



## Module 6: Agri-Systems Across the City-Rural Gradient Speaker Notes

### MOD6\_LECTURE\_EXTENDED\_DECK\_12-01-2025

#### How to Use Speaker Notes (For Teachers)

These speaker notes are designed to support your presentation of Module 8: Energy Use & Technology in Agriculture. They provide suggested explanations, sample dialogue, and prompts to help you guide discussion and deepen student understanding.

#### Flexible and Adaptable

- You are not expected to read the notes word-for-word. Use them as a resource to help you frame each slide and select what works best for your teaching style and time constraints.
- The level of detail you include can vary based on your class. For AP students, you may choose to explore more technical or data-rich explanations. For other groups, simplify the language or focus on key takeaways.

#### Use Your Voice

- You are encouraged to rephrase content in your own words and bring in local or current examples.
- Feel free to add metaphors, stories, or connections that make the material more relevant and memorable for your students.
- If you have relevant videos, articles, or short activities, these can be used to reinforce or replace certain parts of the notes.

#### Promote Active Engagement

- The notes often include reflection questions, discussion prompts, and interactive activity suggestions.
- All activities listed are optional. Choose those that best fit your group's time, interests, and learning level.
- A student-facing worksheet has been provided to support note-taking, reflection, or review during and after the lesson.

#### Be Selective and Strategic

- Not every slide needs to be covered in the same way. Some may require brief explanations; others may invite more time and exploration.
- Consider selecting two to three main points or questions per slide that align with your goals for the lesson.
- Focus on the overall learning objectives: helping students understand how energy is used in agriculture, how technology is changing the field, and how we can design sustainable systems.

## Module 6: Agri-Systems Across the City-Rural Gradient

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## Introduction

Slides 1 to 2

### Slide 1: Introduction

Introduction to Module 6: Introduce exploring climate-smart food systems from rooftop to orchard.

Begin by posing a framing question: What does it mean to grow food in a city versus the countryside, and why should we care?

- *“Today, we’re exploring how where we grow food—urban rooftops, peri-urban greenhouses, or rural orchards—shapes the sustainability of our entire food system. These zones all face different pressures: water access, land prices, infrastructure, and labor. We’ll see how farmers adapt their tools and practices to these different spaces—and how each space can become part of a climate-smart, circular food system.”*

Provide context on the diversity of growing zones in agriculture:

- *“Urbanization is rapidly reshaping where and how we grow food. Traditional farming has always been associated with rural areas, but today, food is also being grown on rooftops, in schoolyards, and inside shipping containers in cities. The food system now spans urban microfarms to rural commodity fields.”*

Emphasize that where food is grown affects sustainability, equity, and climate resilience:

- *“Land availability, food miles, labor types, and energy use all vary depending on the zone. These differences matter when designing climate-smart food systems that are efficient and fair.”*

This module will break down:

- How we define urban, peri-urban, and rural growing zones
- What the key trade-offs are between land cost, labor, and logistics
- How climate-smart agriculture techniques work across these zones
- How to evaluate systems using sustainability metrics like L/kg and biomass per kWh

Wrap up the introduction.

- *“As you move through this lesson, keep this question in mind: If you were responsible for feeding your city, what types of farms would you invest in—and where would you place them to maximize sustainability and resilience?”*

### Slide 2: Learning Outcomes

Address the purpose of the slide: Tell students they’ll be looking at the goals and structure of the module.

*“This slide previews the three main lessons, each of which will take a different lens to analyzing food systems across the urban–rural gradient. We’re starting with spatial differences, then moving into climate-smart innovations, and finishing with how to evaluate and compare sustainability across systems.”*

Explain the different lessons and their focus.

Lesson A: From Balcony to Back-Forty

- **Remember/Understand:** Define and distinguish urban, peri-urban, and rural food-system contexts, and describe how food miles, land cost, and labor differ across the gradient.
- **Apply/Analyze:** Classify and analyze farming systems from visual/text examples, noting trade-offs in productivity, sustainability, and logistics.
- **Create/Evaluate:** Design and justify a modified city-region food layout that optimizes space and labor under real-world constraints.

Lesson B: Climate-Smart Growing Spaces

- **Remember/Understand:** Identify and explain climate-smart techniques used in each zone (urban, peri-urban, rural) and how they conserve water, reuse waste, or minimize energy.
- **Apply/Analyze:** Match and deconstruct techniques to zone-specific conditions, showing how they form circular resource loops.
- **Create/Evaluate:** Design and defend a hybrid system that integrates strategies from at least two zones to close resource loops and increase long-term sustainability.

Lesson C: Tech & Metrics That Matter

- **Remember/Understand:** Define and explain key efficiency metrics (e.g., L/kg, biomass per kWh, input–output ratio) and their purpose.
- **Apply/Analyze:** Calculate and interpret resource-use metrics (e.g., water per yield) from provided or classroom data to compare systems.
- **Evaluate/Create:** Recommend and justify a food production model using sustainability metrics, clearly defending trade-offs and resource constraints.

## Lesson A: From Balcony to Back-Forty

Slides 3 to 19

### Slide 3: How is space reshaping where and how we grow food?

**Objective:** Introduce students to the idea that physical space—urban, peri-urban, or rural—reshapes what kinds of food can be grown, how it is grown, and what sustainability challenges or opportunities arise in each setting.

Begin with a prompt to spark curiosity and reflection.

- *“How is space reshaping where and how we grow food?”*

Encourage them to think broadly:

- Population density, land prices, transportation distances, labor availability, and climate pressures.
- Highlight that in cities, food might be grown in vertical towers or rooftop gardens, while in rural areas, large-scale monocrops still dominate. Peri-urban zones often act as a bridge, combining aspects of both.

Set up an interactive activity:

- Allow students to contribute their thoughts through a live word cloud using a tool like Wooclap (<https://www.wooclap.com/en/word-cloud-generator/>).
- Invite them to type in a single word or short phrase that reflects their initial thinking.
- Examples might include: innovation, rooftops, efficiency, transportation, or equity. As the responses populate, read a few aloud and note any emerging patterns, surprising connections, or unique insights.

Emphasize that this exercise sets the stage for systems thinking.

- Food systems aren’t just about crops and soil; they’re deeply shaped by the spatial context like land availability, infrastructure, and proximity to consumers.
  - Urban farms reduce food miles but face high land costs.
  - Peri-urban systems often benefit from affordable land near cities but face zoning and resource challenges.
  - Rural farms benefit from scale but must rely on transportation networks.

Close this segment by reinforcing that understanding these spatial trade-offs is key to designing sustainable and resilient food systems.

- Encourage students to keep thinking about this question throughout the module: If you were tasked with feeding your own community, how would you use urban, peri-urban, and rural spaces together to create a balanced, sustainable system?

### Slide 4: Why Study the City-Rural Gradient?

**Objective:** Introduce students to the global context for studying the urban–rural food gradient, highlighting urbanization trends, the role of peri-urban zones, and the sustainability stakes such as reduced food miles and emissions.

Provide global context:

Begin by showing a quick map or visual of urban sprawl if available.

- *“Let’s start with the big picture—why are we even studying the gradient from city to countryside when it comes to food?”*

Explain that over 55% of the world’s population now lives in cities, and that percentage continues to rise.

- *“Think about that—more than half of the world lives in urban areas, and cities are still growing.”*

Emphasize urban expansion and its impacts:

Urban growth often converts farmland into housing, roads, and infrastructure.

- *“As cities expand, they often push into surrounding farmland, replacing fields with buildings and highways. That means we’re losing some of the very land that could be growing our food.”*

Introduce the critical role of peri-urban zones:

Peri-urban areas, sitting at the edge of cities, are increasingly important for fresh food production.

- *“This is where peri-urban zones come in. These edge areas are becoming essential—they’re close enough to supply city markets but still have the space for greenhouses, orchards, and small farms.”*

Point out a regional example if relevant.

- *“For instance, in California, greenhouse belts in peri-urban zones supply a huge share of leafy greens and vegetables to nearby urban centers.”*

Connect to sustainability stakes:

Designing efficient food systems in these zones can reduce emissions and improve resilience.

- *“When we design smarter food systems—using nearby land wisely—we cut down on food miles, reduce transportation emissions, and create more resilient supply chains.”*

Wrap up the slide:

- *“So when we look at the city–rural gradient, we’re not just looking at geography. We’re looking at how food, land, people, and the planet are all connected.”*

## Slide 5: The Gradient: Urban, Peri-Urban, Rural

**Objective:** Help students interpret the key characteristics of Urban Agriculture (UA), Peri-Urban Agriculture (PUA), and Rural Agriculture (RA) as shown in the Venn diagram. Explain how each zone contributes differently to food systems, highlighting trade-offs like food miles, infrastructure costs, land availability, and resource use.

Introduce the visual and context:

Show the Venn diagram comparing UA, PUA, and RA.

- *“Take a look at this diagram — it compares three major zones where we grow food: urban, peri-urban, and rural. Each has its own defining features, and each contributes differently to the food system.”*
- Reference the source if desired (Mulya et al. 2023, adapted from Opitz et al. 2016).
- *“These attributes are not just academic—they shape how much food can be produced and how it reaches cities.”*

Explain Urban Agriculture (UA):

- *“Let’s start on the left with Urban Agriculture — think rooftop farms, school gardens, or container farms right in the city. They have very low food miles, since they’re close to consumers, but they face high infrastructure costs and limited space. Land is expensive, plots are small, and farmers often rely on short-term contracts or shared spaces in and on buildings.”*
- Tie to diagram terms: dense population, microfarms, non-agricultural land, short-term contracts, legal status dominance, shared spaces.

Explain Peri-Urban Agriculture (PUA):

- *“Now look at the middle; Peri-Urban Agriculture, right on the urban fringe. These are the greenhouse belts and small to medium farms near cities. They’re in a sweet spot: lower land costs than the city, proximity to markets, and enough room for mid-scale operations. These zones often use limited land contracts but can distribute food to both urban and regional supply chains.”*
- Connect to diagram terms: urban periphery, small/medium farms, agricultural land, land ownership dynamics.

Explain Rural Agriculture (RA):

- *“On the right, we have Rural Agriculture — large-scale farms farther from cities. They benefit from abundant land and automation, often using massive plots with high mechanization. But they also face higher water use, longer transport times, and sometimes less secure land tenure. These farms feed wider markets but with more inputs and greater distances to consumers.”*

Connect to diagram terms: sparsely populated areas, large-scale farms, massive agricultural land, dominance of no legal status, extensification.

