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GEAVET TRAINING PROGRAMME FOR CSA

LIVESTOCK SMART SKILLS AND CLIMATE-SMART POST-HARVEST PROCESSING:

UGANDA

UNIT 2.3 USE OF LOW GHG EMISSION FOOD PROCESSING

<u>**ENGLISH VERSION**</u>

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PART I - LEARNING MATERIAL

1. Introduction

1.1. What are Greenhouse Gases?

Many chemical compounds in the atmosphere act as greenhouse gases (GHG). These gases allow sunlight (shortwave radiation) to freely pass through the Earth's atmosphere and heat the land and oceans. The warmed Earth releases this heat in the form of infrared light (longwave radiation), invisible to human eyes. Some of the infrared light released by the Earth passes through the atmosphere back into space. However, greenhouse gases will not let all the infrared light pass through the atmosphere. They absorb some and radiate it back down to the Earth. This phenomenon, called the greenhouse effect, is naturally occurring and keeps the Earth's surface warm. It is vital to our survival on Earth. Without the greenhouse effect, the Earth's average surface temperature would be about 15.6^0C or 60^0F colder, and our current way of life would be impossible (Doll et al., 2011).

Although greenhouse gases occur naturally and play a vital role in keeping the Earth warm enough to sustain life, human activities have significantly increased their concentration in the atmosphere. This rise in greenhouse gases is intensifying the greenhouse effect, leading to climate change. Consequently, these changes are impacting various human activities, particularly agriculture, which is highly sensitive to climatic variations.

1.2 Low GHG Emission Food Processing

Food processing plays a vital role in adding value to agricultural products, improving food security, and supporting livelihoods. However, traditional processing methods often rely heavily on fossil fuels and inefficient technologies, leading to significant GHG emissions that contribute to global climate change (FAO, 2021). To promote environmental sustainability and climate resilience, it is essential to adopt low-GHG emission food processing techniques.

Low-GHG emission food processing focuses on reducing the release of gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) during food transformation and preservation (IPCC, 2023). This approach emphasizes the use of energy-efficient technologies, renewable energy sources, waste recovery systems, and environmentally friendly innovations throughout the production chain (UNIDO, 2020).

Key strategies include improving energy efficiency, utilizing solar and biogas energy, minimizing waste, using low-emission refrigeration systems, and applying innovative non-thermal processing methods (IEA, 2022). Sustainable water and waste management practices, as well as efficient packaging and transport systems, also contribute to lowering emissions and promoting cleaner production (World Bank, 2021).

Adopting these low-emission practices not only reduces environmental impacts but also improves operational efficiency, lowers production costs, enhances product quality, and supports national and global efforts to mitigate climate change (FAO, 2021; IPCC, 2023). This training will therefore equip participants with the knowledge and practical skills needed to apply climate-smart and energy-efficient techniques in food processing, leading to greener and more sustainable food systems.

Food system activities are closely interconnected with climate, weather patterns, environmental resources, and human behavior. Globally, these activities account for approximately 21–37% of total anthropogenic greenhouse gas (GHG) emissions. Of this, about 10% arises from direct food production, while 18–29% results from food production combined with land-use change, highlighting the significant role of the food system in driving climate change.

Food system activities also contribute to land-use change, biodiversity loss, freshwater depletion, pollution of air, water, and soil, and nutrient runoff, particularly nitrogen and phosphorus, into water bodies. Conversely, climate change directly impacts food system activities, threatening food security, especially in regions already vulnerable to hunger and malnutrition. These areas are expected to experience the most severe increases in climatic variability and extreme weather events, while having limited or no capacity to adapt or cope.

2. Overview of Global and Local Greenhouse Trends

Global greenhouse gas emissions are still going up. In 2023, they increased by about 1.2% compared to 2022, reaching around 51.8 billion tons of CO_2-equivalent (Alakbarov, 2025).

