omega-3 and Omega-6 Fatty Acids**: Especially important for fish feed, where they contribute to healthy growth and reduce inflammation.
- **Digestibility**: Algae cell walls can be pretreated to improve digestibility, making nutrients more bioavailable to animals.

This makes algae-based feed not only a viable substitute but often a superior alternative in terms of nutritional efficiency and animal health outcomes.

Use of Urban Rooftops, Vertical Tanks, or Modular Units

One of the key design principles behind this solution is adaptability to urban environments. PBRC's model supports the use of:

- **Urban rooftops**: Flat roofs on residential or commercial buildings can host lightweight photobioreactors or shallow raceway ponds.
- **Vertical tanks**: Stacked systems inside buildings, garages, or containers maximize yield per square meter.
- **Modular units**: Prefabricated, transportable algae growing stations can be placed near fish farms, community gardens, or school farms.

These units require minimal infrastructure. Water piping, solar panels, and CO_2 input systems are included in modular setups, making them easy to deploy in both developed and low-resource settings.

Chapter 6: Energy Inputs and Integration with Renewable Sources

Energy consumption is one of the main concerns with intensive algae production. To address this, PBRC's model includes:

- **Solar panels** for lighting and pumping
- **Battery storage** for night-time operations
- **Low-energy air bubbling systems** to enhance mixing and gas exchange
- **Heat recovery** from nearby buildings or greenhouses to support thermal regulation

Where applicable, waste heat from composting systems or HVAC systems is captured and used to maintain optimal temperatures for algae cultivation.

Chapter 7: Zero-Waste Aspect and Reuse of Residues

Algae-based feed production aligns with zero-waste principles in several ways:

- **Water Recycling**: After algae are harvested, the remaining water can be filtered and reused for new growth cycles or redirected for irrigation.
- **Residual Biomass**: Byproducts or algae strains with lower protein can be composted or converted into biochar, enhancing soil fertility.
- **CO_2 Capture**: Algae directly use captured CO_2 from fermentation, exhaust, or industrial sources, helping reduce emissions.

This circularity ensures that waste inputs are transformed into useful outputs, while maintaining a minimal ecological footprint.

Broader Relevance and Future Potential

As urban agriculture grows in response to climate and supply chain shocks, the need for locally produced feed is increasing. Traditional supply chains for feed ingredients are vulnerable to price volatility, climate disruptions, and geopolitical events.

Algae-based systems offer a low-risk, low-input, high-output solution that aligns with the goals of sustainable urban development. Their modular nature allows them to scale gradually, and their ability to close loops with urban waste systems makes them highly relevant for cities aiming to become more self-sufficient and climate resilient.

By offering a system that transforms waste into food for animals and fish, PBRC's algae feed model supports food sovereignty, waste reduction, and environmental restoration. It complements rooftop farming, hydroponics, and other urban agri-tech strategies, making it a key piece of the sustainable food puzzle.

This solution is already being explored in pilot sites linked to municipal waste programs, university test beds, and rooftop farming cooperatives. With further validation, algae-based feeds can move from pilot to mainstream, transforming how cities feed their animals and themselves.

Technology and Innovation

Algae-based animal feed is not just a concept it is a practical, evolving technology that addresses urban agriculture challenges while aligning with circular economy and climate-smart strategies. This section outlines the technological backbone of the solution, the innovations involved, and real-world applications that show its scalability and relevance.

Algae Cultivation Systems

At the core of algae-based feed solutions are two main cultivation systems: photobioreactors (PBRs) and open tanks.

Photobioreactors (PBRs)

PBRs are closed systems where algae are grown in controlled environments. These can be horizontal, vertical, or tubular, using transparent materials like glass or polycarbonate. The system optimizes light exposure, temperature, and nutrient input to ensure high-density growth. Urban rooftops and compact lots are ideal for vertical PBR installations, making them practical for city settings. The closed nature of PBRs limits contamination, increases biomass yield, and allows for year-round operation.

Open Tanks

These are open ponds or raceway systems often used where space is less limited. While cheaper to build, they are more exposed to contaminants and temperature fluctuations. However, with proper maintenance and periodic monitoring, they can still yield quality biomass. Some hybrid systems combine features of both to balance cost and performance.

Closed-loop Nutrient Cycles

The algae feed solution fits into a closed-loop nutrient cycle. Urban waste streams like organic food waste, greywater, and CO_2 emissions are repurposed as inputs. After primary treatment, wastewater serves as a nutrient-rich growth medium. CO_2 sourced from nearby facilities or even buildings' HVAC systems enriches photosynthesis.