Discuss trade-offs and planning:

- *“Each system has strengths and weaknesses. Urban farms cut transport emissions but struggle with scale. Peri-urban farms balance cost and access. Rural farms produce in bulk but use more water and*

energy. *There's no one-size-fits-all approach — understanding this gradient helps us plan smarter, place-based solutions.*

Classroom engagement prompt:

- *“Looking at this diagram, where do you think your community's food comes from? How might the mix of urban, peri-urban, and rural farms affect freshness, cost, or sustainability?”*

## Slide 6: Land Cost and Food Miles Across Zones

**Objective:** Help students interpret the trade-off between land cost and food miles in urban, peri-urban, and rural zones. Show how these two factors are inversely related and why that matters for planning sustainable food systems.

Introduce the graphic and context:

- Show the bar chart comparing the Land Cost Index and Food Miles Index across zones.
- *“This chart shows an inverse relationship between two key factors in agriculture: land cost and food miles. Let's walk through what that means in each zone.”*

Trade-Offs Across the Gradient:

Urban Zones:

- *“On the far left, look at the orange bar for urban land cost — it's the tallest. Land in cities is expensive. But notice the red bar for food miles — it's very short. That's because urban farms are close to their consumers. You can harvest lettuce in a rooftop garden and deliver it down the street.”*

Peri-Urban Zones:

- *“Now look at the middle. As you move to peri-urban areas, land cost drops — see how the orange bar is lower? At the same time, the red food-miles bar climbs a bit. These farms are on the outskirts of the city, so the produce travels a little farther, but still reaches markets relatively quickly.”*

Rural Zones:

- *“On the right, land cost is at its lowest — the orange bar is shortest. But look at food miles: the red bar is highest. Rural farms are far from city centers, so their products travel the longest distance to reach consumers.”*

Explain the inverse relationship:

- *“As land gets cheaper the farther you move from a city, the distance food has to travel increases. That's the trade-off we're seeing here. Urban farms save on transport but pay more for land. Rural farms pay little for land but spend more moving food into cities. Peri-urban farms sit in between.”*

Engagement prompt:

- *“What do you think about this trade-off? If you were planning a new greenhouse operation, would you choose to pay more for land to be closer to your customers, or pay less for land but spend more on transportation?”*

## Slide 7: Labor Models by Zone

**Objective:** Show how labor models change across the urban–rural gradient and what that means for wages, job security, and sustainability.

Introduce the concept and context:

- Discuss who actually works in these systems and the wage implications.
- *“As we move across the urban-rural gradient, labor models shift significantly. Let's look at who does the work in each zone and how they're compensated.”*

Labor Models Across the Gradient:

Urban Farms:

- Labor: Volunteers, local community members
- Compensation: Often unpaid or very low-wage
- Key Point: Labor framed as civic engagement or educational experience rather than formal employment
- *“Urban farms often rely on volunteers or community members. People help out because they believe in sustainability or want to improve local food access, not necessarily for a paycheck.”*

Peri-Urban Farms:

- Labor: Small hired crews or family labor
- Compensation: Modest wages, sometimes informal arrangements
- Key Point: More commercial than urban farms, but still small-scale
- *“On the urban fringe, these farms hire small crews or rely on family labor. Pay is usually modest, and employment can be seasonal or less formal.”*

Rural Farms:

- Labor: Seasonal or migrant workers, plus increasing mechanization
- Compensation: Often low wages with precarious working conditions

Key Point: Raises ethical questions about labor rights and long-term sustainability

- *“Large rural farms rely heavily on seasonal or migrant labor, often with low pay and fewer protections. Mechanization reduces some labor needs but also limits job opportunities.”*

Engagement Prompt:

- *“How do these differences in labor models affect fairness and sustainability in our food system? Which approach seems most sustainable or equitable to you?”*

## Slide 8: California Spotlight: From Rooftop to Orchard

**Objective:** Give students concrete, real-world examples of urban, peri-urban, and rural agriculture in California. Highlight distinguishing features in each photo and connect them back to the gradient concepts.

Introduce the photos and context:

- *“Let’s take a quick tour through California’s foodscape, from the city to the countryside, using three examples that show how food is grown in different zones.”*

Explain the different examples across the city-rural gradient in California:

Rooftop Farm (Urban):

- Location: San Francisco, Los Angeles
- Features: Small-scale, often on rooftops or in shipping containers
- Key Point: Very close to consumers; high land cost and limited space
- *“This rooftop farm represents urban agriculture. It’s right in the city, just steps away from the people who eat the food. The challenge is space and high land costs, but the benefit is incredible freshness and community connection.”*

Greenhouse Belt (Peri-Urban):

- Location: Salinas, Ventura County, Central Valley edges
- Features: Mid-sized greenhouse operations on the urban fringe
- Key Point: Land is cheaper than urban areas; close enough to supply city markets
- *“Here we see peri-urban agriculture. Greenhouse belts like these sit on the edges of cities, balancing cost and access. They’re bigger than urban farms, but still close enough to deliver fresh produce quickly.”*

Orchard (Rural):

- Location: Central Valley, Imperial Valley

Features: Large-scale farms, extensive land, often mechanized

- Key Point: Cheapest land and largest scale; farthest from consumers
- *“Finally, this orchard represents rural farming. Out in places like Fresno County or the Imperial Valley, you’ll find massive farms producing almonds, citrus, and other crops. The land is cheap and abundant, but food has to travel farther to reach markets.”*

Wrap-Up Prompt:

- *“Looking at these three photos, how do you think location influences what gets grown and how quickly it reaches you?”*

## Slide 9: Gradient Planning Tools for Smarter Food Systems

**Objective:** Introduce students to planning tools from the New Urbanism Movement that help design food systems across the urban–rural gradient. Show how each tool contributes to more resilient, inclusive, and spatially aware agriculture planning.

Introduce the concept:

- *“These tools come from the New Urbanism Movement, which started in the 1990s as a response to urban sprawl. Its goal was to make cities more walkable, livable, and sustainable—ideas that also apply to how we grow and distribute food.”*

Four Key Tools from the New Urbanism Toolkit:

1. Transect:

- Defines zones across a spectrum—from dense urban to remote rural
- Helps planners identify where certain agricultural strategies make sense
- *“The transect gives us a vocabulary to define zones. It’s like a scale that moves from urban to peri-urban to rural—just like our gradient.”*

2. Charette:

- A collaborative design workshop that includes community input
- Brings together farmers, gardeners, planners, and residents
- *“A charette is all about listening. It invites real people—urban gardeners, rural farmers, city planners—to design better food systems together.”*

3. Form-Based Codes:

- Regulate land use and building form to integrate food production
- Can be used to support rooftop farms, community gardens, or greenbelts
- *“Form-based codes help us ask: How does food fit into our built environment? Should rooftops be designed to hold gardens? Can zoning allow for vertical farms?”*

4. SmartCode:

- A comprehensive planning tool that combines the others
- Guides development at the regional scale, integrating food, land use, and sustainability
- *“SmartCode brings everything together. It helps cities plan food systems that stretch from balcony gardens to rural orchards in one unified design.”*

Wrap-up Point:

- *“These tools help us think spatially and inclusively. They’re not just about where to build, but how to design food systems that work across the entire gradient—from rooftops to orchards.”*

## Slide 10 to 16: Urban-Rural Gradient Agriculture Examples

**Objective:** Help students explore concrete examples of agriculture across the urban–rural gradient. From rooftop beds and shipping-container farms in dense cities, to peri-urban greenhouse belts on the urban fringe, to expansive rural orchards, these slides illustrate how location shapes farming methods, infrastructure needs, resource use, and supply chains. Students will compare key features, benefits, and trade-offs for each system to understand how space influences sustainability, efficiency, and resilience in food production.

## Slide 10 to 11: Urban Agriculture Example

**Objective:** Show three creative approaches to growing food in dense urban environments—rooftop kale beds, shipping container farms, and school parking-lot micro-farms. Highlight their unique setups, shared traits, and the trade-offs of growing food in “found spaces.”

Introduce the slide:

- *“Urban agriculture uses creative spaces to grow food right where people live. Let’s look at two examples that show how cities are making this work.”*

Examples:

1. Rooftop Kale Beds:

- Description: Lightweight raised beds or modular planters installed on commercial rooftops
- Key Features:
  - Drip irrigation systems and on-site composting

- Requires verifying roof load limits and installing safety railings
  - Often needs freight elevators or hoists to bring soil and materials to the roof
  - Benefits & Challenges:
    - Very close to consumers → low food miles
    - Limited space and high setup costs; structural reinforcement needed
    - *“In Los Angeles, you’ll see rooftop kale beds set up in lightweight planters. They use drip irrigation and compost bins right on site. But before you can even build, you have to verify that the roof can handle the weight and install safety features like railings.”*
2. Shipping Container Farms
- Description: Climate-controlled 40-foot shipping containers equipped with vertical farming technology
  - Key Features:
    - LED vertical racks, hydroponic systems, and sensors
    - Minimal ground footprint, fits in a parking space
    - Requires electricity 24/7 to maintain climate control
  - Benefits & Challenges:
    - Can grow food in dense urban areas with no open land
    - High capital costs and significant energy demands
  - *“Shipping-container farms are another approach. Inside a single container, you’ll find vertical racks, hydroponics, and sensors running around the clock. It’s a brilliant way to grow food in tight urban spaces, but the equipment and energy needs are expensive.”*
3. School parking-Lot Micro-Farms
- Description: Stacked crate planters and wicking-bed reservoirs under shaded carport frames
  - Key Features:
    - Minimal heavy equipment; uses cafeteria compost like coffee grounds
    - Needs shade structures, water hookups, and school community buy-in
  - Benefits & Challenges:
    - Very low food miles; turns underused space into productive growing areas
    - *“In some schools, parking lots become micro-farms. Students help with compost, while simple structures and wicking beds keep crops growing despite limited soil.”*

#### Shared Traits Across All Three Urban Systems:

- Limited Space:
  - *“Each one makes use of ‘found space’—rooftops, parking lots, shipping bays—places where traditional soil farming won’t fit.”*
- High Infrastructure Needs:
  - *“To replace soil and open land, they use engineering: LEDs, irrigation lines, reinforced structures, and custom systems.”*
- Very Low Food Miles:
  - *“Because they’re in the city, produce travels just blocks from farm to table—cutting emissions and preserving freshness.”*

#### Engagement Prompt:

- *“Looking at these three examples, which approach do you think would work best in your city? What trade-offs stand out to you between cost, infrastructure, and food miles?”*

### Slide 12 to 13: Peri-Urban Greenhouse Belts

**Objective:** Explain how peri-urban greenhouse clusters operate as a buffer between rural and urban zones, supplying nearby cities with fresh produce while cutting emissions, reducing resource use, and supporting circular economies.

