Table of Contents

MOD2_TCHGDE_TCH_FV_092025

Grade: 11-12	**Subject:** Agricultural Science	**Topic:** Waste-to-Resource Strategies in Agri-Food Systems **Sub-topic:** Beyond the Trash: The Five Pathways of Food Waste, Carbon Math & Upcycling Toolkit (Quantifying impacts and trade-offs), Measuring Waste & Calculating CO_2 Impact	**Lesson:** Multi-day Unit (Lessons A-C + Activity Corners / Worksheets)

Key Question to be Addressed in the Module:
How can we transform food and organic waste into valuable resources while minimizing climate impact and balancing practical trade-offs?

Sub-questions:
- How can we redefine “waste” as a resource in agricultural and school settings?
- What are the environmental (carbon) impacts of different waste management strategies, and how can we quantify and compare them?
- How can implementing multiple waste-valorization methods together create a more sustainable, closed-loop campus or community?

Time (lesson length): 3–4 class periods (45–55 minutes each)	**Class size:** 25-30 students	**Resources:** Wi-Fi, projector, PC, whiteboard, markers, presentation slides, printed student-guided notes, student activity worksheets, materials for design activities (poster boards, graph paper, rulers, colored pencils)

Objectives and Outcomes:
At the end of this module, students should be able to:
- Review the concept of circular vs. linear systems
- Identify the major waste-to-resource pathways for organic waste
- Quantify and compare the climate impacts of each waste pathway using real data
- Examine trade-offs/resources of each technology
- Analyze [campus] waste generation
- Apply systems thinking to propose solutions

Breakdown
<u>Lesson A – Beyond the Trash: The Five Pathways of Food Waste</u>
- **Identify:** Five major waste-valorization pathways—landfill, aerobic composting, anaerobic fermentation / digestion (Bokashi & digesters), biochar pyrolysis, and insect bioconversion
- **Describe:** Inputs, process conditions, and primary outputs of each pathway
- **Compare:** Greenhouse-gas profiles of the five pathways and determine which emit or avoid the most CO_2-equivalent
- **Predict:** Which pathway would deliver the greatest carbon reduction for a given food-waste scenario

Lesson B – Carbon Math & Upcycling Toolkit

- **Understand**: Recognize the ΔCO_2-equivalent for landfilling 1 kg of food waste versus treating it with alternative valorization options, using provided emission factors or data.
- **Create**: Design an optimal valorization route for a specific real-world waste stream (e.g. cafeteria leftovers or farm waste), supporting the recommendation with evidence from carbon calculations and practical considerations.
- **Evaluate**: Assess the trade-offs of each pathway – considering factors like cost, scalability, speed, and nutrient recovery – to justify which option might be preferable in a given context.
- **Rank:** Categorize different waste-to-resource technologies by their net carbon impact (most to least climate-friendly) and also compare their energy requirements and useful co-products.

Lesson C - Measuring Waste & Calculating CO_2 Impact

- **Analyze**: Quantify their campus's waste-generation hotspots, estimating weekly amounts of food, yard, and paper waste at key locations and computing the associated CO_2-equivalent emissions for each.
- **Apply**: Utilize the feasibility and projected carbon savings of their proposed solution in a brief presentation or "mini-pitch," using data (emission reductions, etc.) and practical reasoning to persuade peers.
- **Create** / Evaluate: Design a prototype waste-to-resource system for one selected hotspot or waste stream, specifying how the waste could be collected and processed (composted, fermented, fed to insects, etc.) to close the nutrient or energy loop.
- **Reflect**: How can implementing multiple different valorization routes in parallel move the entire campus toward a circular economy, and identify challenges and next steps for making it happen.