This creates a self-sustaining loop:

- Nutrient-rich waste feeds the algae.
- Algae absorb nutrients and CO_2 while producing oxygen.
- Harvested algae become animal feed or biofertilizer.
- Residues from processing can go back into compost or energy generation.

Such a cycle minimizes external inputs and maximizes reuse, reducing reliance on chemical fertilizers and improving sustainability.

Tech Stack: Automation, Sensors, IoT

The system's success hinges on smart technology. Sensors monitor key variables like:

- pH levels
- Temperature
- Light intensity
- CO_2 concentration
- Biomass density

Data from these sensors are processed in real-time through IoT platforms. This allows remote monitoring and automated adjustments. For example, when light intensity drops, LEDs supplement natural light. If nutrient levels dip, dosing systems add more organically sourced compounds.

Mobile apps or desktop dashboards display live data, historical trends, and alerts. These platforms make operation simple, even for users without technical backgrounds. They also support preventive maintenance by signaling when filters need cleaning or if pumps are malfunctioning.

Innovations in Harvesting, Drying, and Feed Formulation

Algae biomass must be harvested, dewatered, dried, and processed into usable animal feed. This involves several technical steps, each with innovation potential.

Harvesting

Innovative flocculation techniques are used to separate algae from water efficiently. These include magnetic harvesting or bio-based flocculants, which speed up settling without chemical contamination.

Dewatering and Drying

Algae naturally contain over 90% water. Removing this moisture without damaging nutritional value is critical. Advanced belt dryers or solar-assisted dryers reduce energy costs. Some systems integrate heat recovery, where waste heat from nearby buildings or greenhouses is used.

Feed Formulation

Once dried, algae can be ground into powder or formed into pellets. These are blended with other nutrients depending on the target livestock poultry, aquaculture, or small ruminants. Enzyme treatments or fermentation may be applied to improve digestibility.

What stands out in the formulation is its customizability. For example, aquafeed may need higher omega-3 content, while poultry feed emphasizes protein. These custom blends match or even exceed the performance of conventional feeds.

Scalability in Small Urban Spaces

Urban farms rarely have access to hectares of land. The algae solution's modularity allows it to scale within tight footprints.

Vertical PBRs can fit on rooftops, balconies, or along building walls.

Shipping container farms can house complete units: cultivation, harvesting, and drying all in one.

Tanks along periurban perimeters can serve larger cooperatives or urban-rural links.

Even a single school or housing complex can deploy a small unit that feeds chickens, fish, or goats while recycling its organic waste.

This urban adaptability makes the solution scalable not just in size but in geography applicable in informal settlements, high-rise apartments, or industrial parks.

Pilot Case Examples in European Cities

Several cities in Europe have piloted algae-based feed systems as part of broader urban sustainability programs.

Barcelona, Spain
In the Poblenou district, a rooftop pilot using vertical PBRs fed spirulina to local aquaculture farms. The system recycled greywater and cut down feed costs by 30%. It also involved local schools in educational tours.

Milan, Italy
A public-private partnership in Milan deployed

containerized algae units near a community kitchen. The harvested algae were mixed with organic waste to produce enriched compost and supplemental livestock feed. It served as a demonstration for integrating circular bioeconomy models in food relief efforts.

Rotterdam, Netherlands

Rotterdam used algae cultivation in periurban greenhouses to supply feed for ducks and fish in urban farms. The project integrated data collection with municipal air quality monitoring showing how algae systems can contribute to both agriculture and environmental goals.

Circular Economy and Climate-smart Agriculture Linkages

The algae feed solution is deeply embedded in circular economy principles.

1. **Input Reuse**

   Urban wastewater, CO_2, and organic waste are not discarded they become inputs for algae production.

2. **Low Waste Output**
   Almost every by-product has value. Even the spent algae cake after oil extraction can be used for feed or bioplastics.

3. **Energy Integration**
   Algae systems align with solar energy, waste heat reuse, and energy-efficient design.

In climate-smart agriculture terms, this approach:

- Increases resource-use efficiency
- Reduces greenhouse gas emissions
- Builds resilience in food production
- Encourages biodiversity and low-impact farming

Conclusion

This algae-based feed solution represents a well-rounded package of innovation, practicality, and sustainability. With adaptable systems like photobioreactors and modular tanks, integration into small urban or periurban spaces is feasible. The use of smart technologies ensures precise, low-effort management. From harvesting and processing innovations to feed customization, each step shows a commitment to performance and environmental responsibility.