Introduce the concept and context:

- *“Just outside city limits—about 10 to 20 kilometers out—we see a different kind of agriculture: peri-urban greenhouse belts. These systems sit between rural farmland and dense urban centers, acting as a bridge that brings fresh food closer to where people live.”*

Key Functions of Peri-Urban Greenhouse Belts:

- Buffer Zone: Between rural production areas and urban consumers
- Fresh Local Supply: Reduces food miles and post-harvest losses
- Sustainability Benefits: Cuts energy use and emissions through proximity
- Economic Value: Generates local jobs and supports circular economies
- Resilience: Provides year-round production and backup during disruptions
- *“These greenhouse clusters supply leafy greens and berries to city markets within hours, lowering transport fuel use and keeping food fresher.”*

#### Key Features and How They Work:

##### 1. Greenhouse Clustering:

- Multiple hoop or poly-greenhouses share infrastructure
- Shared access roads, cold storage, and distribution hubs
- *“By clustering facilities together, farmers share infrastructure, which lowers individual costs while keeping them close enough for same-day deliveries.”*

##### 2. Compost-Generated Heat:

- Sited near municipal compost or biodigesters
- Captured waste heat warms greenhouses at night
- Cuts winter heating bills by 15–25% and diverts waste from landfill
- *“These greenhouses often tap into nearby compost operations, capturing waste heat to keep crops warm at night—saving money and closing nutrient loops.”*

##### 3. Storm-Water Irrigation:

- Rain runoff from warehouses or greenhouses collected in ponds/cisterns
- Filtered and used for drip irrigation
- *“Instead of relying solely on city water, they collect and reuse storm water—providing a backup supply during droughts or restrictions.”*

##### 4. Ideal Crops:

- Leafy greens (spinach, lettuce, kale) and berries (strawberries, raspberries)
- Quick-turn, high-value, and delicate crops benefit from short trips to market
- *“Because greens and berries spoil quickly, these greenhouses are perfect—food reaches consumers in 1–2 hours, with minimal refrigeration and maximum nutrition.”*

#### Wrap-Up Prompt:

- *“How do these peri-urban systems balance the best of both worlds—close to cities, yet with more space than urban farms? What other crops or techniques could you imagine in a greenhouse belt near your community?”*

### Slide 14 to 16: Large-Scale Rural Orchards

**Objective:** Show how large rural orchards operate at scale, the technology and infrastructure they use, and the trade-offs they face in labor, water, pest management, and transport.

Introduce the concept:

- *“Now let’s move to the far end of the gradient—large-scale rural orchards like those in California’s Central Valley. These farms look very different from urban or peri-urban systems.”*

#### Extensive Acreage:

- Hundreds to thousands of hectares planted in high-density monoculture rows (e.g., citrus, almonds)
- GPS-guided tractors and harvesters boost efficiency
- Economies of scale lower per-unit production cost
- Challenges: high pest pressure and distance from markets
- *“These orchards often span thousands of hectares. You’ll see rows of almonds or citrus, all managed with GPS-guided tractors, mechanical shakers, and optical sorting lines. By operating at scale, they reduce labor per ton and lower costs through bulk purchasing of fertilizer and fuel. But monocultures bring risks—pest pressure increases, so they depend on strong integrated pest management programs.”*

#### Mechanization and Irrigation:

- Mechanization:
  - Mechanical shakers and optical graders reduce labor per ton

- Skilled technicians needed to run and maintain equipment
- Large upfront capital investment
- Irrigation:
  - Drip or micro-sprinkler systems deliver precise water and fertilizer (fertigation)
  - Saves 15–20% more water than flood irrigation
  - Overall water demand remains high due to massive acreage
  - *“Mechanization is key here—machines do much of the heavy work, but they require skilled technicians and significant investment. On the irrigation side, drip and micro-sprinkler systems deliver water and fertilizer efficiently. They save water compared to flood irrigation, but remember, the scale of these farms means total water use is still enormous.”*

#### Transport and Cold Chain:

- Produce often shipped 200–800 km to packing houses or ports
- Requires refrigerated or ventilated trailers (“reefers”)
- Centralized infrastructure for processing and export standards
- Implications: high fuel costs, CO<sub>2</sub> emissions, and spoilage risks
- *“Because these orchards are far from cities, their produce travels 200 to 800 kilometers to reach packing houses or ports. That means relying on refrigerated trailers, cold storage, and strong road networks—adding cost, emissions, and complexity to the supply chain.”*

#### Wrap-Up Prompt:

- *“Rural orchards clearly benefit from scale and technology, but they also face challenges like high water use and long transport distances. What do you think is the biggest trade-off for these systems compared to urban or peri-urban farms?”*

### Slide 17: Optional Activity Corner (Think-Pair-Share): Guided Design Jam

**Objective:** Engage students in applying what they’ve learned by designing their own urban, peri-urban, and rural food-production systems. This activity reinforces key concepts—components, inputs/outputs, circularity, and efficiency—through collaborative design and discussion.

#### Introduce the activity:

- *“Now that we’ve explored real examples across the urban–rural gradient, let’s see what you can create. In this activity, you’ll work in small groups to design your own food-production systems for each zone.”*

#### Group Design Challenge Instructions:

- Form small teams (2–3 students each).
- Design three systems:
  - One urban farm
  - One peri-urban farm
  - One rural farm
- For each system, identify:
  - Key components (e.g., hydro towers, hoop houses, orchard rows)
  - Inputs (water, labor, energy)
  - Outputs (food produced, by-products like compost or biochar)
  - Circular links (e.g., cafeteria compost → fertilizer, stormwater capture → irrigation)
  - Notes on efficiency (technologies used, rough estimates for saving water/energy)

#### Suggested Dialogue:

- *“Think about what you’ve seen in the examples—rooftop beds, greenhouse belts, rural orchards. How would you design your own versions? What components would you include, and how would you close the loops with waste, water, and energy? Be ready to share: What makes each system efficient and sustainable for its zone?”*

#### Wrap-Up Prompt:

- *“After designing, we’ll do a quick share-out. This is your chance to show how the urban–rural gradient can work together as one resilient food system.”*

## Slide 18 to 19: Review Questions and Answers

**Objective:** Reinforce key concepts from the module by checking understanding of land cost vs. food miles, sustainability trade-offs, and optimal crop placement across zones.

Introduce the review:

- *“Let’s wrap up with a quick review. Think back to the examples we’ve explored and the trade-offs we’ve discussed.”*

Review Questions:

1. Define urban, peri-urban, and rural zones in the context of food systems. How do land cost and food miles change across the urban-to-rural gradient, and why are they inversely related?
2. What are two sustainability trade-offs between rooftop farming and rural orchards?
3. If you had to grow spinach, strawberries, and almonds for a local market, how would you divide them across urban, peri-urban, and rural zones for optimal efficiency?

Review Answers:

1. How do land cost and food miles change across the urban-to-rural gradient, and why are they inversely related?
  - Urban = cities, peri-urban = city edges, rural = far from cities. Land cost decreases as you move from urban to rural zones, while food miles increase.
  - *“Cities have expensive land but are close to consumers; rural zones have cheap land but require longer transport.”*
2. What are two sustainability trade-offs between rooftop farming and rural orchards?
  - Rooftop farms use more energy (LEDs, irrigation) but have very low transport needs.
  - Rural orchards use large volumes of water and require long-haul shipping, but they benefit from scale and efficiency.
  - *“Each system has strengths and weaknesses—rooftops save transport emissions but cost more in tech, while orchards spread resources over huge acreage but rely on heavy water and trucking.”*
3. If you had to grow spinach, strawberries, and almonds for a local market, how would you divide them?
  - Spinach → Urban: Grows fast, spoils quickly, ideal for rooftop or container farms close to consumers.
  - Strawberries → Peri-Urban: Need controlled conditions and short transport; greenhouses on the urban fringe are ideal.
  - Almonds → Rural: Need extensive land, water, and mechanization; best suited for large-scale rural orchards.
  - *“Think of each crop’s needs and match them to the zone where it makes the most sense.”*

Wrap-Up Prompt:

- *“Looking back at these questions, how do you see the three zones working together to build a resilient, efficient food system?”*

## Lesson B: Climate-Smart Growing Spaces

Slides 20 to 50

### Slide 20: How do we grow more with fewer resources?

**Objective:** Introduce the big-picture challenge driving all the examples and strategies in this module: increasing food production while reducing inputs like water, energy, and land. Prompt students to synthesize what they've learned and think critically about innovation and trade-offs.

Introduce the guiding question:

- *“Let’s bring it all together. Across urban rooftops, peri-urban greenhouses, and rural orchards, the central question remains: How do we grow more food while using fewer resources?”*

Key points to highlight:

- Efficiency in inputs (water, labor, energy)
- Closing loops (compost → fertilizer, stormwater → irrigation)
- Balancing trade-offs (land cost vs. food miles, tech investment vs. output)
- Designing systems that are both productive and sustainable

Engagement Prompt:

- *“Think about the examples we’ve seen—what’s one strategy that stood out to you as a way to grow more with less? Could it work in your community?”*

### Slide 21 to 22: What is Climate-Smart Agriculture?

**Objective:** Define climate-smart agriculture (CSA), outline its core goals, and show how those goals are achieved through zone-specific innovations in urban, peri-urban, and rural systems.

Definition of Climate-Smart Agriculture:

- *“It’s not just about growing food—it’s a strategy that helps farmers respond to the challenges of climate change while still producing enough to meet today’s needs.”*

There are three main goals:

- Increase productivity and income – so farms can be more efficient and profitable.
- Adapt to climate change – by using practices that can handle extreme weather, like drought or flooding.
- Reduce greenhouse gas emissions – or even help remove carbon from the atmosphere.
  - *“Now, take a look at this image. It shows examples of climate-smart practices in action. You can see greenhouses, which protect crops and help regulate growing conditions, even when the weather is unpredictable.”*
  - *“There are also compost piles—those steaming heaps of organic waste are breaking down thanks to microbes. That steam is a sign of active decomposition. When ready, this compost becomes a natural fertilizer, improving soil health without synthetic chemicals.”*
- These methods help reduce waste, recycle nutrients, and support more sustainable food production overall.

