

Module 8: Technological Solutions to achieve I-US from SYMSITES

This project has received funding from the European Union's Horizon Europe program under GA Project 101058426.





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Module Overview

In this module, industries and SMEs can learn how to transform waste streams into valuable resources. The four chapters focus on understanding industrial and urban waste streams, including nutrient and water flows and their potential for reuse, and presenting innovative technologies for waste valorisation. Additionally, it will be presented how these recovered outputs can be transformed into High-Value New Resources (HVNRs) with economic and environmental benefits and how to commercialize these resources, including market analysis, regulatory compliance, supply chain design, and marketing strategies.

- [Chapter 8.1: Understanding Waste Streams in Industrial-Urban Symbiosis](#)
- [Chapter 8.2: Innovative Technologies for Waste Valorisation](#)
- [Chapter 8.3: From Waste to High-Value New Resources \(HVNR\)](#)
- [Chapter 8.4: Market Integration and Product Applications for Recovered Resources](#)





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Chapter 8.1: Understanding Waste Streams in I-US

This chapter introduces key performance indicators (KPIs) for I-US, covering environmental, economic, and social metrics. Measuring resource efficiency, cost savings, and emissions reductions allows municipalities to quantify the impact of their initiatives and adjust strategies accordingly.

- Target audience: Industry and SMEs
- Estimated time: 10 minutes
- Includes: Explanations





Understanding Waste Streams in Industrial-Urban Symbiosis

Industrial-Urban Symbiosis (I-US) relies on the principle that **waste from one process can become a resource for another**. For industries and SMEs, this chapter provides a practical roadmap for identifying, mapping, and evaluating waste streams in order to unlock their potential as inputs for new processes. Understanding the types, composition, and availability of waste is a prerequisite for implementing effective I-US projects, reducing disposal costs, and creating new revenue streams.

1. Reframing Waste as a Resource

Industries often perceive by-products, effluents, and residual materials as a disposal burden. In I-US, these same materials are **considered potential high-value inputs**. Similarly, urban waste (organic fractions, construction debris, wastewater solids) contains nutrients, energy potential, and raw materials that can be harnessed in industrial processes.



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Understanding Waste Streams in Industrial-Urban Symbiosis

Key considerations for SMEs include:

- **Material characterization:** Determine chemical composition, physical properties, moisture content, and contaminants.
- **Volume and seasonality:** Quantify how much of each waste stream is produced and whether its availability fluctuates seasonally.
- **Potential value:** Identify nutrients, metals, organics, or energy content that can be recovered.

2. Industrial Waste Streams

Industrial activities generate a variety of by-products that are often underutilized. These streams can vary by sector:

- **Chemical and pharmaceutical industries:** Process effluents containing high concentrations of phosphorus, nitrogen, or specialty chemicals.



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Understanding Waste Streams in Industrial-Urban Symbiosis

- **Food and beverage industries:** Organic residues, wastewater with high biochemical oxygen demand (BOD), and heat-rich streams.
- **Manufacturing and metal processing:** Scrap metals, slag, dust, and cooling water effluents.
- **Textile and paper industries:** Fibers, sludge, and dye-containing wastewater.

Industries must **analyse these streams for reuse potential**, identifying whether they can be converted into secondary raw materials, energy carriers, or inputs for other industrial processes. Mapping these flows internally and with potential partners is essential for establishing **symbiotic exchanges**.



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Understanding Waste Streams in Industrial-Urban Symbiosis

3. Urban Waste Streams

Urban areas contribute significant streams of materials that industries can utilize:

- **Organic waste:** Food scraps, garden residues, and green waste, which are suitable for composting, biogas production, or as feedstocks for bio-based materials.
- **Construction and demolition waste:** Concrete, metals, and wood, which can feed secondary materials markets.
- **Wastewater solids and nutrients:** Nitrogen, phosphorus, and carbon-rich sludge that can be redirected to agriculture or industrial processes.
- **Plastic and packaging residues:** Potential for recycling into construction materials or feedstock for chemical processes.

SMEs should evaluate **availability, logistics, and quality consistency** when planning to source urban waste streams, as variability can affect processing feasibility.