Real-world pilots across Europe confirm its viability and scalability. Whether addressing feed scarcity, reducing urban waste, or building climate resilience, the algae system proves to be more than a concept it’s a working solution aligned with circular economy goals and urban agricultural needs.

Environmental and Economic Impact of Algae-Based Feed Solutions

Algae-based feed systems present a breakthrough for cities looking to build climate-resilient, low-carbon food systems. These innovations not only reduce environmental pressures but also support inclusive economic development. By transforming underutilized resources like wastewater and urban CO_2 into high-value feed, this solution cuts emissions, saves water, and opens new urban job markets.

1. Lower Greenhouse Gas Emissions

One of the most significant contributions of algae-based feed lies in its carbon footprint. Traditional livestock feeds, especially soy and fishmeal, carry high emission profiles due to land-use change, deforestation, and fossil-fuel-intensive production. In contrast, algae systems especially those integrated with photobioreactors or closed-loop biotanks absorb CO_2 during photosynthesis.

In urban environments, these systems can be co-located near industrial or traffic-heavy zones to utilize ambient carbon emissions. This serves dual purposes: lowering the overall carbon intensity of animal production and turning cities into active carbon sinks.

Estimates from pilot initiatives suggest that replacing 1 metric ton of soy feed with algae-based alternatives can offset up to 2 metric tons of CO_2 equivalents. These offsets become even more impactful when scaled across periurban or rooftop installations in densely populated cities.

2. Water and Energy Efficiency

Algae require far less freshwater than traditional crops. When grown using treated wastewater, they effectively recycle city-generated greywater into biomass. In many PBRC models, wastewater becomes a primary nutrient input, especially in spirulina or chlorella production systems.

The energy demand for algae farming varies depending on the system open ponds use more land but require minimal energy, whereas photobioreactors consume more energy but allow vertical scaling. However, when paired with renewable energy sources like rooftop solar or biogas from urban waste, algae systems become largely self-sustaining.

Several feasibility studies show that photobioreactors powered by solar panels can achieve positive net energy balances, making them not just sustainable but also economically viable over time.

3. Upcycling Urban and Agro-Waste

Urban centers generate tons of organic waste daily, much of which ends up in landfills, releasing methane. Algae cultivation offers a way to upcycle these waste streams. Residual nutrients in food waste or agro-industrial effluent can be converted into algae biomass.

After harvesting, the leftover algae residues such as cell walls or non-digestible fractions can be repurposed into compost, biogas substrates, or industrial feedstock, creating a nearly zero-waste loop. This level of resource efficiency contributes to a circular urban economy, where waste becomes a resource for feed and energy rather than an environmental burden.

4. Economic Model and Feasibility

The upfront cost (CAPEX) of installing algae production units varies by system type and scale. Photobioreactors cost more per unit but can be modular, making them suitable for rooftop installations. Open raceway ponds, although cheaper, need more space and are less viable in urban cores.

Operational costs (OPEX) include labor, energy, maintenance, and water. However, when systems are integrated with city infrastructure using existing rooftops, wastewater, and renewable energy these expenses drop substantially.

Break-even timelines for microfarms range between 3–5 years depending on scale and local subsidies. Larger community-scale systems (run as cooperatives or through public-private partnerships) often reach profitability faster due to economies of scale.

Moreover, algae-based feed can be priced competitively with fishmeal and soy, especially in regions where import costs inflate traditional feed prices. This economic case strengthens further when carbon credits or sustainability certifications are factored in.

Urban Job Creation and Inclusive Growth

Algae farming does not require high technical skills at the operator level, making it ideal for low-barrier employment in cities. Each modular farm unit creates several local jobs in cultivation, harvesting, packaging, and distribution.

In European pilot cities, algae initiatives have trained unemployed youth, women, and migrants to run algae microfarms or participate in cooperative models. This contributes to inclusive urban development and decentralization of agri-value chains.

Additionally, small and medium-sized enterprises (SMEs) are finding opportunities in algae system installation, equipment maintenance, and logistics creating new economic pathways beyond the feed sector.

6. Strengthening Hyperlocal Supply Chains

One of the main vulnerabilities in global feed markets is over-reliance on long-distance supply chains. Urban algae-based systems address this by producing feed within or near consumption zones.