The Methods and Sequence of Activities

Day 1: Lesson A - Beyond the Trash: The Five Pathways of Food Waste

Teacher Activities:	**Student Activities:**	**Duration of Activities:**
Introduction ● Warm-Up Discussion: "How can we redefine "waste" as a resource in agricultural and school settings?" ○ Begin with a quick poll or show of hands: "Imagine you have an orange peel – who would throw it in the trash? Compost it? Try something else (bokashi, biochar, etc.)?" ● Lecture Slides: ○ Where Does Your Waste Go? ■ Organic Waste = Biodegradable materials from plants or animals ■ Environmental Impact; In landfills → decomposes without oxygen → methane emissions ○ Where Does the Peel Go? ■ Nutrient Potential: Rich in carbon, nitrogen, and minerals that can be returned to soils or converted into valuable products.	● Participate in discussion and brainstorming ● Watch slide / video presentation and take guided notes ● Engage in activity corner(s) ● Apply lecture content to exit ticket questions	Introduction - 15 minutes Activity Corner - 25 minutes Closure - 10 minutes Total - 50 minutes

- Why It Matters: Managing organic waste sustainably can cut GHG emissions and support a circular economy.
- Food Waste by the Numbers
  - Discuss the waste from food and how it affects the ecosystem + watch the video
- Optional Review: Linear VS. Circular Loop Pathway
  - Linear Path Loop: Take, Make; Waste
  - Circular Path Loop: Reduce, reuse, refuse, repurpose, regenerate
- Where Does the Peel Go? (Pathways):
  - Path 1: Landfill
  - Path 2: Compost
  - Path 3: Anaerobic Fermentation with two scales – bokashi bucket (small scale) and anaerobic digester (larger scale).
  - Path 4: Biochar Pyrolysis
  - Bonus Path 5: Insect Bioconversion
- Double Valorization: Introduce the concepts + more valorization
• Case Study:
  - Circular Thinking in Action: Transforming Citrus Waste in California
    - Researchers at LabtoFarm tested a double valorization pathway on citrus nurseries: Bokashi fermentation and biochar pyrolysis
<u>Activity Corner</u>
• Dear Principal, Reimagining Waste (Think-Pair-Share):
  - Students will pick a composting pathway and write a short letter to the principal asking for a change in waste management.
<u>Closure</u>
• Exit Ticket:
  - List the five major waste-valorization pathways we discussed in class.
  - Which pathway avoids the most CO_2-e emissions per kilogram of food waste, and why?
  - Given a scenario where you must process food scraps quickly with minimal equipment, which pathway would you recommend and what trade-offs would you accept?
<u>Materials</u>
• Presentation slides, student-guided notes, student activity worksheets		

<table>
<tr>
<td>● Presentation slides or visuals (diagrams of each waste pathway, images of bokashi bucket, biochar kiln, larvae bin); whiteboard or chart paper for listing student ideas; an actual orange (as a prop to reference the “peel” example)
● Optional: A sample of finished bokashi bran or compost to show, and a small container of biochar (to show its look/feel)</td>
<td></td>
<td></td>
</tr>
<tr>
<td colspan="3">Student Assessment: Student understanding will be assessed through a required quiz focused on the five pathways of food waste. The quiz will assess students’ ability to Identify the five major waste-valorization pathways: landfill, aerobic composting, anaerobic fermentation / digestion (Bokashi & digesters), biochar pyrolysis, and insect bioconversion; Describe the inputs, process conditions, and primary outputs of each pathway; Compare the greenhouse-gas profiles of the five pathways and determine which emit or avoid the most CO_2-equivalent; and Predict which pathway would deliver the greatest carbon reduction for a given food-waste scenario. Optional activities, such as the Think-Pair-Share: Dear Principal, Reimagining Waste activity, are enrichment opportunities and will not be graded.</td>
</tr>
<tr>
<td colspan="3">Day 2: Lesson B - Carbon Math</td>
</tr>
<tr>
<td>Teacher Activities:
<u>Introduction</u>
● Warm-Up Discussion: “What are the environmental (carbon) impacts of different waste management strategies, and how can we quantify and compare them?”
● Lecture Slides:
○ Why Each Path Works: Present a table or chart of the ΔCO_2-eq for 1 kg of orange peel via different paths
○ Every Path Has Trade-Offs: No single “perfect” pathway – each balances climate benefit, cost, speed, and usability differently.
○ Which Path Shrinks Emissions Most? Introduce the idea that context matters, and introduce the idea that carbon math is used as a quantitative comparison of different pathways
○ Guided Calculation: How to Use Δ CO_2-eq?
■ Show the formula and emphasize that the more negative the number, the better for the climate
○ Guided Calculation: Carbon Math Usage:
■ Students will learn how to compare the climate impacts of different waste strategies using Δ CO_2-eq (using CH_4 (Methane) instead of CO_2 (Carbon Dioxide) as CH_4 is the gas that is produced most in landfills)
○ Looking At An Impact of Carbon Math: Campus Scenario
■ School generates 50 kg of lunch scraps/day
● Case Study:</td>
<td>Student Activities:
● Participate in discussion and brainstorming
● Watch slide / video presentation and take guided notes
● Engage in activity corner(s)
● Apply lecture content to exit ticket questions</td>
<td>Duration of Activities:
Introduction - 15 minutes
Activity Corner - 30 minutes
Total - 45 minutes</td>
</tr>
</table>