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Understanding Waste Streams in Industrial-Urban Symbiosis

4. Nutrient and Water Cycles in I-US

A critical aspect of I-US is understanding **how industrial and urban systems contribute to nutrient and water cycles**:

- **Nitrogen and phosphorus**: Often lost in effluents but can be recovered and returned to agriculture or industrial use.
- **Carbon**: Organic residues are potential sources of biogas or bio-based materials.
- **Water**: Industrial and urban wastewater can be treated and reused, reducing freshwater consumption and closing water loops.

Mapping these flows requires a **material flow analysis (MFA)** approach (see module 5), identifying where nutrients or water are concentrated, lost, or available for recovery. This analysis informs technology selection and symbiotic partnerships, ensuring that recovered resources are utilized efficiently.



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Understanding Waste Streams in Industrial-Urban Symbiosis

5. Practical Steps for Industries and SMEs

To implement a waste-to-resource strategy, businesses should follow a structured approach:

1. **Inventory all waste streams:** Include chemical, physical, and energy characteristics.
2. **Assess availability and variability:** Understand daily, seasonal, or batch-based fluctuations.
3. **Evaluate reuse potential:** Identify which streams can feed other industrial processes or urban applications.
4. **Screen for regulatory constraints:** Classify waste under local and EU regulations to identify handling requirements.
5. **Identify symbiotic partners:** Collaborate with nearby industries, municipalities, or SMEs to exchange resources.
6. **Prioritize high-value streams:** Start with waste that offers maximum environmental and economic benefit.



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Chapter 8.2: Innovative Technologies for Waste Valorisation

This chapter explores High-Value New Resources (HVNR), showcasing how recovered materials can be repurposed into valuable products. By leveraging advanced processing methods, industries can generate secondary raw materials, alternative fuels, or high-quality chemicals with significant market potential. Case studies from SYMSITES illustrate how companies have successfully converted waste into commercially viable resources, driving both economic and environmental benefits.

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Innovative Technologies for Waste Valorization

Once industries and SMEs have mapped and characterized their waste streams (as presented in Chapter 8.1), the next essential step is to **apply appropriate technologies to transform waste into valuable resources**. Waste valorisation enables I-US by extracting energy, nutrients, and materials from by-products and urban residues. This chapter provides an **in-depth understanding of technologies**, their operational principles, applications, and considerations for SMEs and industrial actors.

1. Categories of Waste Valorisation Technologies

Waste valorisation technologies can be grouped into four main categories, depending on the **nature of the waste stream and desired recovery outputs**.





Innovative Technologies for Waste Valorization

a) Physical and Mechanical Processes

Physical separation and treatment form the foundation of many waste valorisation pathways:

- **Screening, sieving, and sedimentation:** Removes coarse solids from liquids, concentrates specific fractions, and reduces downstream processing costs.
- **Centrifugation:** Separates liquids from solids in sludges or emulsions, enhancing nutrient recovery or energy extraction potential.
- **Magnetic, density, and eddy current separation:** Useful for recycling metals, minerals, and plastics from mixed streams.

Membrane filtration systems:

- **Ultrafiltration (UF)** – removes suspended solids and macromolecules.





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Innovative Technologies for Waste Valorization

- **Nanofiltration (NF) and reverse osmosis (RO)** – concentrate dissolved nutrients, salts, or specialty chemicals while producing clean water.
- **Sedimentation and flotation techniques:** Recover fats, oils, or other low-density components from industrial wastewater.

b) Chemical Processes

Chemical valorisation transforms waste streams through **reaction, extraction, or precipitation**, often producing high-value chemicals or purified materials:

- **Advanced Oxidation Processes (AOPs):** Use ozone, hydrogen peroxide, or UV light to break down complex organic compounds in wastewater.
- **Precipitation and crystallization:** Recover minerals such as **phosphorus, calcium, magnesium**, and produce struvite or other fertilizers.





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Innovative Technologies for Waste Valorization

- **Solvent extraction and ion exchange:** Extract metals, salts, and rare elements from industrial effluents.
- **Neutralization and pH adjustment:** Facilitate recovery of specific components or stabilize the waste stream for safe reuse.