### Slide 23 to 40: Climate-Smart Agriculture Examples

**Objective:** Show how farming practices adapt across urban, peri-urban, and rural zones by examining real-world examples. These slides highlight how each zone uses different technologies, scales of operation, and circular resource loops to meet local needs.

### Slide 23 to 24: Urban Closed-Loop Micro Farm

**Objective:** Show a detailed example of an urban climate-smart system that closes resource loops. Explain how materials cycle through wicking beds, mushrooms, and compost to grow greens, and highlight the efficiency gains.

Introduce the concept:

- Connecting to Climate-Smart Agriculture:
  - *“So how does Climate-Smart Agriculture actually look in action? It’s one thing to talk about using fewer resources or adapting to climate change — but what does that mean on the ground, especially in a city? Well, let’s zoom in on a system that does all three CSA goals in a really creative way. Urban microfarms like this one are small, smart, and*

*circular. They grow food using less water, less waste, and reuse materials in ways that fight emissions. This is a real example of CSA on a small scale — not just sustainable, but actually regenerative.”*

- *“Here’s a real example of an urban closed-loop micro farm—designed to reuse every drop of water and every scrap of organic waste.”*

#### Material Flow:

1. Inputs – Coffee Grounds:
  - Cafeteria coffee grounds collected as a steady organic input.
  - Used as a substrate to grow mushrooms.
  - *“Instead of tossing coffee grounds in the trash, these farms use them as mushroom substrate.”*
2. Mushrooms to Compost:
  - After mushroom production, the spent substrate becomes compost.
  - *“Once the mushrooms are harvested, what’s left is turned into rich compost.”*
3. Compost to Wicking Beds:
  - Compost enriches wicking-bed planters, which store water in a reservoir below the soil.
  - Wicking beds deliver consistent moisture from the bottom up.
  - *“The compost feeds leafy greens growing in wicking beds—these beds draw water from below, so almost nothing is wasted.”*
4. Outputs – Fresh Greens:
  - Harvested greens go back into the cafeteria or local markets.
  - Compost bins on site visibly complete the loop.

#### Efficiency Impact:

- According to a case study, these systems cut waste and water use by 40% compared to conventional beds.
- *“By cycling materials through mushrooms, compost, and greens, these farms reduce both waste and water use by nearly half.”*

#### Visual Cues:

- Point out compost bins, drip lines, and wicking reservoirs in the photo.
- *“Notice the compost bins along the edge—this is where spent mushroom substrate gets collected before being added back into the beds.”*

#### Wrap-Up Prompt:

- *“What other waste streams in a city could you imagine plugging into a system like this? How might you adapt this loop for your own campus or community?”*

#### Video on Urban Closed-Loop Micro Farm:

- *“Now, let’s explore a real-world example of urban closed-loop agriculture. This video showcases a micro-farm that reuses organic waste, such as coffee grounds, to grow mushrooms, which then produce compost to nourish leafy greens. This cycle reduces both waste and water usage by 40%.”*

### Slide 25: Urban Closed-Loop Micro Farm Graphic

**Objective:** Introduce students to the structure and function of a basic wicking bed system as an example of a closed-loop micro farm. Highlight how water and nutrients cycle through the layers, and how optional components can enhance efficiency and sustainability.

#### Introduce the content:

- *“Let’s take a closer look at how a basic wicking bed system works in an urban closed-loop micro farm. This setup is designed to store water, wick it up to plant roots, and even integrate composting—so the system keeps recycling resources in a small footprint.”*

Key points to highlight:

#### System Overview:

- *“There are two main parts: the lower reservoir zone that stores water, and the upper soil zone where plants grow.”*
- *“Water is added through a fill pipe, stored in the reservoir, and drawn upward by wicking materials—keeping the soil consistently moist.”*

- *“An overflow pipe prevents flooding, and optional layers like a sand barrier or mulch can improve water management.”*

Optional Closed-Loop Features:

- *“A worm composting bin can feed nutrients directly back into the soil.”*
- *“Mulch and woodchips help retain moisture and build soil health.” • “Interface mats or false bottoms prevent clogging and maintain the separation of layers.”*

Benefits:

- Reduces water use through capillary action
- Minimizes runoff and recycles nutrients
- Fits urban settings with limited space while creating a productive micro farm
- *“For example, if you add a worm composting bin, you’re not just growing plants—you’re closing the loop by turning food scraps into nutrients right in the same bed.”*

Engagement Prompt:

- *“What’s one optional feature you’d add to this wicking bed system—like composting worms or a sand layer—and how would that improve the system’s performance?”*

### Slide 26 to 37: Optional Extended Learning: Composting in Closed-Loop Urban CEA

**Objective:** Introduce how composting can be integrated into urban controlled-environment agriculture (CEA) to recycle organic waste into useful inputs. Highlight the specific supporting technologies that make these systems safe and efficient in cities, and explain why this matters for sustainable food systems.

Introduce the topic:

- *“Today we’re looking at composting in closed-loop urban farming systems. Imagine rooftop farms, container systems, or vertical farms that don’t just grow food—they recycle waste streams from the city itself.”*

Key points to highlight:

- Composting urban waste feeds the system:
  - Food scraps and plant residues are composted
  - Outputs: nutrients, CO<sub>2</sub>, and heat are captured and reused in the growing environment.
  - *“Instead of sending food scraps to landfill, they’re turned into fertilizer, extra carbon dioxide for photosynthesis, and even warmth for greenhouses.”*
- Nutrient looping reduces synthetic inputs:
  - Nitrogen, phosphorus, and potassium from compost replace synthetic fertilizers.
  - *“These nutrients cycle back into the crops, closing the loop and cutting down on chemical inputs.”*
- CO<sub>2</sub> capture and reuse:
  - CO<sub>2</sub> from composting is fed into the grow space to boost plant growth.
  - *“Even the gases released become a resource, speeding up photosynthesis.”*
- Supporting technologies make it work in cities:
  - Biofilters to maintain air quality
  - Ozonation or UV treatment to control pathogens in recycled materials
  - Energy recovery systems like compost heat exchangers to reuse heat
  - *“These systems only work in dense cities when we have safeguards like biofilters, UV treatment, and heat exchangers to keep air, water, and energy flows safe and efficient.”*
- Scientific and technical risks:
  - Gas management requires safeguards:
    - Composting releases CO<sub>2</sub>, CH<sub>4</sub> (methane), and NH<sub>3</sub> (ammonia)
    - If unmanaged, these gases contribute to air pollution and greenhouse warming
    - Biofilters or scrubbers are needed to capture gases, and careful monitoring keeps emissions under control
    - *“We can’t just let compost ‘do its thing’ in cities — filters and monitoring are essential to prevent greenhouse gas buildup.”*
  - Pathogens and food safety require treatment:

- If composting isn't complete, harmful microbes can survive. • These pathogens can contaminate crops in soil or hydroponics
    - Urban compost systems rely on heat treatment, ozonation, or UV sterilization to make compost safe for reuse
    - *"Without sterilization steps like heat or UV, we risk spreading disease through our food systems."*
  - System trade-offs must be managed:
    - Composting can recover energy as heat, but space and cost are limiting factors in urban settings
    - Nutrient release is not always consistent — sometimes too fast, sometimes too slow
    - Balancing energy recovery, nutrient stability, and available space is an ongoing challenge
    - *"Even with good technology, composting in cities requires trade-offs between cost, space, and nutrient reliability."*

Why it matters:

- Cuts food miles and reduces reliance on long, fragile supply chains
- Turns urban waste into valuable resources; this is circular farming in action
- Makes city farming more efficient and sustainable as urban populations grow
- *"These loops help cities feed themselves with fewer inputs, less waste, and more resilience against disruptions."*

From ideas to action:

- Nutrients back into crops: Compost turns waste into fertilizer
- CO<sub>2</sub> and heat as byproducts: Can be reused in greenhouses
- Challenges to manage: Pathogens, gases, space, and trust
- Putting it together: Combine recycling, capture, safeguards, and design

Engagement Prompt:

- *"Think about our own community. If we collected cafeteria scraps for a rooftop greenhouse, which technology—biofilters, UV treatment, or heat recovery—would you prioritize first, and why? How would it help make the system safe and productive?"*

### Slide 38: Extended Learning Optional Activity Corner (Think-Pair-Share): Optimize Your Compost System

**Objective:** Engage students in applying what they've learned about composting systems. Have them work in groups to optimize a composting setup by adding management strategies that reduce greenhouse gas emissions and improve safety.

Introduce the activity:

- *"Now we're going to switch gears into an optional design challenge. You've learned how composting in closed-loop systems can recycle nutrients and CO<sub>2</sub>, but it can also create risks like methane or pathogens if not managed well. Let's see how you would fix that."*

Key points to highlight:

Task overview:

- *"You'll work in small groups to mark on the compost system diagram where you'd place interventions—like aeration pipes, biofilters, or covers."*
- *"Then, list at least three management strategies you would use to make this composting system safer and more efficient."*
- *"Finally, explain how each strategy changes gas pathways—what emissions you reduce or redirect."*

Examples of management strategies:

- Aeration to prevent methane buildup
- Biofilters to scrub odors and volatile compounds
- Cover materials or bulking agents to keep the pile aerobic
- Heat-capture ducts to route compost heat into greenhouses
- UV treatment or safety barriers to control pathogens

- *“For instance, if you add forced aeration, you’re shifting gas pathways from anaerobic methane production to cleaner CO<sub>2</sub> release.”*

Metrics and reasoning:

- *“Remember, this is about optimization. Use your knowledge of nutrient loops and gas management to justify your choices.”*

Engagement Prompt:

- *“What’s one place on this compost system diagram you’d intervene first—and why? How would that change the gases coming off this system?”*

### Slide 39: Peri-Urban Compost-Heat Hoop Houses

**Objective:** Show how peri-urban farms use location advantages and innovative design to save energy and water while growing high-value crops.

