Waste-to-Resource Strategies in Agri-Food Systems

This module examines how organic “waste” can be transformed into valuable resources within the agri-food system, emphasizing sustainability through a circular economy approach. Students investigate multiple waste-valorization pathways—including landfilling, composting, anaerobic fermentation, biochar production, and insect bioconversion—and compare their effects on greenhouse gas emissions and nutrient cycling. Using the 5R’s framework (Refuse, Reduce, Reuse, Repurpose, Regenerate), the lessons introduce circular thinking alongside real-world case studies and career pathways. Across three lessons, learners analyze the science underlying waste-to-resource strategies, engage in inquiry and data collection (such as a campus waste audit and carbon footprint calculations), and apply systems thinking to design solutions that close resource loops. By the conclusion of the module, students will understand how accessible technologies and innovations can convert organic byproducts into energy, fertilizer, animal feed, bioplastics, and other products—transforming a linear “take-make-waste” model into a sustainable circular system.

Standards Alignment:

Next Generation Science Standards (NGSS) – Performance Expectations:

Disciplinary Core Ideas (DCIs) – This module ties into several DCIs by contextualizing science concepts within food systems:

- **HS-ESS3-1: Earth and Human Activity:** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
- **HS-ESS3-2: Earth and Human Activity:** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
- **HS-ESS3-3**: **Earth and Human Activity:** Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
- **HS-ESS3-4**: **Earth and Human Activity:** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- **HS-ETS1-3:** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs (students design and evaluate waste-management solutions, considering constraints like cost, scalability, environmental benefit).
- **HS-LS2-7: Life Science (from GLBRC crosswalk**): Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Science and Engineering Practices (SEPs):

- **Using Mathematics and Computational Thinking:** Students calculate emissions and carbon savings for different treatments (quantitative analysis of ΔCO_2-eq).
- **Constructing Explanations and Designing Solutions:** Students propose and justify solutions for campus waste hotspots and articulate how those solutions work and why they’re beneficial.
- **Engaging in Argument from Evidence:** Through discussions and the design mini-pitch, students use data (e.g. carbon footprint numbers) to argue for the best waste management approach.
- **Asking Questions and Defining Problems:** The module opens with essential questions about waste destiny and frames the problem of cafeteria waste management for students to solve.

Crosscutting Concepts (CCCs):

- **Systems and System Models:** The school waste audit activity models the campus as an interconnected system of inputs and outputs, illustrating how interventions in one part of the system affect the whole.
- **Energy and Matter:** Flows, Cycles, and Conservation – Students see that matter (food waste) isn’t destroyed but transformed; pathways like composting and biochar illustrate matter cycling and energy flow (e.g. methane as energy vs. carbon stored in char).

- **Stability and Change:** Students examine how introducing new technology (e.g. an anaerobic digester) can change the balance of outputs (less waste to landfill, more reusable energy/fertilizer) and make the system more sustainable over time.
- **Cause and Effect:** Each pathway demonstrates cause-effect relationships (e.g. cause: lack of oxygen in landfill → effect: methane production; adding biochar to soil → improved water retention, etc.).

California CTE Standards (Agriculture & Natural Resources Pathway):

- **Foundation Standard 1.0:** Academics Students apply essential academic content—science, mathematics, environmental systems—to understand waste valorization, carbon calculations, and systems thinking in sustainability practices.
- **Foundation Standard 2.0:** Communications Learners use accurate agri-food terminology (e.g., "biochar," "anaerobic digestion," "carbon footprint") and communicate effectively through science-writing, presentations, and data visualizations (e.g., audit reports, prototype pitches).
- **Foundation Standard 5.0:** Problem Solving & Critical Thinking — Through campus waste audits, carbon math, and solution design, students engage in systems analysis and creative problem-solving to develop circular waste strategies.
- **Foundation Standard 9.0:** Leadership and Teamwork – Team-based prototype pitches and waste hotspot investigations foster collaboration, peer feedback, and leadership in real-world sustainability projects.
- **Foundation Standard 11.0:** Demonstration and Application – Students apply theoretical knowledge—about greenhouse gas impacts, nutrient cycles, microbial processes—into practical designs and demonstrations across lab investigations and solution development.
- **Sustainable Agriculture Pathway Integration:** This module strengthens students' capacity to understand and evaluate the environmental, economic, and social impacts of waste-management decisions—bridging systems thinking with stewardship and innovation in food systems.
- **Innovation & Resource Management:** By comparing waste reduction strategies and assessing resource conversion methods (e.g., Bokashi, compost, biochar), students evaluate technical innovations and make data-informed decisions in resource management contexts.

UC A–G "D" Laboratory Science:

This module is designed to meet UC/CSU A–G "D" Laboratory Science requirements as part of an approved science course.

- **Inquiry & Hands-On Activities:** At least 20% of instructional time is teacher-supervised lab-style work, including a campus waste audit (measuring, categorizing, and quantifying waste streams), carbon math investigations (ΔCO_2-equivalent calculations), and experimental trials with Bokashi fermentation, composting, biochar pyrolysis, and insect bioconversion.
- **Scientific Practices:** Students pose scientific questions, collect authentic datasets, calculate and analyze greenhouse gas emissions, and present evidence-based conclusions. Activities emphasize inquiry and NGSS-aligned practices, such as using computational tools for CO_2 modeling and designing prototype waste-to-resource systems.
- **Interdisciplinary Science:** Module 2 integrates biology/ecology (nutrient cycles, microbial decomposition, insect metabolism), earth and environmental science (greenhouse gas emissions, climate impacts, land-use implications), and chemistry (fermentation reactions, pyrolysis processes, carbon sequestration mechanisms), ensuring both breadth and depth of scientific foundations.
- **Rigor & Depth:** Students engage in data analysis and scientific communication through design pitches and presentations. Reflection activities and peer evaluations further develop higher-order thinking and align with UC expectations for rigorous, college-preparatory laboratory science.

Content supports NGSS disciplinary core ideas ESS3.C (Human Impacts on Earth Systems), LS2.B (Cycles of Matter and Energy Transfer in Ecosystems), and ETS1.B (Developing Possible Solutions), while engaging students in cross-cutting concepts such as Systems and System Models and Energy and Matter Flows.