This reduces transport emissions, lowers costs, and improves feed security for urban livestock and aquaculture operations. In disaster-prone or food-insecure areas, this model also ensures continued feed supply even when international logistics are disrupted.

The flexibility of algae systems allows them to be scaled according to need from backyard tanks to neighborhood farms making them adaptable to different city environments and governance setups.

Conclusion

The environmental and economic benefits of algae-based feed systems go hand in hand. By lowering emissions, saving water, and reusing waste, these systems offer a sustainable alternative to conventional feed production.

They also create new jobs, promote local enterprise, and stabilize food and feed supply chains in cities.

With increasing urbanization and climate pressure, adopting such decentralized, regenerative systems is not just ideal it is urgent.

Implementation Strategy & Stakeholders

The rollout of an algae-based feed system under the PBRC (Portable Bioresource Conversion) framework requires a structured implementation strategy that is realistic, cost-effective, and inclusive. The strategy must align with urban planning frameworks while drawing from grassroots networks and institutional partners to ensure long-term viability.

Chapter 8: Rollout Plan: Pilot → Demonstration → Scale

The initial phase focuses on targeted pilot projects. These pilots are typically implemented on small scales such as rooftops, underutilized urban lots, or modular containers to test the viability of algae-based feed production in different urban contexts. Pilot programs assess performance under varying climatic, wastewater, and infrastructure conditions. Metrics include yield rates, operational costs, energy consumption, and regulatory feasibility.

Once technical feasibility and regulatory safety are confirmed, pilots transition into the demonstration phase. Demonstration units operate at medium scale, serving schools, municipal animal shelters, small poultry farms, or aquaponic farms in cities. They showcase tangible benefits: reduced feed costs, lower environmental impact, and reliable production.

The final phase is full-scale implementation. This includes mainstreaming algae feed modules in public spaces (such as food hubs or urban farming parks) and private facilities (cooperatives, green tech incubators, or feed distributors). Scale-up is driven by local councils and regional investment in sustainable agriculture and circular economy practices.

Public-Private Partnerships (PPPs)

A crucial component of successful implementation is partnership. Public-private partnerships bring together municipalities, technology firms, algae producers, and distribution networks. Municipal governments may provide space, basic utilities, and regulatory approval. Private partners supply technical expertise, materials, and commercial distribution pathways.

For example, a municipality might lease rooftop space on government buildings to an algae start-up, which installs vertical photobioreactors and manages feed production. The feed is then sold to urban poultry farms, with a portion allocated for public facilities such as community farms or youth-led agricultural initiatives.

This shared-risk, shared-reward model increases local ownership and improves economic returns. Public incentives (tax reliefs, carbon credits, waste management subsidies) encourage investment from the private sector, while social returns (job creation, food security, environmental benefits) justify public involvement.

Key Actors

Municipalities

Local governments are primary enablers. They integrate PBRC feed systems into waste management, public procurement, and urban planning. They can embed algae-based feed into food strategies or climate resilience programs. Municipal support can also include licensing, sanitation approvals, and integration into educational initiatives.

Start-ups and SMEs

Small- and medium-sized enterprises are key drivers of technology deployment and business model innovation. Start-ups bring agility in prototyping, customer engagement, and lean operations. They often lead in creating modular units, managing digital platforms, and training new workers in system operations.

These companies also drive value-added services, such as mobile apps for monitoring algae growth, subscription-based feed delivery models, or service contracts for algae module maintenance.

Research Centers and Universities

Academic and applied research institutions provide scientific validation, monitor results, and offer training. They test feed composition, growth variables, and animal health outcomes. Research hubs also play a major role in engaging students and researchers in low-tech climate solutions and improving long-term knowledge transfer.

European centers working on circular agriculture, microbiology, or sustainable animal husbandry are essential collaborators in building localized algae strains or refining feed conversion ratios.

European Union Programs

EU programs such as Horizon Europe, LIFE, or the European Innovation Council offer funding and policy support. These programs prioritize green transition projects, urban food innovation, and circular systems. Participation in such frameworks enables cross-country replication, access to open data, and policy harmonization.

Moreover, alignment with European Green Deal goalsbespecially on biodiversity, climate adaptation, and reducing dependency on imported feed positions the algae-feed strategy for broader political support and co-financing opportunities.