Different parts of the world, however, show different trends. For example, the European Union has managed to cut its emissions a lot since 1990 thanks to strong climate and energy rules. During COVID-19, global emissions dropped for a short time because many activities stopped. But as soon as things reopened, emissions rose again and by 2022 they were already higher than before the pandemic (Sham, 2021).

3. Contribution of Agriculture and Food Processing to GHGs

Agriculture and food processing are major contributors to global greenhouse gas emissions. Food systems are estimated to account for approximately 21–37% of total global emissions, compared to about 10% from food production alone and 18–29% when land-use change is included (Crippa, 2021). The majority of these emissions originate from on-farm activities, particularly livestock and crop production. However, pre- and post-production processes—including fertilizer manufacturing, transportation, food processing, and waste management—also contribute substantially to the overall emissions footprint of the global food system (Duku et al., 2022). Food system activities remain a major driver of anthropogenic GHG emissions.

However, the magnitude and trends of these emissions vary significantly across regions due to differences in land use changes, food production systems, transportation, and processing activities.

4. References/Sources

Alakbarov, A., & Hajiyeva, A. (2025). The Environmental Harms of Greenhouse Gas Emissions: An Interdisciplinary Assessment. Journal of Economics and Management Advances, 1(1), 46-67

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. J. N. F. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature food*, *2*(3), 198-209.

European Commission. (2019). The European Green Deal. COM(2019) 640 final. Brussels: European Commission. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640

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International Energy Agency. (2022). *Energy efficiency and low-carbon technologies for the food sector*. IEA. https://www.iea.org/reports/energy-efficiency

Shan, Y., Ou, J., Wang, D., Zeng, Z., Zhang, S., Guan, D., & Hubacek, K. (2021). Impacts of COVID-19 and fiscal stimuli on global emissions and the Paris Agreement. *Nature Climate Change*, *11*(3), 200-206.

United Nations Industrial Development Organization. (2020). *Reducing greenhouse gas emissions in the food processing industry*. UNIDO. https://www.unido.org/resources/publications

PART 2 – CURRICULUM

Learning Objectives:

KNOWLEDGE	SKILLS	ATTITUDES
Students will know: ● The sources and impact of greenhouse gas emissions in food processing. ● Identify climate-smart and energy-efficient food processing techniques. ● Apply renewable energy and waste management strategies to reduce emissions. ● Integrate sustainability into food value chains through green innovations.	*Student will be able to:* ● Estimate emission hotspots in food processing operations. ● Adopt low-energy, low-carbon processing technologies. ● Implement waste-to-energy and circular economy practices. ● Promote sustainable food systems and comply with green certification standards.	*Student will develop the following mindset:* ● Through this training, students will develop a sustainability-oriented and innovative mindset that values environmental responsibility, systems thinking, and practical problem-solving. ● They will become more conscious of the impacts of food processing on climate change and motivated to apply green, energy-efficient, and waste-reducing practices. ● The training will nurture adaptability, ethical awareness, and leadership for sustainability, empowering students to champion climate-smart innovations and promote sustainable transformation across food value

		chains.

TRANSVERSAL SKILLS INTEGRATED:

- **Ethical responsibility and adaptability:** Making responsible decisions and adjusting to new environmental technologies and policies
- **Entrepreneurial and leadership skills:** Promoting green innovations and sustainable value chains
- **Innovation and creativity:** Developing and applying climate-smart and energy-efficient technologies
- **Critical thinking and problem-solving:** Analyzing environmental challenges and finding practical solutions

DIGITAL SKILLS INTEGRATED:

- **Digital communication and collaboration:** Sharing information and working in virtual teams on sustainability projects
- **Technology innovation:** Leveraging emerging digital solutions like sensors, and AI for climate-smart food systems
- **Digital safety and ethics:** Ensuring responsible and secure use of digital tools and data in environmental management

GREEN SKILLS INTEGRATED:

- **Environmental awareness and literacy:** Understanding the sources, impacts, and mitigation of greenhouse gas emissions
- **Sustainable resource management:** Promoting efficient use of energy, water, and materials in food processing
- **Renewable energy application:** using and promoting clean energy technologies in food systems
- **Climate change adaptation and mitigation competence:** Integrating climate-smart approaches to enhance resilience and reduce carbon footprints

Implementation plan of pedagogical activities - Scheme of work

Duration: 3 hours				
Target: VET learners, Food processors, farmers, and Extension workers and related trainers				
No. of Activity	**Duration**	**Training Methods / Activity**	**What the trainers do**	**What the participants do**

1.	60 min	Sources and impact of greenhouse gas emissions in food processing (Interactive lecture, brainstorming, group discussion, case studies)	● Explain key GHG sources and their impacts on the environ ment and food system ● Facilitat e discussi ons using real example s	● Participate in discussions ● Identify GHG sources in their own practices ● Share local examples
2.	40 min	Identify climate-smart and energy-efficient food processing techniques (PowerPoint presentation, Demonstration, group work and video presentation	● Demonst rate energy-efficient processi ng methods and technolo gies ● Guide participa nts in identifyi ng suitable techniqu es	● Observe demonstrations ● Discuss benefits ● Suggest local adaptations
3.	40 min	Renewable energy and waste management strategies to reduce emissions	● Present example s of renewab le energy	● Participate in demonstrations ● Design simple renewable energy or waste

		(Case analysis and field base demonstrations)	applications (e.g., solar dryers, biogas) ● Supervise waste management practice sessions	management systems for their context
4.	40 min	Sustainability into food value chains through green innovations (Group presentations, innovation challenge, plenary discussion)	● Facilitate brainstorming on sustainable value chains ● Guide innovation exercises and presentations	● Develop and present ideas on green innovations ● Evaluate sustainability impacts
Materials (What trainers need to have prepared): ● Projector and laptop ● Flip charts, markers, and notebooks ● Case studies and handouts on GHG emissions, renewable energy, and green innovations ● Samples or visuals of energy-efficient equipment (e.g., solar dryer, biogas system ● Access to field demonstration sites				
Other notes: ● Encourage peer learning and exchange of local experiences. ● Integrate transversal skills such as teamwork, problem-solving, digital literacy, and environmental responsibility.				

PART 3 – ACTIVITY GUIDE

DESCRIPTION OF THE ACTIVITIES

1. Sources and impact of greenhouse gas emissions in food processing

This activity introduces learners to the main sources and consequences of greenhouse gas (GHG) emissions arising from food processing systems. The session aims to build awareness and analytical skills that help participants identify emission hotspots across various processing stages such as energy use, refrigeration, packaging, transportation, and waste management and understand their environmental and socio-economic implications.

During the training, participants will explore the major GHGs associated with food processing, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Trainers will demonstrate how these gases are produced from combustion of fossil fuels for energy, use of synthetic refrigerants, and disposal of organic waste. Learners will discuss how these emissions contribute to global climate change by enhancing the greenhouse effect and leading to increased global temperatures, altered rainfall patterns, and reduced agricultural productivity (IPCC, 2021).

The session will also emphasize the food industry's contribution to global emissions - estimated to account for nearly one-third of total anthropogenic GHG emissions (Crippa et al., 2021). Case studies will be used to illustrate how processing technologies and supply chain inefficiencies influence emission levels. By the end of the activity, learners should be able to identify emission sources in their own processing contexts and propose feasible mitigation strategies, such as adopting energy-efficient technologies, renewable energy sources, and improved waste utilization methods (UNEP, 2022).

1. Aim of the activity: To build learners' understanding of the key sources and impacts of greenhouse gas emissions in food processing systems and to strengthen their ability to identify emission hotspots and propose practical mitigation strategies for more environmentally sustainable food processing practices.