Practical insight: Chemical processes are highly effective for industries generating **metal-rich or nutrient-rich effluents**, such as food processing, textiles, or chemical SMEs.

c) Biological and Biochemical Processes

Biological methods rely on **microorganisms or enzymes** to convert organic matter into energy, nutrients, or bio-based products:

- **Anaerobic digestion (AD):** Converts organic waste into biogas, while producing digestate rich in nitrogen, phosphorus, and potassium





Innovative Technologies for Waste Valorization

- agricultural or industrial reuse.
- **Composting and aerobic treatment:** Stabilizes organic residues into soil amendments.
- **Fermentation and bioconversion:** Generates organic acids, bioethanol, biopolymers, or feedstock chemicals.
- **Enzymatic hydrolysis:** Breaks down complex carbohydrates or proteins into monomers for further processing.

SYMSITES example: Urban organic waste combined with food processing residues was co-digested to produce biogas for electricity and heat, while the digestate was sold as fertilizer, demonstrating circular economy benefits.





Innovative Technologies for Waste Valorization

d) Thermal Processes

Thermal valorisation converts waste through **heat and controlled reactions**:

- **Pyrolysis**: Decomposes organic waste into **biochar, bio-oil, and syngas**, which can be used for energy, soil amendments, or chemical feedstocks.
- **Gasification**: Produces syngas from biomass, plastics, or mixed organics, which can fuel power generation or chemical synthesis.
- **Incineration with energy recovery**: Generates heat or electricity while reducing landfill volume.
- **Thermal hydrolysis**: Pre-treats sludge to enhance anaerobic digestion efficiency and improve nutrient recovery.





Innovative Technologies for Waste Valorization

- **Torrefaction:** Mild pyrolysis of biomass to produce energy-dense solid fuels.

SME insight: Thermal processes are particularly relevant for **industries generating high-organic-content residues** (e.g., food, pulp and paper, biomass) and can create both energy and material outputs.

2. Advanced Hybrid and Integrated Technologies

SMEs can also benefit from **hybrid approaches**, combining multiple technologies to maximize resource recovery:

- **Membrane + anaerobic digestion:** Concentrates nutrients before digestion, enhancing biogas production and digestate quality.
- **Chemical precipitation + pyrolysis:** Extracts metals or phosphorus before thermal processing, generating high-purity secondary materials.





Innovative Technologies for Waste Valorization

- **Fermentation + membrane separation:** Produces bio-based chemicals from organic residues while separating usable side streams.

These integrated solutions **optimize yield, quality, and environmental benefits**, but require careful design to match waste composition and operational capacity.

3. Key Considerations for SMEs and Industries

When selecting waste valorisation technologies, businesses should evaluate:

- **Waste composition and variability:** Ensure the technology is compatible with chemical, physical, and biological properties of the waste.
- **Scale and modularity:** Solutions should match production volume, with modular systems providing flexibility for SMEs.





Innovative Technologies for Waste Valorization

- **Energy and resource efficiency:** Analyse energy inputs, water consumption, and chemical use to maintain positive environmental impact.
- **Process integration:** Assess how the technology can fit within existing workflows and potential symbiotic partnerships.
- **Capital and operating costs:** Consider investment, maintenance, and labour requirements against expected revenue from recovered resources.
- **Regulatory compliance:** Ensure outputs meet EU and national standards for waste-derived products, fertilizers, chemicals, or energy.





Innovative Technologies for Waste Valorization

4. Implementation Roadmap for SMEs and Industries

To successfully adopt waste valorisation technologies:

1. **Conduct detailed waste audits:** Characterize composition, quantity, and variability.
2. **Define recovery objectives:** Determine whether the focus is on nutrients, energy, materials, or a combination.
3. **Select suitable technologies:** Evaluate mechanical, chemical, biological, thermal, or hybrid solutions.
4. **Assess integration feasibility:** Consider retrofit options, infrastructure needs, and partnerships.
5. **Pilot and optimize:** Test at small scale to validate efficiency, quality, and economics.