<table>
<tr>
<td>

- Turning Campus Waste into Plant Power
  - 10% Bokashi + 10% Biochar → Half the fertilizer, healthier citrus

<u>Activity Corner</u>

- Toolkit Trade-Offs Discussion (Think-Pair-Share):
  - Students will work in pair / groups to fill in a table and use realistic examples that they have learned
  - They will decide which pathway to choose for a school cafeteria waste stream and deged their choice with at least two criteria from the table

<u>Closure</u>

- Exit Ticket:
  - What does a negative ΔCO_2-eq value mean when comparing waste-treatment pathways?
  - Order the following pathways from most to least climate-friendly: landfill, biochar, insect bioconversion, compost, Bokashi.
  - If a digester has higher upfront costs but produces renewable energy, in what situations might it still be the best choice?

<u>Materials</u>

- Presentation slides, student-guided notes, student activity worksheets
- Slide or handout with ΔCO_2-equivalent data for waste pathways (could be a table/chart for students to reference)
- Simple calculators if needed (though numbers are easy), whiteboard or chart paper for the comparative toolkit chart

</td>
<td></td>
<td></td>
</tr>
<tr>
<td colspan="3">

Student Assessment: Student understanding will be assessed through a required quiz focused on Quantifying impacts and trade-offs. The quiz will assess students' ability to Understand the ΔCO_2-equivalent for landfilling 1 kg of food waste versus treating it with alternative valorization options, using provided emission factors or data, Create an optimal valorization route for a specific real-world waste stream, supporting the recommendation with evidence from carbon calculations and practical considerations, Evaluate the trade-offs of each pathway to justify which option might be preferable in a given context, and compare different waste-to-resource technologies by their net carbon impact, energy requirements, and useful co-products. Optional activities, such as the Toolkit Trade-offs Discussion activity, are enrichment opportunities and will not be graded.

</td>
</tr>
<tr>
<td colspan="3">

Day 3: Lesson C - Measuring Waste & Calculating CO_2 Impact

</td>
</tr>
<tr>
<td>

Teacher Activities:
<u>Introduction</u>

</td>
<td>

Student Activities:

- Participate in discussion and brainstorming
- Watch slide / video

</td>
<td>

Duration of Activities:
Introduction - 5 minutes
Activity Corner - 25 minutes

</td>
</tr>
</table>

● Warm-Up Discussion: “How can implementing multiple waste-valorization methods together create a more sustainable, closed-loop campus or community?” ● Lecture Slides: ○ Why Measure Waste? ■ Why should we care about the data and how do we calculate it? ■ Step 1: Estimating Waste Volumes ■ Step 2: Converting Volume to Mass ■ Step 3: Calculating Weekly Totals ■ Step 4: From Waste to CO_2-equivalent ● Case Study: ○ Dorm Kitchen Food Waste ■ Display a short worksheet with a practice scenario with Juan and Katie, show the calculation steps and the interpretation of the results <u>Activity Corner</u> ● Mini Waste-to-Resource Pilot (Think-Pair-Share): ○ Students will pick one cafeteria waste item and design a mini blueprint, choosing the best valorization method and estimating CO_2 reduction <u>Closure</u> ● Exit Ticket: ○ Which location on campus produces the highest CO_2-e emissions from food waste, and how do you know? ○ If you implemented insect bioconversion at your largest hotspot, what would happen to CO_2-e emissions and what co-products would you generate? ○ Why might using multiple waste-valorization methods together be more effective than relying on a single solution? ● Module 2 Key Takeaways and Mindmap ● Career Pathways ● Sneak Peek on Hands-On Activity <u>Materials</u> ● Presentation slides, student-guided notes, student activity worksheets ● A calculator or prepared conversion table for CO_2 factors; a slide or poster with the conversion factors for common wastes (for student reference); markers to label hotspot solutions	presentation and take guided notes ● Engage in activity corner(s) ● Apply lecture content to exit ticket questions	Closure - 10 minutes Total - 40 minutes
Student Assessment: Student understanding will be assessed through a required quiz focused on Measuring Waste & Calculating CO_2 Impact.		

<table>
<tr><td colspan="3">The quiz will assess students’ ability to analyze and quantify their campus’s waste-generation hotspots, estimating weekly amounts of food, yard, and paper waste at key locations and computing the associated CO_2-equivalent emissions for each. Students will be able to apply the feasibility and projected carbon savings of their proposed solution in a brief presentation or “mini-pitch,” using data (emission reductions, etc.) and practical reasoning to persuade peers as well as how to create a prototype waste-to-resource system for one selected hotspot or waste stream, specifying how the waste could be collected and processed (composted, fermented, fed to insects, etc.) to close the nutrient or energy loop. Students will reflect on how implementing multiple different valorization routes in parallel can move the entire campus toward a circular economy, and identify challenges and next steps for making it happen. Optional activities, such as the Mini Waste-to-Resource Pilot activity, are enrichment opportunities and will not be graded.</td></tr>
<tr><td colspan="3">Day 4 / Day 5 - Hands-On Activities</td></tr>
<tr>
<td>Teacher Activities:
<u>Activity Corner</u>
● Cafeteria Food Waste Audit (Hands-On Activity):
○ Students work in small groups to measure cafeteria food waste by category.
○ They will:
■ Collect uneaten food into labeled buckets (entrées, fruits, vegetables, milk, unopened items).
■ Interview peers about reasons for food waste (e.g., taste, temperature, time).
■ Weigh food waste by category to identify what is wasted most.
■ Create graphs and charts to visualize findings.
■ Brainstorm solutions such as sliced fruit, creative naming, or recess before lunch.
● DIY Bokashi Bucket Set-Up (Hands-On Activity):
○ Students set up a two-bucket bokashi system to ferment cafeteria scraps using bran inoculated with microbes.
○ They will:
■ Collect 1 kg of cafeteria scraps, chop into small pieces, and layer with bran.
■ Assemble a two-bucket system with cloth liners to allow leachate collection.
■ Track changes over time by measuring pH, leachate volume, and odor.
■ Analyze results to understand microbial fermentation and how waste becomes a resource for soil health.</td>
<td>Student Activities:
● Participate in the hands-on activities, and in data collection and analysis</td>
<td>Duration of Activities:
Travel: 0 minutes (within school classroom or lab)
Activity Corner: 1 class period (35-40 minutes) for setup, observation, and data collection</td>
</tr>
</table>

- Biochar vs. Pollution (Hands-On Activity):
    - Students compare how untreated water, soil, and soil with biochar affect water contaminated with copper sulfate ($CuSO_4$).
    - They will:
        - Prepare three treatments:
            - Cup A: $CuSO_4$ only (control)
            - Cup B: $CuSO_4$ + soil
            - Cup C: $CuSO_4$ + soil + biochar
        - Stir each mixture, let settle, and observe changes over 7–8 minutes.
        - Record data on water color, clarity, pH, and any other observations (smell, particles).
        - Determine which treatment removes the most contaminant (blue color).
        - Reflect on real-world applications of biochar in cleaning polluted water, such as mining runoff, industrial waste, or drinking water cleanup.