Chapter 9: Community Organizations and Cooperatives

Community groups play a key role in awareness, training, and localized management. In areas with limited digital infrastructure or technical capacity, cooperatives or farmer groups take over day-to-day operations. They handle local waste collection, oversee feeding schedules, manage small sales, and support social inclusion (by involving youth, women, and the unemployed).

Community participation also increases trust and enhances accountability, especially in underserved or marginalized areas.

Cooperatives may also serve as anchor customers for algae feed, using it in collective livestock rearing, fish ponds, or composting hubs.

Regulatory Frameworks and Safety Protocols

Implementation must comply with health, safety, and food chain regulations. These include standards for algae cultivation (e.g. avoiding contaminated water sources), processing (e.g. drying temperatures, moisture content), and storage (e.g. traceability, expiry labeling). Regulations depend on national and EU-level frameworks.

Safety measures include regular testing of inputs (e.g. wastewater), certified strain usage, documented hygiene procedures, and end-user guidelines. Collaboration with regulatory bodies such as EFSA or local food agencies ensures compliance and eases approval processes.

Traceability systems must track algae batches from production to distribution. Digital monitoring tools or QR-coded packaging help meet transparency requirements and increase consumer confidence.

In pilot projects, regulatory flexibility (such as sandboxing provisions) can accelerate experimentation and validation. Over time, lessons from early implementations help refine national guidelines and enable smoother replication in other cities or regions.

In sum, the implementation strategy for algae-based feed under the PBRC framework must be deeply rooted in practical partnerships, clear governance roles, and transparent safety mechanisms. By balancing innovation and regulation, public interest and commercial viability, the system can scale across urban contexts and serve as a cornerstone of circular, climate-smart urban agriculture.

Scalability and Replication Potential

The success of algae-based feed production within PBRC (Portable Biocircular Resource Centers) lies not only in its localized impact but also in its high scalability and adaptability. Designed for decentralized deployment, the PBRC feed solution has the structural and technical flexibility to replicate across a variety of urban and peri-urban environments. It offers a sustainable pathway to feed production that meets the specific challenges of space, resource scarcity, and economic resilience in different regions.

Replicability Across Urban and Peri-Urban Areas

One of the core strengths of the PBRC model is its modular and compact design. Whether set up on rooftops, vacant lots, schoolyards, or inside unused warehouses, algae cultivation systems like vertical bioreactors or containerized units can be adjusted to fit the physical constraints of any urban or peri-urban site. This ensures ease of deployment in densely populated areas, where land availability is a key limitation.

In peri-urban areas with slightly more space, open ponds or hybrid systems can be integrated to produce higher volumes of algae feed. These can supply nearby livestock farms, poultry cooperatives, or fish farms, reducing reliance on long-haul feed transport and promoting local economic loops.

The PBRC's infrastructure is transportable and quick to install, making it well-suited for disaster recovery, refugee camps, or informal settlements. Once on-site, the system can begin producing valuable feed inputs within weeks, depending on climatic conditions and resource availability.

Chapter 10: Customization for Different Climates and Space Types

Algae strains and cultivation methods can be adapted to local weather patterns and infrastructure. For hot, arid regions, species like spirulina thrive in elevated temperatures and can be grown in covered raceway ponds or shallow tanks to minimize evaporation. In cooler climates, chlorella or nannochloropsis may be favored, grown in insulated photobioreactors to ensure consistent productivity.

Indoor cultivation systems using LED lighting and climate control can enable year-round production in areas with harsh winters or frequent rainfall. Integration with geothermal or solar energy ensures sustainable operations even in energy-constrained settings.

PBRCs can also be adjusted for different levels of technological maturity. In low-tech contexts, gravity-fed flow systems and manual harvesting may be implemented, while in more advanced environments, automation and sensor-based monitoring can be added for higher precision and efficiency.

Adaptation to Other Sectors

While PBRC Ba focuses on algae as animal and aquaculture feed, the platform opens doors for diversified applications. Residual biomass can be processed into organic fertilizer for urban gardens or peri-urban farms, helping close the nutrient cycle.

The same algae biomass if cultivated under food-grade conditions can feed into other sectors, including:

- **Cosmetics**: Extracts from spirulina and chlorella are widely used in skin creams, shampoos, and health masks for their antioxidant and anti-inflammatory properties.
- **Biofertilizers**: Dried algae residue rich in nitrogen and micronutrients can enrich soil and support regenerative agriculture.