Innovative Technologies for Waste Valorization

6. **Scale-up strategically:** Gradually expand operations with monitoring to ensure reliability and profitability.
7. **Monitor regulatory compliance:** Ensure outputs meet legal and industry standards.

Benefits of Waste Valorisation

- Reduce waste disposal costs and dependence on raw materials.
- Generate revenue streams from **High-Value New Resources (HVNRs)**.
- Improve **environmental performance** by reducing greenhouse gas emissions and landfill use.
- Build stronger local and industrial networks through Industrial-Urban Symbiosis partnerships.
- Gain **competitive advantage** by positioning as sustainable and innovative.





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Chapter 8.3: From Waste to High-Value New Resources (HVNR)

In this chapter, the focus shifts to technology, where innovative processes for resource recovery, waste treatment, and material transformation are introduced. Advanced techniques such as membrane separation enable the extraction of valuable elements from waste, supporting circular economy practices within industrial operations. Companies will gain insights into selecting and integrating the most suitable technologies for their specific waste streams, with an emphasis on efficiency, scalability, and regulatory compliance.

- Target audience: Industry and SMEs
- Estimated time: 10 minutes
- Includes: Explanations





From Waste to High-Value New Resources (HVNRs)

After identifying waste streams and applying appropriate valorisation technologies, industries and SMEs move to the next critical step: **transforming recovered materials into High-Value New Resources (HVNRs)**. HVNRs are secondary products derived from industrial or urban waste streams that possess **economic, functional, or environmental value**, such as fertilizers, energy carriers, chemicals, or construction materials. This chapter provides practical guidance on selecting, producing, and optimizing HVNRs, emphasizing both **technical feasibility and market potential**.

1. Defining High-Value New Resources (HVNRs)

HVNRs are outputs from waste streams that meet quality standards and can replace primary resources in industrial or urban applications.



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From Waste to High-Value New Resources (HVNRs)

They differ from conventional waste by-products in that they:

- **Have market relevance:** They are desirable to buyers or industries as inputs or finished products.
- **Provide environmental benefits:** Their production reduces raw material extraction, landfill disposal, or greenhouse gas emissions.
- **Deliver economic value:** They generate cost savings, revenue streams, or energy efficiency improvements.

Examples of HVNRs include:

- **Recovered phosphorus and nitrogen compounds** from wastewater, usable as fertilizers or industrial chemicals.
- **Bio-based chemicals** or feedstocks obtained through fermentation or chemical conversion of organic waste.



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From Waste to High-Value New Resources (HVNRs)

- **Secondary construction materials** from industrial slag or urban construction debris.
- **Biogas or biomethane** produced through anaerobic digestion of organic residues.
- **Biochar** generated from pyrolysis for soil improvement or carbon sequestration.

2. Transforming Waste into HVNRs

The transformation process involves three key stages:

a) Pre-treatment and separation

Before recovery, waste must be prepared to optimize output quality.



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From Waste to High-Value New Resources (HVNRs)

Techniques include:

- **Filtration or centrifugation** to remove solids or contaminants.
- **Thermal or chemical pre-treatment** to improve nutrient extraction or digestibility.
- **Sorting and homogenization** to ensure consistency in composition and processing.

b) Conversion and valorisation

Selected technologies convert waste into valuable products:

- **Anaerobic digestion** converts organic waste into biogas, with digestate as a nutrient-rich by-product.
- **Chemical precipitation and crystallization** recover minerals like struvite for fertilizers.



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From Waste to High-Value New Resources (HVNRs)

- **Pyrolysis or gasification** transforms biomass into biochar, syngas, or bio-oil.
- **Membrane separation** concentrates nutrients or specialty chemicals for industrial reuse.

c) Post-processing and quality optimization

To create market-ready HVNRs, post-processing ensures purity, stability, and performance:

- **Drying, pelletizing, or granulation** of nutrient products for easier transport and application.
- **Refinement or purification** of recovered chemicals to meet industrial specifications.
- **Blending or stabilization** to ensure consistent quality, shelf life, and regulatory compliance.