Explain Location Choice:

- *“These hoop houses sit on the urban fringe—close enough to tap into city waste streams like compost and stormwater, but far enough out to afford cheaper land and larger footprints.”*

Highlight the Heat Hack:

- Municipal compost piles naturally reach 140 °F (60 °C) as they decompose.
- Heat is ducted into the greenhouses overnight, cutting the need for propane or electric heaters.
- *“Compost piles naturally heat up during decomposition. By piping that warm air into the greenhouse at night, farmers avoid firing up fossil-fuel burners.”*

Quantify Energy Savings:

- Passive heating reduces winter fuel use by ~20 %.
- Savings can be reinvested in better seeds, equipment, or wages.
- *“Energy meters show about 20 % less fuel burned each winter month—money that can go toward other farm improvements.”*

Storm-Water Angle:

- Roof runoff is filtered and stored in cisterns.
- Offsets municipal water use by 30–40 %.
- *“Instead of sending stormwater down city drains, these farms capture and reuse it, cutting their dependence on tap water and saving costs.”*

Ideal Crops:

- Leafy greens, strawberries, raspberries—fast-turnover, high-value crops that benefit from reduced heating needs.

Prompt for Students:

- *“What other urban by-products—like brewery CO<sub>2</sub> or grocery store cardboard—could you imagine capturing and using on a farm?”*

### Slide 40: Rural Renewable Dryland Farming

**Objective:** Show how rural farms can pair renewable energy with precision irrigation to save water, cut fuel costs, and boost efficiency. Highlight the role of wind power, soil probes, and pulse drip in improving sustainability.

Why Wind?

- Many rural farms have steady winds but limited or costly grid access
- A small (5–10 kW) turbine powers a pump to lift well water into header tanks
- Cuts diesel dependence, with long-term payback in ≈ 5 years
- *“These farms use steady rural winds to power pumps directly, avoiding expensive diesel or unreliable grid electricity.”*

Moisture-Probe Logic:

- Soil moisture probes track root-zone tension in real time
- Irrigation triggers only when the crop reaches a mild stress threshold
- *“Think of it like a Fitbit for the soil—watering only when the plants actually need it.”*

Pulse Drip Irrigation:

- Short, frequent pulses instead of long irrigation sets
- Saves ≈ 30% more water compared to fixed-schedule drip

- *“Rather than running drip lines for hours, short bursts keep the root zone ideal and reduce waste.”*

Note on Dryland Farming:

- Climate-Smart Agriculture can happen even in rural dryland farming where there is not enough natural water sources, i.e. rain

Prompt for Students:

- *“If water became twice as expensive overnight, how fast do you think this system would pay for itself?”*

## Slide 41: More Climate-Smart Agricultural Examples

**Objective:** Walk through concrete climate-smart innovations in urban, peri-urban, and rural zones, then challenge students to consider how these innovations might migrate between zones.

Introduce the slide and activity:

- *“We’ve seen how each zone uses its own techniques to save water, energy, and inputs. Now let’s explore how some of these innovations might migrate from one zone to another.”*

Urban Innovations:

- Examples: Sack gardens and NFT (nutrient film technique) rooftops
- Impact: 40 % less water use, ultra-low food miles
- *“Urban farms use stacked sack gardens and NFT rooftop systems to cut water use by about 40% while keeping food right in the city.”*

Facilitation Tip:

- Ask: *“What makes NFT portable? What utility hookups would they still need?”*
- Strong Student Answer: *“The NFT rack is modular and can sit on cheaper peri-urban warehouse roofs; land is still pricey but roofs are plentiful. Cheaper rent plus storm-water from large roofs can supply the beds while keeping low food miles.”*

Peri-Urban Innovations:

- Examples: Greenhouse clusters convert food scraps → biochar → berry tunnels
- Impact: Circular nutrient loops, reduced emissions
- *“Peri-urban greenhouses capture heat from compost piles and even convert food scraps to biochar, cycling nutrients right back into berry tunnels.”*

Facilitation Tip:

- Prompt: *“Where else do we see huge organic-waste piles?”*
- Strong Student Answer: *“Large rural packhouses already generate fruit pomace; a rural biochar plant could convert that on-site and feed it back to orchards, cutting fertilizer haul-back and sequestering carbon.”*

Rural Innovations:

- Examples: Deficit-irrigated citrus with solar VFD pumps
- Impact: ~25 % water savings, reduced diesel emissions
- *“Rural orchards use solar-powered variable-frequency pumps and deficit irrigation schedules to save about 25% water and cut fuel costs.”*

Facilitation Tip:

- Challenge: *“Is the tech footprint small enough for peri-urban plots?”*
- Strong Student Answer: *“Peri-urban farms pay higher water tariffs than rural wells; solar-powered VFD pumps plus deficit schedules could slash those bills and market their produce as ‘water-wise.’”*

Migrating Zones Discussion:

- Urban → Peri-Urban: community gardens moving outward
- Peri-Urban → Rural: biochar loops or greenhouse practices at scale
- Rural → Peri-Urban: deficit-irrigation or solar pumps adapted to smaller farms

Guided Discussion:

1. Revisit criteria: Space, water, energy, labor, distance to market.
2. Think-Pair-Share:
  - 1 min: Quiet think, jot one transferable innovation.
  - 2 min: Pair up, compare ideas.
  - 2 min: Share out, with rationale.

3. Press for “why”:
  - “What resource constraint is eased?”
  - “What new constraint appears?”

4. Synthesize on board:

Create a quick T-chart:

- Resource Lever Gained | New Limitation Introduced
- “Ground your claims in a metric or zone constraint—like water savings %, energy demand, or food-mile impact.”

## Slide 42: More Climate-Smart Agricultural Examples (Specifics)

**Objective:** Present key performance metrics from three climate-smart systems across the gradient and prompt students to evaluate which system they would invest in based on data.

Introduce the metrics and context:

- “Let’s look at real numbers from three climate-smart systems. As you watch or imagine the operations, think about which system you’d invest in if you had limited funds.”

Three Climate-Smart Systems:

Urban – NFT Lettuce:

- Metric: ~25 L of water per kilogram of lettuce produced
- Key Point: Extremely water-efficient compared to conventional soil beds
- “Urban NFT lettuce systems recycle water through thin films—using about 25 liters per kilogram, far below traditional methods.”

Peri-Urban – Berries

- Metric: ≤10 kWh of energy per kilogram of berries
- Key Point: Controlled greenhouse environments minimize heating/cooling energy per unit output
- “Peri-urban berry operations in clustered greenhouses average under 10 kilowatt-hours per kilogram—low energy intensity while staying near urban markets.”

Rural – Citrus + Biochar

- Metric: 0.6 kg of fruit per liter of water used
- Key Point: Biochar-amended soils improve water retention and yield
- “Rural orchards using biochar and deficit irrigation reach about 0.6 kilograms of fruit per liter of water—a big improvement over conventional fields.”

Engagement Prompt:

- Show a drone clip or still image of a solar-powered drip orchard (if available).
- “If you had \$10,000 to invest, which of these systems would you choose based on the metric that matters most to you—water use, energy efficiency, or yield per input?”

Follow-up question:

- “What trade-offs would you consider beyond the metric—space, infrastructure costs, or market distance?”

## Slide 43 to 45: Seeing the Loops

**Objective:** Help students visualize how different farming zones close resource loops by reusing water, energy, and nutrients on-site. Show that while the specific inputs and outputs differ in urban, peri-urban, and rural contexts, the underlying goal is the same—design systems where waste becomes a resource and external inputs are minimized. Encourage students to trace material flows, identify remaining leaks, and consider how these loop strategies could be improved or adapted.

## Slide 43: Urban Loop - Rooftop Sack Garden

**Objective:** Show how an urban rooftop sack-garden system creates a closed loop—cycling food scraps, rainwater, and condensate back into production, eliminating the need for outside trucking of inputs or waste.

Introduce the loop:

- “This slide shows how an urban farm can create its own resource cycle. Instead of importing fertilizer and water, it reuses what’s already on-site.”

Material Flows:

- Food scraps (e.g., household or cafeteria): Collected in an on-site Bokashi compost bin → converted into compost and nutrient-rich leachate → fed directly into sack gardens.

- Condensate from appliances & rooftop rainwater: Captured and routed into an irrigation system → stored in a water tank or barrel → delivered to sack gardens as needed.
- Output: Fresh greens for a salad bar or local consumption.
- Key Point:
  - *“All inputs are sourced and cycled on-site, and no off-site trucks are needed to bring in fertilizer or remove waste. Imagine food scraps from the building going into a Bokashi bin on the rooftop. The compost and leachate from that bin feed the sack gardens, while condensate from appliances and rainwater collected in barrels supply irrigation. Everything loops back; waste becomes resource.”*

Engagement Prompt:

- *“Seeing this loop, what other urban waste streams—like coffee grounds, greywater, or even cardboard mulch—could be captured and reused in a similar system?”*

#### Slide 44: Peri-Urban Loop - Compost-Heat Greenhouse Cluster

**Objective:** Show how peri-urban greenhouse clusters close resource loops by capturing heat, nutrients, and water from city by-products. Encourage students to trace loops and identify remaining resource leaks.

Introduce the loop:

- *“Peri-urban greenhouse clusters sit on the edge of cities, close enough to tap municipal waste streams but with enough space to scale up. These systems almost close the nutrient and water cycle.”*

Material Flows:

- Food scraps → Municipal compost pile → Heat ducts → Hoop houses
  - *“City food waste is trucked to a compost site. As the piles break down and reach high temperatures, that heat is piped into nearby greenhouses overnight—warming crops without propane burners.”*
- Food scraps → Compost leachate & fines → Biochar plant → Berry tunnels:
  - *“Leachate and compost fines can be sent to a biochar plant, then returned as soil amendments to berry tunnels, enriching the beds and sequestering carbon.”*
- Biochar plant → Storm-water reservoir → Berry tunnels:
  - *“Rainwater captured from nearby roofs is stored in reservoirs. Biochar is mixed into beds to improve water retention, so each drop goes further.”*

Trace the loop for students:

- *“Let’s trace one loop together: city food scraps go to compost piles, which give off heat; that heat travels through ducts into hoop houses, cutting fossil fuel heating.”*

Invite student narration:

- *“Now, who wants to narrate another loop you see? Maybe the path from leachate to biochar to the berry tunnels?”*

Discuss resource leaks:

- *“As you describe these loops, think: where might resources still leak out? Are there steps where water, heat, or nutrients are still lost?”*

Engagement Prompt:

- *“If you were designing this cluster, what other city by-products, like brewery CO<sub>2</sub> or sawdust from a mill, could you integrate into the loop?”*

#### Slide 45: Rural Loop - Wind-Powered Citrus Block

**Objective:** Show how a rural orchard can create its own loop by pairing renewable energy with precision irrigation and soil-building practices like biochar.