- **Bioplastics and packaging**: Algal polymers are emerging as alternatives to petroleum-based plastics, supporting local circular economies.
- **Pharmaceuticals and nutraceuticals**: Specific algae strains produce bioactive compounds useful in immune boosters or anti-inflammatory products.

By diversifying applications, PBRCs can increase their financial viability and reduce risks tied to single-market dependency.

Alignment with EU Green Deal and SDG Goals

The algae-based PBRC solution is well aligned with current European and global sustainability agendas. The European Green Deal encourages regional self-sufficiency in food and feed, reduced carbon emissions, and circular bioeconomy practices. PBRCs support these goals by:

- Reducing dependence on imported soy and fishmeal
- Lowering carbon and water footprints

- Upcycling urban waste streams
- Creating localized, traceable, and safe food/feed chains

In the context of the UN Sustainable Development Goals (SDGs), PBRC Ba contributes directly to:

- **SDG 2: Zero Hunger** – by improving feed availability and reducing livestock input costs
- **SDG 11: Sustainable Cities and Communities** – through localized, resource-efficient feed production
- **SDG 12: Responsible Consumption and Production** – by reusing waste and minimizing environmental impact
- **SDG 13: Climate Action** – via low-emission operations and carbon capture from algae cultivation
- **SDG 8: Decent Work and Economic Growth** – by generating jobs in algae farming, logistics, and processing

As cities continue to grow and climate pressures intensify, the replication of PBRCs becomes more than an optionbit becomes a strategic necessity. Their adaptability across sectors, climates, and urban formats makes them a vital tool in shaping resilient, circular, and climate-smart food systems.

Risks and Mitigation

Despite the promise of algae-based animal feed in urban agriculture, certain risks must be recognized and proactively addressed.

1. Technical Failures

A key concern is system contamination microbial intrusions or imbalanced nutrient levels can reduce yield or spoil entire batches. Yield variability may also occur due to temperature shifts, poor water quality, or light availability. To mitigate this, proper system monitoring using sensors and IoT controls can help maintain optimal growing conditions. Backup protocols and redundancies (e.g., multiple small-scale units rather than a single large system) reduce vulnerability.

2. Acceptance and Market Uptake

While algae feed is scientifically validated, public and industry perception remains a challenge. Some farmers may hesitate to adopt algae as a protein source due to unfamiliarity or concerns about taste, digestibility, or regulatory acceptance. This risk is especially present in conservative markets with limited exposure to alternative feeds.

3. Mitigation Measures

Targeted training for end users especially small-scale urban or peri-urban farmers can improve confidence and technical capacity. Demonstrations and pilot trials also play a crucial role in showing tangible benefits. Partnering with local universities and labs for certification and quality assurance ensures trust and consistency. Awareness campaigns and co-branding strategies with municipal programs can normalize algae-based feed as a smart, resilient choice for the future of sustainable farming.

Conclusion

Algae-based feed production offers a smart, sustainable solution for the challenges facing urban agriculture today. With land scarcity, rising input costs, and increasing pressure on conventional feed sources like soy and fishmeal, the need for alternative, circular systems is urgent. Algae feed answers that call delivering high-protein, low-footprint nutrition using waste streams, CO_2, and minimal space.

The system's compatibility with urban settings, from rooftops to modular tanks, makes it both scalable and adaptable. It reduces greenhouse gas emissions, recycles local waste, and opens up new economic opportunities for urban communities. It aligns with EU sustainability goals, the Green Deal, and global efforts to build resilient, climate-smart food systems.

Looking ahead, algae-based feed systems have the potential to become core infrastructure in future cities powering local food chains, supporting green jobs, and easing the environmental burden of livestock and aquaculture. With the right support, this vision is well within reach.

We call on policymakers, investors, and local governments to recognize the potential of algae feed and support its rollout. Funding for pilot programs, regulatory clarity, and partnerships with research institutions and SMEs will be key to success. Together, we can make urban food production cleaner, smarter, and more circular starting from the feed.

***J W T* joules water team**

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(54) Title (EN): METHOD FOR GROWING
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IMPLEMENTING SAID

METHOD

(54) Title (FR): PROCÉDÉ DE CULTURE DE MICROALGUES ET DISPOSITIF DE MISE EN OEUVRE DE CE PROCÉDÉ

(57) Abstract:

(EN): This invention relates to a method and to a device to implement said method, to cultivate microalgae and to obtain the simultaneous separation of oleic and protein parts, reducing the required space and drawing mainly from renewable energy sources.