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From Waste to High-Value New Resources (HVNRs)

3. Considerations for Producing HVNRs

Industries and SMEs should consider several factors when producing HVNRs:

- **Market potential:** Identify sectors that demand the recovered resources, assess pricing, and forecast demand.
- **Quality standards and certification:** Ensure HVNRs meet regulatory requirements, such as fertilizer regulations, chemical purity standards, or building material norms.
- **Process efficiency and economics:** Balance capital and operating costs against potential revenue, including energy and resource savings.
- **Scalability and modularity:** Ensure production can adjust to variable waste availability and business growth.



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From Waste to High-Value New Resources (HVNRs)

- **Supply chain and logistics:** Plan storage, transport, and distribution, especially for perishable or sensitive materials.
- **Environmental and reputational benefits:** Quantify reductions in waste disposal, greenhouse gas emissions, and resource extraction.

SYMSITES experience shows that **early integration of market and technical considerations** maximizes both environmental impact and economic returns.



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From Waste to High-Value New Resources (HVNRs)

4. Strategic Benefits for SMEs and Industries

Producing HVNRs offers multiple strategic advantages:

- **Economic diversification:** Turn waste into revenue streams or reduce costs associated with raw material procurement and waste management.
- **Environmental compliance and leadership:** Meet EU circular economy targets, reduce carbon footprint, and enhance corporate sustainability.
- **Industrial collaboration:** Strengthen symbiotic networks by supplying HVNRs to local industries, agriculture, or urban applications.
- **Innovation and competitiveness:** Position businesses as innovators in the circular economy, enhancing reputation and access to funding or incentives.



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Chapter 8.4: Market Integration and Product Applications for Recovered Resources

Finally, this chapter explores market applications, analysing how businesses can position their reclaimed resources for end-users and product applications. Identifying potential buyers, meeting regulatory standards, and developing viable business models are essential for transforming waste into marketable commodities. The discussion also includes certification processes, quality assurance measures, and strategies to integrate recovered materials into supply chains.

- Target audience: Industry and SMEs
- Estimated time: 10 minutes
- Includes:

Explanations

Exercises





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Market Integration and Commercialization of HVNRs

Producing High-Value New Resources (HVNRs) from waste streams is only part of the I-US journey. For industries and SMEs, the ultimate goal is to **transform these recovered resources into marketable products**, ensuring that technical efforts deliver both **economic returns and environmental benefits**. Chapter 8.4 provides a detailed roadmap of the considerations that businesses must address to successfully commercialize HVNRs.

1. Understanding Market Potential

Before launching a recovered resource, companies must carefully analyse **demand, competition, and pricing**:

- **Target sectors:** Determine which industries or markets can use the HVNRs. Common sectors include agriculture (fertilizers, soil amendments), chemicals (industrial feedstocks), energy (biogas or biomethane), and construction (secondary materials).



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Market Integration and Commercialization of HVNRs

- **Market size and demand:** Assess potential volumes and seasonal trends to ensure that production aligns with buyer needs.
- **Competitive advantage:** Highlight unique qualities of HVNRs, such as sustainability credentials, reduced environmental impact, or cost benefits compared to conventional alternatives.

Understanding the market ensures that recovered resources are not only technically viable but also **commercially attractive**, helping SMEs avoid oversupply or investment in products without buyers.

2. Regulatory Compliance and Quality Assurance

HVNRs must meet **legal, safety, and quality standards** before entering the market.





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Market Integration and Commercialization of HVNRs

Key considerations include:

- **Regulatory frameworks:** EU and national regulations govern fertilizers (e.g., CE marking, Fertilizer Regulation 2019/1009), chemicals (REACH compliance), building materials, and waste-derived products.
- **Testing and documentation:** Conduct rigorous quality checks to confirm chemical composition, purity, and safety.
- **Certifications and labeling:** Obtaining recognized certifications can enhance credibility and accelerate adoption, such as organic or sustainability labels for agricultural products.
- **Traceability systems:** Maintain records of waste origin, processing methods, and final product composition to ensure compliance and build trust with buyers.