Introduce the loop:

- *“In rural zones, loops look different—wide spaces, larger infrastructure—but the idea is the same: reuse resources and cut inputs over time. Here’s a wind-powered citrus block as an example.”*

Material Flows:

- Turbine → Pump → Pulse drip lines → Citrus trees:
  - *“A mid-size wind turbine powers a variable-frequency pump. Water is delivered through pulse drip lines only when soil-moisture probes signal it’s needed.”*

- Turbine → Soil-moisture probes → Cloud dashboard → Drip lines:
  - *“The turbine also powers sensors that feed data to a cloud dashboard. From there, the grower can open or close drip blocks remotely to respond to conditions.”*
- Pruned wood → Biochar kiln → Soil amendment:
  - *“After pruning, branches and wood are converted in a biochar kiln on-site. That biochar is returned to the orchard soil, improving moisture retention and reducing future water demand.”*
- Cloud dashboard → Biochar kiln scheduling:
  - *“Even the kiln’s operation can be planned based on data—timing production when energy and labor are available.”*

Highlight efficiency:

- *“By using renewable energy and returning prunings as biochar, this orchard not only saves water and fuel today but also builds soil that needs less irrigation tomorrow.”*

Engagement Prompt:

- *“If you were managing this orchard, which part of the loop would you invest in first—better sensors, biochar kilns, or expanded drip lines? Why?”*

## Slide 46 to 47: Social Impacts Across the City-Rural Gradient

**Objective:** Explore the social benefits and risks of farming across urban, peri-urban, and rural zones. Highlight how these systems support communities, create jobs, and shape food access, while also surfacing equity issues and trade-offs that need to be addressed.

Urban Impacts:

Community Benefits:

- Fresh produce reaches food deserts faster, improving dietary health in underserved neighborhoods.
- Youth engagement through school gardens and local volunteer programs.
- Reduces urban heat-island effects by adding vegetation and shading.

Equity & Risk Issues:

- Rooftop gardens often appear in high-income districts, which can widen disparities in who benefits.
- High start-up costs limit how many rooftops can host farms.
- “Green” amenities can contribute to gentrification, pushing up rents and displacing long-time residents.
- *“Urban farming brings greens and fresh produce into neighborhoods that often lack them—improving diets and community health. But we have to watch for inequities; many rooftop farms end up in wealthier areas, leaving low-income districts behind.”*

Peri-Urban Impacts:

Community Benefits:

- Creates living-wage jobs near the city while supporting circular economies (waste → compost → crops).
- Shorter supply chains mean better market access for small growers and less transport cost.

Equity & Risk Issues:

- Farmland preservation vs. real-estate pressure: developers often compete for the same peri-urban land.
- Land speculation can drive up prices, pushing farmers out.
- *“Peri-urban zones provide space for greenhouse clusters and compost operations, creating jobs and recycling city waste. But these lands are under constant pressure from development, which can drive up costs and threaten long-term farming.”*

Rural Impacts:

Community Benefits:

- Large farms supply bulk food for national markets and export revenue.
- Mechanization raises overall productivity and lowers per-unit costs.

Equity & Risk Issues:

- Heavy reliance on seasonal and migrant labor, often with low wages and limited access to healthcare or education.

- Infrastructure gaps—like poor roads or lack of cold storage—can hurt smallholders trying to compete.
- Long food miles add carbon emissions and price volatility for consumers.
- *“Rural agriculture anchors national food security and exports, but it depends heavily on migrant labor. Workers often face tough conditions and limited services, and long distances add both environmental and economic costs.”*

Engagement Prompt:

- *“Thinking across these zones, which social benefit stands out to you, and which risk do you think is most urgent to solve? Why?”*

### Slide 48: Optional Activity Corner (Think-Pair-Share): Peri-Urban Loops

**Objective:** Reinforce understanding of circular resource flows by having students sketch a farm system (urban, peri-urban, or rural) that integrates climate-smart components and demonstrates outputs cycling back as inputs.

Introduce the activity:

- *“Here’s an optional design challenge to wrap up. In your groups, you’ll pick a zone—Urban, Peri-Urban, or Rural—and sketch out a circular farm system. Think about how you can connect different parts of the system so that waste or outputs in one area become valuable inputs in another.”*

Instructions for Students:

- Choose your zone: Urban, Peri-Urban, or Rural
- On your paper or whiteboard, sketch a simple layout of your farm:
  - Add components like compost-heated greenhouses, stormwater capture systems, wind-powered pumps, or hydroponic towers
  - Clearly show at least one loop where an output (like heat, water, or compost) feeds back as an input elsewhere
- Set a clear metric goal for your design, for example: “Achieve 20% less energy use through compost-generated heat.”
- Identify one resource currently being wasted in your chosen zone and propose a specific plug-in solution to address it

Facilitation Tips:

- Circulate and ask guiding questions:
  - *“Where could waste be reused in your layout?”*
  - *“How does this component help with water or energy savings?”*
  - *“What metric will show that your design improves sustainability?”*
- Encourage students to label their loops and explain why they chose those components
- Remind them to think about zone-specific constraints like space in urban areas or labor in rural areas

Engagement Prompt:

- *“Which component made the biggest difference in closing your loops? If you moved your design to a different zone, what would you have to change?”*

### Slide 49 to 50: Review Questions and Answers

**Objective:** Reinforce key concepts by checking understanding of climate-smart agriculture’s goals, its social benefits across zones, and the challenges of scaling certain systems.

Introduce the Review:

- *“We’ve covered a lot of ground—urban sack gardens, peri-urban greenhouse belts, rural orchards, and all the loops and trade-offs in between. Before we wrap up, let’s check in on some key takeaways.”*

Review Questions:

1. What are the main goals of Climate-Smart Agriculture?
2. What are some social benefits of climate-smart agriculture across regions?
3. What challenges limit the scaling of rooftop urban farms?

Review Answers:

1. What are the main goals of Climate-Smart Agriculture?
  - Produce more food while using fewer resources.
  - Adapt farming systems to climate change (e.g., heat, drought, flooding).
  - Reduce greenhouse gas emissions (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) from fertilizers, fuel, and transport.

- *“Climate-smart agriculture feeds more people, adapts to changing conditions, and cuts the carbon footprint of farming.”*
2. What are some social benefits of climate-smart agriculture across regions?
    - Creates local jobs and supports small growers.
    - Brings fresh food to underserved urban areas.
    - Reduces urban heat-island effects by adding greenery.
    - Builds shorter, more resilient supply chains that keep value in local communities.
    - *“From rooftop farms to peri-urban clusters, CSA systems strengthen communities by creating jobs, improving access to healthy food, and making supply chains more reliable.”*
  3. What challenges limit the scaling of rooftop urban farms?
    - High start-up costs for infrastructure and reinforcement.
    - Limited availability of structurally suitable rooftops.
    - Gentrification pressures—‘green’ amenities can drive up rents, creating equity issues.
    - *“While rooftop farms offer clear benefits, expanding them is difficult because of cost, space limits, and unintended social impacts like rising rents.”*

Engagement Prompt:

“Looking at these answers, which goal or challenge do you think is most important for your region? How would you prioritize solutions?”

## Lesson C: Tech & Metrics That Matter

Slides 51 to 67

### Slide 51: How do we know if a farming system is truly sustainable?

**Objective:** Prompt students to synthesize what they've learned by considering the criteria that define sustainability—environmental, economic, and social—and how to evaluate real farming systems.

Introduce the reflection:

- *“We’ve seen many innovations and trade-offs across urban, peri-urban, and rural farms. But here’s the big question: how do we know if a farming system is truly sustainable?”*

Key Points to Guide Discussion:

- Sustainability is multi-dimensional:
  - Environmental – Does it reduce resource use, emissions, and waste?
  - Economic – Can it pay for itself and support livelihoods long-term?
  - Social – Does it improve equity, access, and community well-being?
- Look for metrics and evidence, not just good intentions:
  - Water use per kilogram of produce
  - Energy input vs. output
  - Labor conditions and wage structures
  - Land-use impact and food miles

Facilitation Tips:

- Pose the question first, let students think or discuss briefly:
  - *“What would you measure to prove a system is sustainable?”*
- Call on a few students or collect responses on the board.
- Tie back to earlier slides:
  - *“Remember the metrics we saw—like 25 L/kg lettuce or 20 % less heating fuel. Numbers like these help us evaluate sustainability in practice.”*

Wrap-Up Prompt:

- *“As you reflect on today’s session, think about what sustainability means to you. Which metric, loop, or design feature stood out as most important?”*

### Slide 52: Why Metrics Matter

**Objective:** Explain why measuring specific data points is essential for evaluating, improving, and comparing farming systems across the urban-rural gradient.

Introduce the concept:

- *“Before we dive into specific metrics, let’s talk about why we need them in the first place.”*

Key Points:

- Guides investment & design choices
  - *“Metrics help us decide where to invest resources—whether that’s money, labor, or land—because they show which systems actually deliver results.”*
- Data reveals true efficiency
  - *“It’s easy to assume a rooftop garden or a drip system is sustainable, but without data—like liters of water per kilogram—we can’t know for sure.”*
- Enables fair comparison across zones
  - *“Metrics let us compare very different systems—urban sack gardens, peri-urban greenhouses, rural orchards—on a level playing field.”*

Set up the next section:

- *“Now that we know why metrics matter, we’re ready to look at specific ones—like water use per kilogram, energy per kilogram, and yield per input—and see how each zone measures up.”*

### Slide 53 to 55: Types of Metrics

**Objective:** Help students understand how quantitative metrics reveal trade-offs in farming systems. These slides show how we evaluate sustainability using concrete data—liters of water per kilogram of crop and biomass per kilowatt-hour—and apply these metrics through real-world examples like container citrus with sensor-driven irrigation.