2. Duration: 60 minutes

3. Material required:

- Flip charts, markers, and notebooks
- PowerPoint presentation or posters showing GHG cycles
- Case study handouts on low-emission food processing
- Short video or infographic on the food industry's role in GHG emissions

4. Step-by-step instruction of the task/practical exercise/case study:

- ➢ Introduction (4 minutes)
    - ○ Trainer briefly reminds participants of the major GHGs (CO_2, CH_4, N_2O) and typical processing sources. Use 1–2 slides or a short verbal summary.

- Explain the exercise goals and deliverables: each group will map the process, identify top 3 emission hotspots, estimate the relative share of each hotspot (qualitative or simple quantitative), and propose 3 feasible mitigation measures with an estimated cost/benefit comment.

➢ Group formation and case assignment (2 minutes)
- Divide participants into small groups (4–6 people).
- Give each group a different case-study handout and an Emission Source Checklist.

➢ Process mapping (10 minutes)
- Task: On flip chart, draw the process flow (inputs → processing steps → outputs → waste). Include energy carriers (electricity, diesel, LPG), refrigeration points, packaging, transport links.
- Outputs expected: Clear process flow with annotations showing where energy is used, where waste is generated, and where refrigerants or chemicals are applied.
- Identify emission sources and rank hotspots with a relative score (High / Medium / Low)

➢ Propose mitigation measures (5 minutes)
- For each hotspot, propose 3 practical mitigation options, specifying:
  - *Description of the measure (technology/practice)*
  - *Expected impact (qualitative: high/medium/low, or % reduction if estimated)*
  - *Approximate capital or operational cost category (low/medium/high)*
  - *Implementation feasibility in local context (easy/moderate/difficult)*
- Encourage low-cost/no-cost options first (e.g., behavioural changes, maintenance, improved scheduling) and include at least one higher-impact investment option (e.g., energy-efficient motors, solar PV, improved refrigeration maintenance).

➢ Prepare short group presentation (10 minutes)
- Create a 5-minute flip-chart presentation covering: process map, top 3 hotspots (with rationale and any estimates), and the 3 priority mitigation measures (with cost/feasibility note).
- Assign one presenter.

➢ Group presentations and peer feedback (25 minutes)
- Each group presents for 5 minutes (presentations can be shortened if many groups).

   - After each presentation, allow 2–3 minutes for peer questions. Trainer emphasizes methodological strengths and highlights additional mitigation ideas where relevant.
- ➢ Reflection and consolidation (4minutes)
   - Trainer summarizes common hotspots across groups and synthesizes the most practical mitigation options.
   - Ask participants to write one concrete action they will implement or recommend in their workplace (on a sticky note) and place it on a "Commitment board." (Optional)

References/Sources/Further materials:

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. (2021). *Food systems are responsible for a third of global anthropogenic GHG emissions*. Nature Food, 2, 198–209. https://doi.org/10.1038/s43016-021-00225-9

Intergovernmental Panel on Climate Change (IPCC). (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report*. Cambridge University Press. https://doi.org/10.1017/9781009157896

United Nations Environment Programme (UNEP). (2022). *Emissions Gap Report 2022: The Closing Window – Climate crisis calls for rapid transformation of societies*. Nairobi: UNEP. https://www.unep.org/resources/emissions-gap-report-2022

2. Identifying energy efficient opportunities

This training activity equips learners with the knowledge and practical skills to identify, evaluate, and apply climate-smart and energy-efficient techniques within food processing systems. The activity introduces participants to modern technologies, processing methods, and operational practices that significantly reduce energy consumption, greenhouse gas (GHG) emissions, and resource waste, while maintaining product quality and food safety.

Participants explore how climate-smart food processing integrates principles of resource efficiency, low-carbon operations, renewable energy adoption, and sustainable waste management. Through guided demonstrations, group tasks, and case studies, learners analyze real-world processing scenarios to identify opportunities for improving energy efficiency for example, optimizing heating and cooling operations, using improved insulation, upgrading motors and boilers, recovering waste heat, and adopting solar-drying or solar-powered systems.