(FR): La présente invention concerne un procédé, et un dispositif permettant de mettre en oeuvre ledit procédé, de culture de microalgues et d'obtention de la séparation simultanée des parties oléiques et protéiques, réduisant l'espace nécessaire et utilisant principalement des sources d'énergie renouvelable. Le procédé est caractérisé par le fait qu'il comprend les phases suivantes : •

ledit mélange aqueux, contenant ledit inoculum, suit un trajet (B) d'un point d'entrée (C) à un point de sortie (D), le long duquel il est irradié par un spectre de rayonnement approprié au développement et à la croissance desdites microalgues; • le long dudit trajet (B) des sels NPK (contenant de l'azote, du phosphore et du potassium) et du CO_2 y sont ajoutés, ces ajouts, conjointement à la diffusion dudit spectre de rayonnement, provoquant une croissance intense desdites algues ; • ledit mélange, fortement enrichi de micro-algues, est inondé d'ultrasons qui détruisent les algues adultes, les séparant en composants oléiques et protéiques, ladite action provoquant la formation d'un nouveau mélange aqueux dans lequel une fraction oléique et une fraction protéique sont présentes ; • ledit nouveau mélange aqueux est soumis à une séparation gravimétrique spontanée de telle sorte que : • une fraction oléique, plus légère, migre dans la partie supérieure dudit nouveau mélange ; • une fraction protéique, plus lourde, migre dans la partie inférieure dudit nouveau mélange ; • une fraction neutre composée presque exclusivement d'eau reste dans la partie intermédiaire dudit nouveau mélange ; · lesdites trois fractions sont prises individuellement. Le dispositif (A) est caractérisé par le fait qu'il comprend : • un bassin (1) adapté pour contenir ledit mélange aqueux ; • un ou plusieurs déflecteurs (3, 4, 5) montés de façon à délimiter un trajet (B) d'un point (C) à point (D), ledit ou lesdits déflecteurs (3, 4, 5) étant des panneaux diffuseurs du spectre de rayonnement homogènes, appropriés à la phase de culture ; • un moyen adapté pour fournir, audit mélange fluide, des sels NPK (sels d'azote, de phosphore et de potassium) et du CO_2, ledit moyen étant disposé le long dudit trajet (B) ; • un moyen (9) adapté pour produire des ultrasons, positionné au niveau du point final

(D) dudit trajet (B), lesdits ultrasons étant d'une puissance suffisante pour détruire les algues adultes en les séparant en composants oléiques et protéiques, donnant lieu à un nouveau mélange fluide dans lequel sont présentes une phase oléique, une phase protéique et une phase neutre ; • un moyen adapté pour diffuser ledit nouveau mélange fluide, afin de mettre en œuvre une séparation gravimétrique desdites phases oléique, protéique et neutre ; • un moyen adapté pour collecter séparément lesdites phases oléique, protéique et neutre.

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- Dream.ZONE (>1 Million People) of the desired shape and capacity, while always remaining withinthe limits of the Sovereign State from which it is pivot/center (State that is always hoped to be sober and constructive, as usually already sanctioned and recognized by our major communities such as

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- 3 BIG transversal projects: GUPC-RE/Lab (Sustainable real estate redevelopment), GUPCHousingCare (Social and welfare redevelopment), MasterPlan (group of Industrial Plans); all interventions with a distributed&pervasive perspective that makes massive use of local work and endogenous resilience of the territory;

- 8 MINOR and vertical but still significant projects in various fields (Efficient pumps/generators, Urban MiniBiogas, Microalgae cultivation, Urban desalination, Agro&Sport, Separation and massive capture of pollutants, Effective dissemination and communications, Selective EMG diagnostics and capture of micro pollutants);

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Summary

Urban agriculture is evolving, and algae is leading a green feed revolution. As a sustainable, nutrient-rich alternative to conventional livestock and aquaculture feed, algae offers a low-impact solution that thrives in compact urban environments. Its rapid growth, minimal resource needs, and ability to recycle waste make it ideal for circular farming systems. From rooftop fish farms to vertical livestock operations, algae-based feed is helping cities produce food more responsibly, reducing emissions, conserving water, and promoting healthier ecosystems. It's not just feed, it's a future-forward strategy for resilient urban food chains.

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For more information, visit:

http://www.expotv1.com/LIC/MISE_0001427412_PBRC.pdf
Patent: https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2016092583

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