### Slide 53: Water Metric - Liters per Kilogram (L/kg)

**Objective:** Explain the water-use efficiency of hydroponics compared to traditional soil farming while cautioning students about energy trade-offs.

Introduce the metric:

- *“One key metric we use to compare systems is water use per kilogram of food produced—measured in liters per kilogram, or L/kg.”*

Present the data (with bar graph):

- Traditional Soil Farming:
  - *“On the bar graph, notice how high the bar is for soil-grown lettuce—this method uses a large amount of water per kilogram.”*
- Hydroponics:
  - *“Now look at the hydroponics bar—much lower. Hydroponic systems use about 75% less water per kilogram of lettuce than traditional soil farming.”*

Discuss trade-offs:

- *“But before we call hydroponics the perfect solution, we have to consider energy use. Those savings in water often come with higher electricity demand for pumps, lights, and climate control.”*
- Efficiency depends on context:
  - *“In sunny regions with renewable power, hydroponics can be a huge win. But in areas with coal-based electricity or poor infrastructure, the trade-off might not be worth it.”*

Engagement Prompt:

- *“Looking at this graph and knowing the energy trade-offs, where do you think hydroponics makes the most sense? Urban rooftops with access to solar? Or rural areas with cheap land and abundant water?”*

### Slide 54 to 55: Energy Metric - Biomass per kWh

**Objective:** Compare how much crop biomass is produced per unit of energy and explain why stacked vertical systems use more energy despite high yields.

Introduce the metric:

- *“Another way we measure efficiency is biomass per kilowatt-hour—how much crop you get for each unit of energy.”*

Vertical LED Systems:

- High kWh, high yield: Stacked layers of plants produce large volumes of food in small spaces.
- Trade-off: Because of light-decay curves, each lower layer gets less light, so more LEDs are added to compensate.
- *“Stacked systems seem perfect—more plants in less space—but light intensity drops with each layer. To maintain growth, you add more LEDs, which increases energy use per kilogram.”*

Field Crops:

- Low kWh: Sunlight is free, so energy use per kg is minimal.
- Trade-off: Yields are weather-dependent and less controllable.
- *“Field crops rely on sunlight, which doesn’t cost energy—but it also means they’re at the mercy of droughts, storms, and seasonal limits.”*

Engagement Prompt:

- *“Would you prioritize high yield in a stacked LED system despite the energy cost, or favor the low-input but less predictable field system?”*

Introduce the case study:

- *“Here’s a real example: a container-grown citrus system that uses 90% less water than a traditional grove.”*

Controlled Environment Features:

- Biochar-amended soil: Improves moisture retention and nutrient cycling.
- Soil-moisture sensors: Readings every 15 minutes adjust drip irrigation precisely.
- *“Sensors act like a feedback loop. If soil tension shows the trees are fine, irrigation waits; if roots show stress, a short pulse begins.”*

Rural vs. Controlled-Environment Trade-Offs:

- Controlled Environments:
  - High setup costs and energy demand, but precise resource control.

- Ideal where water is expensive or scarce.
- Rural Open Fields:
  - Lower capital costs and free sunlight, but heavy water use and weather risks.
  - *“In a rural context, a grower might weigh these trade-offs: do I invest in controlled systems with sensors and biochar, or keep using broad irrigation and accept higher water use?”*

Engagement Prompt:

- *“If you were farming citrus in a drought-prone area, would you adopt this sensor-driven system despite the upfront cost? Why or why not?”*

## Slide 56: Interpreting Efficiency Trade-Offs

**Objective:** Help students synthesize what they’ve learned about water, energy, and yield metrics by recognizing that improving one often impacts another. Emphasize that sustainable design means balancing multiple metrics rather than chasing a single “perfect” number.

Introduce the idea:

- *“Let’s step back and think about trade-offs. A system that saves water might use more energy. A system that maximizes yield might demand more inputs. There’s no perfect solution—it all depends on location, goals, and resources.”*

Key Points to Highlight:

- Low water use can mean high energy costs.
  - *“For example, hydroponic systems save huge amounts of water but rely on pumps and lights that increase electricity demand.”*
- Best design balances multiple metrics.
  - *“An efficient system finds a sweet spot—reducing water use without driving energy use out of control.”*
- No universal answer.
  - *“What’s sustainable in a water-scarce city might be very different from what works in a windy rural orchard.”*

Engagement Prompt:

- *“If you had to prioritize one metric—water use, energy use, or yield—which would you choose, and why?”*
- Encourage quick individual reflection or a short discussion.
- Follow up:
  - *“What trade-offs might come with that choice?”*

## Slide 57: Better, Not Perfect - Navigating Trade-Offs

**Objective:** Help students understand that every agricultural system involves trade-offs. Emphasize that there is no universal “perfect” design; what’s better depends on specific priorities and context. Show how metrics guide these comparisons.

Introduce the topic:

- *“Let’s step back for a moment. Across all the systems we’ve looked at—urban, peri-urban, rural—there isn’t one perfect solution. Every approach has strengths and weaknesses.”*

Key points to highlight:

- Every system has trade-offs:
  - *“Urban farms save water miles but require high tech investment. Rural farms are efficient on land cost but have higher transport and water needs.”*
  - Point out trade-offs are normal and must be weighed.
- Better is based on your priorities:
  - Maximize yield? • Reduce water or energy use?
  - Improve circularity or local resilience?
  - *“If your priority is water savings, you might choose hydroponics. If your priority is high yield at scale, a rural system might make more sense.”*
- Context matters:
  - *“What works in a dense city might not work in a rural valley. The goal is to design for your local conditions.”*

- Metrics guide comparisons:
  - Metrics like liters per kilogram (L/kg) or biomass per kWh help explain why one option may be better.
  - *“Using metrics, we can compare options objectively—how much water, energy, or land each system needs—and explain our reasoning.”*

Engagement Prompt:

- *“Think back to the examples we’ve seen. If you had to choose a system for your own community, what would you prioritize—yield, water use, energy efficiency, or circularity—and why?”*

## Slide 58: Water Efficiency - Hydro Tower VS. Soil Bed

**Objective:** Show the dramatic difference in water use between hydroponic and soil systems, and introduce the Water Ledger Activity to help students apply input-output thinking during their lab.

Introduce the comparison:

- *“Here’s a striking example of how different systems use water to produce the same crop—lettuce.”*

Key Data (show on slide or chart):

- Hydroponic tower lettuce: ~25 L of water per kilogram of lettuce.
- Soil-grown lettuce: ~100 L of water per kilogram of lettuce.
- *“Look at that difference—a hydroponic tower uses about one-quarter of the water a soil bed needs for the same amount of lettuce.”*

Explain input-output thinking:

- *“When we talk about efficiency, we’re asking: How much input do you need to get your output? The more efficient the system, the less water is wasted for every kilogram harvested.”*

Water Ledger Activity:

- During your lab:
  - Record system type (hydro or soil).
  - Log liters of water used.
  - Log kilograms of yield harvested.
- Class Water Ledger:
  - *“We’ll combine everyone’s data into a class ledger to compare real numbers and see which systems are most efficient in practice.”*

Engagement Prompt:

- *“Before we start the lab, what do you predict—will your hydro system hit closer to 25 L/kg? Or will your soil bed surprise us with better efficiency?”*

## Slide 59: Optional Activity Corner (Think-Pair-Share): Scenario Optimization

**Objective:** Give students a hands-on challenge to apply everything they’ve learned—designing a 1-acre farm within resource limits while maximizing food yield and calculating efficiency metrics.

Introduce the challenge:

- *“Now it’s your turn to put the pieces together. In groups, you’ll design a 1-acre farm that stays within a resource limit and maximizes yield using sustainable tech.”*

Group Design Instructions

1. Design a 1-acre farm:
  - Pick your system components: hydroponic towers, soil beds, drip lines, solar pumps, etc.
  - Arrange them in a way that balances inputs and outputs.
2. Work within resource limits
  - You’ll be given constraints (e.g., max liters of water, energy budget).
  - Use your chosen components to meet those limits.
3. Use provided data to calculate:
  - Water-Use Efficiency (L/kg)
  - Energy-Use Efficiency (kg/kWh)

Worksheet Needed:

- Space for design sketch (map layout of your 1-acre farm).
- Table for data calculations:

System Type	Area Used	Water Used (L)	Yield (kg)	L/kg	Energy (kWh)	kg/kWh
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- Prompt questions:
  - Which resource is your limiting factor?
  - What trade-offs did you consider?

Facilitation Tips:

- Circulate during the activity:
  - *“How are you balancing your water and energy use?”*
  - *“What’s your biggest design challenge so far?”*
- After groups finish, invite quick share-outs:
  - *“Which design achieved the best L/kg or kg/kWh? What choices led to that?”*

Engagement Prompt:

- *“If you had to expand this design to 5 acres, what would change first—your tech choices, your layout, or your resource strategy?”*

### Slide 60: Vertical-Stack Math and Biomass per kWh

**Objective:** Explain how light intensity decreases in vertical stacks, how that impacts biomass per kWh, and why optimizing spacing and design increases energy efficiency.

Introduce the concept:

- *“In vertical farming, the way we stack plants affects how efficiently we convert electricity into food. Let’s look at how light intensity changes across tiers and what that means for biomass per kilowatt-hour.”*

Light Decay in Vertical Stacks:

- Top tier: receives  $\approx$  100% light intensity.
- Lower tiers: each level down receives less light—by Tier 3, intensity is  $\approx$  60%.
- *“Light intensity drops the farther plants are from the source. In tiered systems, the upper layers get strong light, while lower layers are shaded, reducing photosynthesis.”*

Biomass per kWh:

- Better light = better photosynthesis:
  - *“More light at the plant canopy means more biomass produced per unit of energy.”*
- Optimizing spacing & reflectors:
  - *“By adjusting tier height, spacing, or using reflective surfaces, you can boost light access and increase yield without adding more LEDs.”*
- Efficiency goal:
  - *“Efficient design means higher yield with less power—maximizing biomass per kilowatt-hour.”*

Highlight trade-off:

- *“Adding tiers increases production area but also increases shading, which can lower your biomass per kWh unless you optimize your design.”*

Engagement Prompt:

- *“If you were designing a vertical farm, would you prioritize more tiers for space or fewer tiers for better light efficiency? Why?”*

### Slide 61: Smarter Citrus: Growing More With Less

**Objective:** Show how controlled-environment citrus systems integrate advanced tools—sensors, biochar, and precision drip—to drastically reduce inputs and increase efficiency compared to traditional orchards.