The activity also emphasizes the role of clean and renewable energy in food processing, such as solar PV for milling and refrigeration, biogas for thermal operations, and improved biomass stoves for rural processing enterprises. Learners examine how these technologies contribute to climate change mitigation by reducing reliance on fossil fuels and minimizing emissions associated with post-harvest handling and value addition (FAO, 2019; UNEP, 2022).

In addition, participants assess process-level strategies for energy efficiency, including good manufacturing practices (GMPs), preventive maintenance, efficient scheduling of operations, and the use of low-emission packaging materials.

1. Aim of the activity: By the end of the activity, learners are expected to identify feasible climate-smart innovations suitable for their own processing environments, recommend energy-saving interventions, and contribute to the development of greener food value chains.

2. Duration: 40 minutes

3. Material required:

- Flip charts or large sheets of paper
- Markers and pens
- Sticky notes (3–4 colors)
- Printed case study handouts (e.g., solar dryer; energy-efficient milk pasteurizer; improved cooking stove; solar-powered mill)
- Process flow diagrams of selected food-processing operations
- Energy-use checklist (equipment, heating, cooling, drying, packaging, transport)
- Laptop and projector (optional)
- Calculator (optional, for simple energy estimation)
- Videos or images of climate-smart technologies (optional)

4. **Step-by-step instruction of the task/practical exercise/case study:**

➢ Introduction to the task and group formation (8 minutes)

The trainer explains the objective:

- Review a processing operation.
- Identify energy-demanding steps.
- Suggest climate-smart and energy-efficient alternatives.
- Group formation and task assignment
- Participants receive process-flow diagrams and an energy-use checklist.

➢ Map energy use and identify inefficiencies (5 minutes)

Groups use their process-flow diagram to:

- Locate all steps requiring energy (*heating, cooling, pumping, lighting, milling, drying*).
- Mark each step using sticky notes coded as:
    - Red = *High energy use*

    - Yellow = *Moderate energy use*
    - Green = *Low energy use*
  - Identify inefficiencies such as old equipment, heat loss, poor insulation, long processing times, or unnecessary operations.

➢ Analyze available opportunities for climate-smart technologies (10 minutes)

Using the energy-use checklist, groups identify possible climate-smart alternatives, such as:

- Solar dryer vs charcoal coolers
- Energy-efficient motors or improved milling machines
- Heat-recovery systems for pasteurizers
- Solar PV for powering grinders, coolers, or lighting
- Improved biomass stoves with higher combustion efficiency
- Switching from diesel to electric or hybrid systems
- Evaluate each alternative
- Feasibility (Easy/Moderate/Difficult based on local context)

➢ Case study distribution (5 minutes)

Trainer gives each group one case study (e.g., solar-powered milk cooler, energy-efficient dryer, biogas-powered cooker).
The case study includes: Description of technology, how it works, benefits, before-and-after comparison of energy use, costs and implementation challenges

➢ Group analysis and recommendations (7 minutes)

- Using guiding questions, groups analyze the case study and create a short list of practical recommendations for small and medium food processors, based on their case study.
  1. *What problem did the enterprise face?*
  2. *What climate-smart or energy-efficient technology was adopted?*
  3. *What were the impacts on energy use, GHG emissions, product quality, and profitability?*
  4. *What challenges were encountered?*
  5. *Could this technology be adopted in the learners' local context? Why or why not?*

➢ Group presentations and Trainer feedback and synthesis (5 minutes)

Each group presents:

- Their mapped energy-use hotspots
- Identified improvement options
- Summary of the case study and recommendations

References/Sources/Further materials:

Food and Agriculture Organization of the United Nations (FAO). (2019). *The state of food and agriculture 2019: Moving forward on food loss and waste reduction*. Rome: FAO.

Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report*. Cambridge University Press.