These steps are critical for SMEs to **mitigate risk**, prevent liability issues, and demonstrate that HVNRs meet professional and regulatory standards.





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Market Integration and Commercialization of HVNRs

3. Business Model and Supply Chain Considerations

To bring HVNRs to market efficiently, businesses must design robust supply chains and appropriate business models:

- **Logistics and storage:** Plan transportation, storage, and handling to maintain product quality, especially for perishable or sensitive materials.
- **Distribution channels:** Decide whether to sell directly to end-users, through distributors, or via industrial symbiotic partners.
- **Contractual agreements:** Clearly define responsibilities for product quality, delivery, and liability. Contracts may include revenue-sharing arrangements, co-branding, or service-based recovery agreements.
- **Flexible business models:** SMEs can adopt scalable models such as fee-for-service recovery, subscription-based supply of materials, or long-term supply contracts with industrial partners.



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Market Integration and Commercialization of HVNRs

Efficient supply chains and well-designed business models ensure that HVNRs **reach the right buyers** while maintaining consistent quality and reliability.

4. Marketing Strategy for HVNRs

Beyond production, a strong **marketing and communication strategy** is essential:

- **Value proposition:** Emphasize the environmental, social, and economic benefits of HVNRs, such as reduced landfill use, lower carbon footprint, or local sourcing advantages.
- **Stakeholder engagement:** Collaborate with regulators, industry associations, and potential buyers early in the product development process.



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Market Integration and Commercialization of HVNRs

- **Customer education:** Explain product applications, quality standards, and environmental benefits to build confidence and accelerate adoption.
- **Branding and visibility:** Leverage sustainability credentials, pilot case studies, or certifications to differentiate HVNRs in the market.

Empirical evidence shows that SMEs who actively **communicate the sustainability and quality of HVNRs** were more successful in securing buyers and establishing long-term market presence.

5. Risk Management and Economic Considerations

SMEs must evaluate **financial and operational risks** when marketing HVNRs:

- **Market price volatility:** Understand fluctuations in raw material or product prices to ensure profitability.



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Market Integration and Commercialization of HVNRs

- **Regulatory changes:** Stay informed about evolving EU and national standards that may affect product acceptance.
- **Product performance and liability:** Establish warranties, testing, and insurance to mitigate risks associated with using waste-derived materials.
- **Scaling and investment:** Begin with pilot or small-scale production to validate market acceptance before large investments.

Proactive risk management helps SMEs **reduce uncertainty**, increase investor confidence, and ensure sustainable market growth.

Benefits of Market Integration

- **Economic gains:** New revenue streams from recovered materials, reduced waste disposal costs, and optimized resource use.



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Market Integration and Commercialization of HVNRs

- **Environmental impact:** Supports circular economy principles, reduces landfill dependency, and promotes sustainable production.
- **Industrial-urban collaboration:** Strengthens partnerships with municipalities, other industries, and SMEs, fostering local symbiotic networks.
- **Reputation and competitiveness:** Positions companies as sustainable innovators, enhancing brand image and access to green incentives or funding.

By addressing market potential, regulatory compliance, business models, and marketing strategies, SMEs and industries can **successfully commercialize HVNRs**, completing the I-US cycle.



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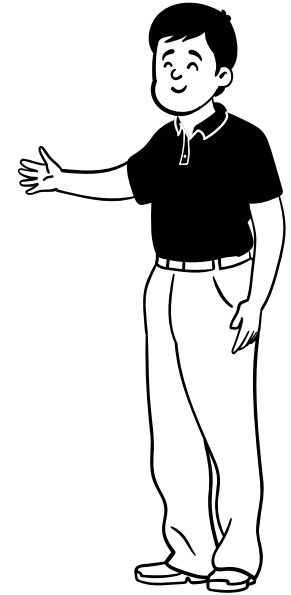


Exercise – Game:

Instructions:

Test your knowledge by playing the I-US Game developed by the Instituto Tecnológico de Galicia (ITG) as part of the SYMSITES project.

Click here to access the game: [SYMSITES I-US Game](#)



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CONSORTIUM MAP