Introduce the idea:

- *“Here’s a real example from controlled-environment citrus research, like the work in the Vidalakis Lab, showing how we can grow more citrus with far fewer resources.”*

Key Components Working Together:

- Sensors:
  - *“Soil-moisture and nutrient sensors constantly monitor conditions—water tension, fertilizer levels, and light intensity. Data drives decisions in real time.”*

- Biochar:
  - *“Biochar is added to the soil to improve structure, hold nutrients, and retain moisture, so less irrigation is needed over time.”*
- Precision Drip:
  - *“Water and nutrients are delivered directly to the root zone through drip emitters, only when sensors signal that plants need them.”*

#### Why It Matters:

- ~90% less water than traditional field citrus because every drop is targeted.
- Higher biomass per kWh by minimizing wasted energy on over-watering or unnecessary pumping.
- Reduced overall energy use by running pumps and systems only when sensors call for it.
- *“Instead of constant irrigation and heavy inputs, this system responds precisely to the plant’s needs—saving water, saving energy, and boosting yield.”*

#### Video on System:

- *“Let’s watch a short video showing this system in action.”*

#### Engagement Prompt:

- *“If you were managing a large orchard, which part of this system—sensors, biochar, or drip lines—would you invest in first, and why?”*

### Slide 62 to 63: Review Questions and Answers

**Objective:** Reinforce key concepts about metrics and trade-offs in sustainable farming systems by checking understanding and encouraging students to reason through answers.

#### Transition into review:

- *“We’ve explored metrics like liters per kilogram and biomass per kWh, and we’ve seen how each system has trade-offs. Let’s check our understanding with a few quick review questions.”*

#### Review Questions:

1. Why do we need metrics like ‘liters per kilogram (L/kg)’ or ‘biomass per kWh’ when designing sustainable farming systems?
2. Hydroponic lettuce systems often use less water than soil systems. What is the trade-off, and how can it affect system design?
3. What are two key metrics to check farm efficiency?

#### Review Answers:

1. Why do we need metrics like ‘liters per kilogram (L/kg)’ or ‘biomass per kWh’ when designing sustainable farming systems?
  - Metrics reveal how much water or energy is needed to grow a crop.
  - They allow fair comparisons between different systems.
  - They guide smarter design and investment decisions.
  - *“These numbers show us exactly how resources are used and help us improve efficiency.”*
2. Hydroponic lettuce systems often use less water than soil systems. What is the trade-off, and how can it affect system design?
  - Hydroponics saves a lot of water but usually requires more energy for lighting, pumps, and temperature control.
  - Designers must consider whether the energy cost outweighs water savings in their specific context.
  - *“You gain water efficiency but may increase energy demand—so system design has to balance both.”*
3. What are two key metrics to check farm efficiency?
  - Water efficiency: liters of water per kilogram of yield (L/kg).
  - Energy efficiency: kilowatt-hours per kilogram of yield (kWh/kg).
  - *“These metrics together tell you how sustainable your system really is.”*

#### Engagement Prompt:

- *“Which of these metrics would you prioritize first for your own design, and why?”*
- *“Can you think of a situation where you might trade a bit of one metric to improve the other?”*

## Wrapping it Up!

Slides 64-66

### Slide 64: Module 6 Key Takeaways

**Objective:** Summarize the central lessons of the module and reinforce why a systems-thinking approach is essential when planning sustainable agriculture across zones.

Introduce the wrap-up:

- *“Let’s close by pulling together the big ideas from today’s session.”*

Key Points to Emphasize:

- Gradient shapes land, labor, and logistics:
  - *“Urban, peri-urban, and rural zones each bring different land costs, workforce models, and supply-chain challenges.”*
- Climate-smart strategies differ by zone:
  - *“There’s no one-size-fits-all—what works on a rooftop won’t always work on an orchard. Each zone adapts climate-smart tools to its own constraints.”*
- Metrics drive data-informed design:
  - *“Measuring water, energy, and yield efficiency gives us the numbers we need to make better decisions and improve sustainability over time.”*

Reiterate systems thinking:

- *“All of these ideas tie back to systems thinking—seeing how land, resources, labor, and technology interact so we can design smarter, more resilient food systems.”*

Closing prompt:

- *“As you leave today, ask yourself: How could you apply these ideas—gradient awareness, climate-smart strategies, and metrics—back in your own community or future projects?”*

### Slide 65: Mindmap Recap: What Did We Learn?

**Objective:** Visually synthesize the module’s concepts using a mindmap and prompt students to recall and connect key ideas—zones, strategies, metrics, and trade-offs.

Introduce the mindmap:

- *“To wrap everything up, here’s a mindmap that pulls together what we’ve learned across the module. Let’s read through it and see how the pieces connect.”*

Mindmap Nodes:

Central Node: Agri-Systems Across the Urban–Rural Gradient

Urban Branch:

- Vertical farming, sensors, closed-loop systems
- Scarce, expensive, built-up land
- Metrics: food miles, energy input per kg
- Social impact: local access through civic programs, legally supported

Peri-Urban Branch:

- Biochar, hoop houses, compost-heat loops
- Mid-cost, transitional land; zoning confusion
- Metrics: adjusting to risk, reducing emissions
- Social impact: mixed labor, critical source for fresh food

Rural Branch:

- Tractors, drip irrigation, remote sensing
- Cheap, abundant, expansive land
- Metrics: adjusting to risk, reducing emissions
- Social impact: migrant/seasonal labor, often informal

Cross-Cutting Metrics & Design:

- Food miles
- Water use per kg food
- Energy input per kg food
- Labor hours or cost
- Yield per square meter

- Systems thinking to balance trade-offs

Engagement Prompt:

- *“Looking at this mindmap, what’s one connection that stood out to you? Or is there a link you’d add that we didn’t show?”*

Wrap-up:

- *“This mindmap is your takeaway: sustainable farming isn’t isolated practices—it’s understanding how zones, metrics, and strategies all fit together.”*

### Slide 66: Career Pathways

**Objective:** Show students how the concepts in this module connect to real-world career paths. Highlight roles across urban, peri-urban, and rural systems to inspire future study or career exploration.

Introduce the slide:

- *“Let’s finish by looking at some career pathways. Everything we’ve talked about—planning zones, closing loops, using metrics—connects to real jobs shaping sustainable food systems.”*

Key points to highlight:

Urban Planning & Sustainable Design:

- Urban Planner – designs city spaces to integrate food systems
- Green Infrastructure Designer – creates rooftop gardens and greenbelts
- City Sustainability Coordinator – leads programs that reduce waste and support local food
- Rooftop Farm Project Manager – runs and scales urban farms
- Environmental Policy Analyst (Urban Ag focus) – shapes regulations for urban agriculture
- *“If you’re excited about cities and sustainability, these roles help design systems that bring food production closer to people.”*

Peri-Urban Systems & Controlled Environments:

- Greenhouse Systems Engineer – designs high-tech growing environments
- Compost-Heat Hoop Designer – builds greenhouses that reuse city waste heat
- Controlled-Environment Agriculture Specialist – manages hydroponic or vertical farms
- Water Reuse Systems Planner – captures stormwater for irrigation
- Agricultural Energy Efficiency Consultant – helps farms cut energy use
- *“On the city fringe, these careers blend engineering and agriculture to make food systems more efficient.”*

Rural Precision Ag & Resource Management:

- Precision Irrigation Specialist – uses sensors to save water
- Soil & Water Conservation Scientist – protects natural resources
- Biochar Systems Technician – turns prunings into soil-building biochar
- Ag Data & Sensor Integration Analyst – manages farm data for smarter decisions
- Renewable Energy Integration Specialist – brings solar or wind to farms
- *“In rural zones, these roles focus on scale—using technology to grow more with less while conserving resources.”*

Engagement Prompt:

- *“Which of these career areas sparks your interest? Urban, peri-urban, or rural—and why? How could what you’ve learned today help you in that path?”*

### Slide 67: Sneak Peek of Hands-On Activities

**Objective:** Preview the two hands-on investigations and show how they turn big ideas—water efficiency, climate-smart design, and the urban–peri-urban–rural gradient—into real data and decisions.

Introduce the slide:

- *“Before we wrap up planning and theory, I want to give you a sneak peek at the two hands-on investigations you’ll actually run: the Water-Budget Ledger and the Urban/Peri-Urban Light BioLab.”*

Key Points to Emphasize:

A: Water-Budget Ledger – Open vs. Closed Water Systems

- *“In this activity, you’ll become ‘water accountants.’ Each team will run two tiny farms: a drip-irrigated soil pot (an open system) and a hydroponic jar (a closed system).”*

- “You’ll track every milliliter of water you add and every bit of runoff you collect over 2–3 weeks, then calculate Water Use Efficiency—how many liters of water it takes to grow one kilogram of plant biomass.”
- “This lets you compare a balcony-style hydroponic setup to a more field-like drip system and ask, Which design really gives us more crop per drop—and why?”

#### B: Urban/Peri-Urban Light BioLab – Light, Medium, and WUE

- “In the Light BioLab, you’ll ‘think like planners’ and test how light spectrum (blue, red, blue+red) and growing medium (urban hydroponic vs. peri-urban soil+compost) affect plant growth and water-use efficiency over a few days.”
- “Each group will manage two lettuce plants—one in a hydro system, one in a soil pot—under a specific LED color. You’ll measure plant height, leaf number, water added, and runoff to calculate WUE in mL per cm of growth.”
- “You’ll then use your data to make a design recommendation: for example, what kind of light and system you’d choose for a climate-smart rooftop garden versus a peri-urban plot.”

#### How These Activities Tie Back to Systems Thinking

- “Together, these two labs connect scale and space: from a single pot or jar to a whole farm, and from urban balconies to peri-urban plots and rural fields.”
- “You’ll see how choices about water delivery, light, and growing medium change the entire system—affecting water losses, plant health, energy use, and overall resilience.”
- “Most importantly, you’ll practice using metrics—like WUE—to make evidence-based decisions instead of just guessing which system ‘seems’ more sustainable.”

#### Closing prompt:

- “As you look at these two upcoming investigations, start thinking like designers: If you were planning a real rooftop garden or a small peri-urban farm, what would you want to test first—water system, light spectrum, or something else—and what data would convince you that your design is truly climate-smart?”