United Nations Environment Programme (UNEP). (2022). Emissions Gap Report 2022: The closing window – Climate crisis calls for rapid transformation of societies. Nairobi: UNEP

3. Apply renewable energy and waste management strategies to reduce emissions

This training activity equips learners with practical knowledge and hands-on skills to reduce greenhouse gas (GHG) emissions in food processing through the adoption of renewable energy systems and improved waste management practices. The session introduces participants to clean energy technologies such as solar photovoltaic (PV) systems, solar dryers, biogas digesters, improved biomass stoves, and energy-efficient thermal equipment demonstrating how these solutions can replace or complement fossil-fuel-based energy sources in small- and medium-scale processing operations. Learners explore the technical requirements, operational benefits, and cost considerations of applying renewable energy in different contexts, including drying, milling, pasteurization, cooling, and storage (FAO, 2019; IRENA, 2020).

The activity further strengthens learners' understanding of sustainable waste management strategies that reduce methane and nitrous oxide emissions. These include composting organic residues, producing biogas from processing waste, generating bio-fertilizer from bio-slurry, reusing process water, and converting by-products into value-added products such as animal feed or biomass briquettes. Through case studies and practical exercises, participants analyze waste streams to identify recovery, recycling, and circular bio economy opportunities (UNEP, 2021; IPCC, 2022).

By integrating renewable energy solutions with improved waste management interventions, learners gain the capacity to design practical and locally appropriate emission-reduction strategies. The activity ultimately promotes climate-smart food processing systems that lower operational costs, improve resource efficiency, minimize environmental footprints, and support resilient and sustainable value chains.

1. Aim of the activity: Learners gain the capacity to design practical and locally appropriate emission-reduction strategies.

2. Duration: 40 minutes

3. **Material required:**

- Flip charts or large A1 paper
- Markers and pens
- Printed case study handouts (*biogas system, solar dryer, improved cooking-stove, solar PV milling, etc.*)
- Waste stream checklist (*organic waste, wastewater, by-products, packaging waste*)
- Renewable energy technology factsheets
- Energy-use and waste-mapping templates
- Laptop & projector
- Photos/videos of renewable energy technologies.

4. Step-by-step instruction of the task/practical exercise/case study:

➢ Introduction to the task and Group formation and task assignment (5 minutes)

Trainer explains the objective:

- Identify where renewable energy can replace fossil fuels.
- Analyze waste streams and propose waste-to-energy or waste-reduction strategies.

Learners form groups and each group selects (or is assigned) a food-processing operation (e.g., fruit drying, grain milling, dairy pasteurization).

➢ Map current energy use and waste generation (10 minutes)

Groups draw a simple process flow and identify:

- Energy-intensive operations (heating, drying, cooling, milling).
- Existing fuel types (diesel, firewood, electricity).
- Key waste streams (organic waste, peels, wastewater, biomass residues).
  Sticky notes are used to classify:
- Red = High energy use
- Yellow = Moderate energy use
- Green = Low energy use

➢ Identify renewable energy opportunities and waste management strategies (10 minutes)

Using the factsheets, groups identify relevant technologies such as:

- Solar PV for powering lights, grinders, coolers
- Solar dryers for fruits/vegetables

- Biogas digesters for heat generation
- Improved biomass stoves with higher combustion efficiency
- Solar water heaters for pasteurization

Groups explore how wastes can be recovered, reused, or converted, such as:

- Anaerobic digestion of organic waste → biogas
- Composting organic fertilizer
- Turning peels/residues into animal feed
- Making briquettes from crop residues
- Recycling or reducing packaging waste

➢ Case study analysis (5 minutes)

Each group receives a case study (e.g., a dairy plant adopting biogas or a cooperative using solar dryers).
Guiding questions:

- What challenge did the enterprise face?
- What renewable energy or waste solution was used?
- How did it reduce emissions or costs?
- What were the benefits and limitations?
- Can this solution fit the learners' context?