<u>Proposed Schedule</u>

(Hands-On Activity: DIY Bokashi Bucket Set-Up)

- Setup – Day 1 (~40 min)
    - Intro & Instructions (10 min) – Overview of anaerobic fermentation, bokashi microbes, and the two-bucket design.
    - Hands-On Build (20 min) – Assemble buckets, chop scraps, layer with bran, and seal airtight.
    - Initial Data Entry (10 min) – Record bucket weights, food types, and preliminary smell/appearance.
- Monitoring – Weeks 2 & 3 (~10–15 min every 3–4 days)
    - Open and check contents briefly.
    - Record smell, appearance, and leachate volume.
    - Measure pH of leachate and note odor changes.
- Final Wrap-Up – Day 21 (~25–30 min)
    - Compile and graph pH, odor, and leachate trends.
    - Reflect on microbial roles in preventing spoilage and recycling nutrients.
    - Discuss total leachate collected and possible uses in soil health or sustainability projects.

Student Assessment: Student understanding will be assessed through their completed data collection worksheets and reflection responses from the Cafeteria Food Waste Audit, DIY Bokashi Bucket Set-Up, and Biochar vs. Pollution – Clean Water Challenge. Worksheets will be graded using a rubric that evaluates the accuracy and completeness of recorded data (bucket weights, food categories, leachate volume, pH values, odor and appearance notes, water clarity, and contaminant reduction), as well as the clarity of graphs, charts, and written observations. Students will also be assessed on their ability to interpret their own results by comparing across treatments (e.g., food categories wasted most, bokashi fermentation trends, soil vs. biochar in pollutant removal) and linking findings to ecological principles such as microbial fermentation, nutrient cycling, and pollution remediation. Reflection and discussion questions will measure systems thinking by asking students to connect their results to broader issues of food waste reduction, soil health, and environmental sustainability. Optional extensions, such as designing posters or sharing recommendations with the school community, will serve as enrichment and are not graded.

Day 5 (Optional) Lesson A - Extended Learning: Bokashi Microbial Diversity

Teacher Activities:

<u>Introduction</u>

- Lecture Slides:
    - Introduce the importance of microbes in fertilizer and their functions in terms of making bokashi effective
    - Focus on a specific paper: “Microbial transformation of traditional fermented fertilizer bokashi alters chemical composition and improves plant growth”
        - Scientists test different bokashi recipes and measured both nutrients and microbial diversity in bokashi as it matured
    - Explain measuring methods, especially α-diversity (Shannon Index) and briefly β-diversity (Bray-Curtis)
    - Teach the students how to read a Shannon Diversity graph by going through the steps:
        - Identify the variables
        - Look for the highest and lowest
        - Compare treatments
        - Interpret the meaning
    - Show the interpreted results for microbial diversity of the different bokashi recipes scientists were studying

<u>Activity Corner</u>

- Optional Extended Learning (Think-Pair-Share): Reading a Graph – Soil Microbial Diversity & Bokashi:
    - Students will read a graph showing Shannon Index across treatments, and interpret and discuss what the data means for soil health

<u>Materials</u>

- Presentation slides, student-guided notes, student activity worksheets

Student Activities:

- Participate in the discussion and take guided notes on metabolic modeling
- Participate in the activity corner, and share and reflect on their work

Duration of Activities:

Introduction - 15 minutes
Activity Corner - 25 minutes
Closure: 10 minutes
Total - 50 minutes

Student Assessment: TBD