➢ Group presentations, Trainer feedback & conclusion (10 minutes)

Each group presents its mapped process, renewable energy opportunities, and waste management proposals.

- Most appropriate technologies
- Cost–benefit considerations
- Potential emission reduction impacts
- Practical implementation approaches

References/Sources/Further materials:

Food and Agriculture Organization of the United Nations (FAO). (2019). *The state of food and agriculture 2019: Moving forward on food loss and waste reduction*. FAO.

International Renewable Energy Agency (IRENA). (2020). *Renewable energy for agri-food systems*. IRENA.

Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Mitigation of climate change*. Cambridge University Press.

United Nations Environment Programme (UNEP). (2021). *Waste management outlook for Africa*. UNEP.

4. Sustainability into food value chains through green innovations

This training activity introduces learners to the concept of sustainability within food value chains and demonstrates how green innovations can improve environmental performance, resource efficiency, and economic resilience across production, processing, distribution, and marketing stages. Learners explore how innovations such as renewable energy technologies, energy-efficient processing equipment, eco-friendly packaging, water recycling systems, and circular bio-economy practices contribute to the reduction of greenhouse gas emissions and waste throughout the value chain (FAO, 2020; UNEP, 2021).

The activity highlights the importance of understanding the entire value chain, from farm to consumer identifying points where resource inefficiencies, losses, and environmental impacts occur. Learners analyze real-world case studies where sustainable technologies have been used to reduce post-harvest losses, enhance food safety, lower energy consumption, and convert processing residues into valuable products. Emphasis is placed on systems thinking, innovation, and integrating sustainability principles during decision-making, investment planning, and enterprise development (World Bank, 2020).

1. Aim of the activity: The aim of this activity is to help learners understand how sustainability can be integrated into food value chains using green innovations. It enables them to identify environmental hotspots and evaluate practical solutions that reduce emissions and improve resource efficiency.

2. Duration: 40 Minutes

3. Material required:

- Projector and laptop
- Flip charts or whiteboard
- Marker pens and sticky notes
- Examples of food value chain diagrams
- Worksheets for mapping environmental hotspots and access to the internet

4. Step-by-step instruction of the task/practical exercise/case study:

- ➢ Introduction to Sustainability in Food Value Chains (10 minutes)
    - Trainer reviews the concept of sustainability and green innovations, and explains how they reduce emissions and resource waste.
- ➢ Present Value Chain Example (15 minutes)
    - Provide a simple example such as milk, maize flour, fruits, or groundnuts.
      Show the stages: production → transport → processing → storage → marketing → consumption.

➢ Identify Environmental Hotspots (20 minutes)
- Learners work in groups to identify points where major emissions, waste, or resource inefficiencies occur. Examples: energy use during drying, water waste during cleaning, spoilage during storage, packaging waste.

➢ Analyze Green Innovation Options (30 minutes)

Each group selects practical innovations that could solve the identified problems.
Examples:
- Solar dryers
- Biogas systems for waste treatment
- Eco-friendly biodegradable packaging
- Water recycling systems
- Energy-efficient stoves and equipment
- Digital monitoring sensors for cold chains

➢ Case Study Application (30 minutes)

Groups apply selected innovations to a real or hypothetical enterprise. They describe:
- The challenge
- The chosen green innovation
- Expected benefits (reduced emissions, cost savings, reduced waste)
- Feasibility in local context

➢ Group Presentations (15 minutes)
- Each group presents its sustainability strategy. The trainer gives feedback.

➢ Reflection and Summary (10 minutes)
- Learners reflect on lessons and discuss how sustainability and innovations strengthen food system resilience.

References/Sources/Further materials:

Food and Agriculture Organization of the United Nations (FAO). (2020). *Sustainable food value chains: A guide for project design*. FAO.

United Nations Environment Programme (UNEP). (2021). *Sustainability and circularity in the food value chain*. UNEP.

World Bank. (2020). *Innovating for sustainable agri-food value chains*. World Bank